Therapeutic Endoscopy in the Gastrointestinal Tract

Georg Kähler
Martin Götz
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Editors

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Foreword

Are books still adequate contemporary media? In particular, teaching books with a didactic claim, since everyone may download all sorts of contents from the Internet, where innumerable experts are assembled with an impetuous desire for self-marketing? Please, time-consuming reading is not up to date. The evidence for our medical actions, which is so important and is deemed crucial as the basis of our decision-making (toward insurers, lawyers, whomever, maybe even toward patients), is brought to us as summaries of summaries of summaries from virtually all directions. Is the duty of reading and thinking taken away from us?

Critique of our current culture indicated? Not at all. But you have to provide your own horizon by yourself. Here are some suggestions:

1. Restart by reading a scientific publication yourself (best a good one in a good journal), and get an idea by yourself, even with regard to small-print information. Try to forget meta-analyses, and meta-analyses of meta-analyses, and overview presentations, where experts present their own opinion as an extract of evidence (including myself).
2. Seek an exchange about whatever you have read with colleagues who are equally engaged in their daily work, and compare the items in the article you have read with your own everyday experience; maybe you will find benefits for both those involved in the discussion. By the way, the recently published guidelines of our society DGVS on the quality of endoscopic examinations and interventions is an excellent example of compromises and the strive for evidence-based and practical interpretation.
3. And: read a book again. For example, this one. I liked it a lot because of its practical and graphical approach, with nice pictures, sketches, and practical recommendations while keeping the ball of evidence rather flat; it does not deliver a pseudo-meta-analysis! And, as said before — may I recommend that you really read several of the cited papers yourself.

I hope you will enjoy this book as much as I did.

Thomas Rösch
Hamburg, Germany

Preface to the English Edition

While the intentions with this book are clearly described in the preceding foreword, the launch of an English version deserves an additional preface.

European researchers and clinicians, and among those numerous colleagues from German institutions, have been pioneers of endoscopic techniques. Meanwhile, developments in this field have to be seen in a global perspective, with similar technical challenges all over the world.

This ongoing international exchange has stimulated both the editors and the chapter authors to better communicate our experience to the English-speaking world of endoscopy. It is our desire to share our expertise with you, our colleagues worldwide.

We sincerely hope that you will enjoy reading and profit from it in your daily work.

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February 2017

Preface to the German Edition

Therapeutic endoscopy of the gastrointestinal tract is part of the practical art of healing where scientific foundations and manual dexterity, but also modern instrumentation techniques, personal experience, and patient-related care, have to be professionally amalgamated. Due to a constant evolutionary progress in medicine as a whole, this demanding method has not only been shown to be indispensable for diagnostics but also for therapy in a wide range of activities previously deemed impossible. Improvements in optical presentation, digital techniques, and optimized instruments, combined with radiological techniques and genetic «profiling,» have induced a maturation process, both for diagnostics and therapy, which has placed therapeutic endoscopy into the center of interest of GI medicine as a whole.

Specifically, endoscopy in its double nature as a method both for diagnostic and therapeutic procedures is benefitting from a close interrelation with gastroenterology and visceral surgery. Therapeutic endoscopy not only complements but increasingly replaces classical surgical procedures. Benefit for the patient mandates the use of these methods in an interdisciplinary and evidence-based manner.

This book pays tribute to the close interaction of operative and conservative disciplines in visceral medicine. «Phenotype before genotype» – this recognition should bring together surgical and internist specialists with the interdisciplinary potential of oncology, pediatrics, radiology, nuclear medicine, and pathology. Additional aspects are determined by the interaction with intensive care, nutritional medicine, hospital hygiene, and medicine law. This book specifically addresses the assistance personnel in endoscopy, an indispensable partner. Only by means of a well-orchestrated cooperation between all disciplines involved is success possible and further development achievable.

«Therapeutic endoscopy» relates to the basis and indications for frequently applied endoscopic procedures in a structured and data-based way. Personnel, instrumentation, and forensic requirements as well as the technical execution of all interventions are described in detail. Last but not least, sources of error and complication management are extensively presented. By means of numerous sketches and pictures and practical recommendations, the authors present their vast experience based on the background of scientific evidence.

We hope sincerely to help our readers find impulses for adequate orientation for their endoscopic practical work and to successfully strive for further solid improvements.

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Abbreviations

AEG	Adenocarcinoma of esophagogastric junction
AIN	Anal intraepithelial neoplasia
APC	Argon plasma coagulation
aPCC	Activated prothrombin complex concentrate
ASA	American Society of Anesthesiologists
BBS	Buried bumper syndrome
BD-IPMN	Branch duct IPMN
BICAP	Bipolar coagulation probe
BMI	Body mass index
BTS	Beneath the scope
CA	Carcinoma
CCC	Cholangiocellular carcinoma
CHE	Cholecystectomy
CH	Charriére («French»)
CHD	Coronary heart disease
CIBD	Chronic inflammatory bowel disease
CM	Contrast medium
COPD	Chronic obstructive pulmonary disease
CPB	Celiac plexus blockade
CPN	Celiac plexus neurolysis
CRP	C-reactive protein
CT	Computed tomography
DES	Diffuse esophageal spasm
DHC	Ductus hepatocholedochus
EASR	Endoscopy-assisted segmental resection
EATR	Endoscopy-assisted transluminal resection
EAWR	Endoscopy-assisted wedge resection
EBUS	Endobronchial ultrasound
EBUS-TBNA	Endobronchial ultrasound-assisted transbronchial needle aspiration
ECG	Electrocardiogram
EGD	Esophagogastroduodenoscopy
EHL	Electrohydraulic lithotripsy
EMR	Endoscopic mucosa resection
ENT	Ear, nose, and throat
EPT	Endoscopic papillotomy
ERC	Endoscopic retrograde cholangiography
ERCP	Endoscopic retrograde cholangiopancreatography
ERP	Endoscopic retrograde pancreatography
ESD	Endoscopic submucosa dissection
ESWL	Extracorporeal shock wave lithotripsy
EUS	Endoscopic ultrasound
EUS-CPN	Endo-ultrasound-guided celiac plexus neurolysis
EUS-FNP	Endo-ultrasound-guided fine-needle puncture
EUS-TCB	Endo-ultrasound-guided Trucut biopsy
EVL	Esophageal variceal ligation
EVT	Endoscopic vacuum therapy
FACS	Fluorescence-activated cell scanning
FAP	Familial adenomatous polyposis
FFP	Fresh frozen plasma
FiLaC	Fistula tract laser closure
FKJ	Fine-needle catheter jejunostomy
FNB	Fine-needle biopsy
FNI	Fine-needle injection
FNP	Fine-needle puncture
FTRD	Full-thickness resection device
G	Gauge ("French," Charriére)
GAVE	Gastric antral vascular ectasia
GERD	Gastroesophageal reflux disease
GI	Gastrointestinal
GIST	Gastrointestinal stromal tumor
GTN	Glyceryl trinitrate ointment
HAL	Hemorrhoidal artery ligation
HCC	Hepatocellular carcinoma
HD	Hemodialysis
HES	Hydroxyethyl starch
HF	High frequency
HL	Hodgkin's lymphoma
HPV	Human papilloma virus

IEN	Intraepithelial neoplasia
INR	International normalized ratio
IPMN	Intraductal papillary mucinous neoplasia
LAER	Laparoscopy-assisted endoscopic resection
LES	Lower esophageal sphincter
LGIB	Lower gastrointestinal bleeding
LGIT	Lower gastrointestinal tract
LHM	Laparoscopic Heller myotomy
LIFT	Ligation of intersphincteric fistula tract
LN	Lymph node
LP	Lithotomy position
MD-IPMN	Main duct IPMN
MGI	Middle GI tract
MGIB	Middle gastrointestinal bleeding
MRCP	Magnetic resonance cholangio-pancreatography
NAPS	Nurse-assisted propofol administration
Nd:YAG	Neodymium-doped yttrium aluminum garnet
NET	Neuroendocrine tumor
NHL	Non-Hodgkin's lymphoma
NOTES	Natural orifice transluminal endoscopic surgery
NPWT	Negative pressure wound therapy
NSAR	Non-steroidal anti-rheumatic
NSAID	Non-steroidal anti-inflammatory drug
NSCLC	Non-small-cell lung cancer
OTSC	Over-the-scope clip
OTW	Over the wire
PDT	Photodynamic therapy
PEC	Percutaneous endoscopic colostomy/cecostomy
PEECS	Post-endoscopic submucosa dissection electrocoagulation syndrome
PEG	Percutaneous endoscopic gastrostomy
PEJ	Percutaneous endoscopic jejunostomy
PEP	Post-ERCP pancreatitis
PET-CT	Positron emission tomography-computed tomography
P-NET	Pancreatic neuroendocrine tumor
POEM	Peroral endoscopic myotomy
PPI	Proton pump inhibitor
PPSB	Prothrombin-proconvertin-Stuart-Prower factor-antihemophilic globulin B
PSC	Primary sclerosing cholangitis
PSI	Pounds per square inch
PTC	Percutaneous transhepatic cholangiography
PTCD	Percutaneous transhepatic cholangiodrainage
PTT	Partial thromboplastin time
RAR	Rectoanal repair
RCT	Randomized controlled trial
RFA	Radio-frequency ablation
r-FVIIa	Recombinant activated factor VII
SEMS	Self-expanding metal stent
SEPS	Self-expanding plastic stent
SET	Subepithelial tumor
SOD	Sphincter of Oddi dysfunction
SSC	Secondary sclerosing cholangitis
SSL	«Steinschnittlage» (lithotomy position)
STEP	Selective tissue elevation by pressure
T2DM	Type 2 diabetes mellitus
TBNA	Transbronchial needle aspiration
TC	Thrombocyte concentrate
TIPSS	Transjugular intrahepatic portosystemic stent shunt
TNM	Tumor node metastasis staging classification of the UEMS
TTS	Through the scope
TTSC	Through-the-scope clip
UES	Upper esophageal sphincter
UGIB	Upper gastrointestinal bleeding
UGIT	Upper gastrointestinal tract
US	Ultrasound
VAAFT	Video-assisted anal fistula treatment
VAC	Vacuum-assisted closure
VATS	Video-assisted thoracoscopic surgery

Endoscopic Resection Methods

Georg Kähler

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1

Endoscopic resections have a diagnostic and a therapeutic value. Their degree of difficulty strictly depends on the size and shape of the lesion. The use of the different methods differs according to the anatomical location. Nevertheless, the methods are described herein from a technological point of view. Organ-specific comments are made in the chapter.

1.1 General Aspects

1.1.1 Taking Biopsies or Not?

All visible lesions of the GI tract need a diagnostic clarification on principle. Frequently, the superficial pattern allows the examiner to predict the histopathological entity. Therefore, the pit pattern classifications according to Kudo (Fig. 1.1) (Toyoshima et al. 2015) or others are helpful.

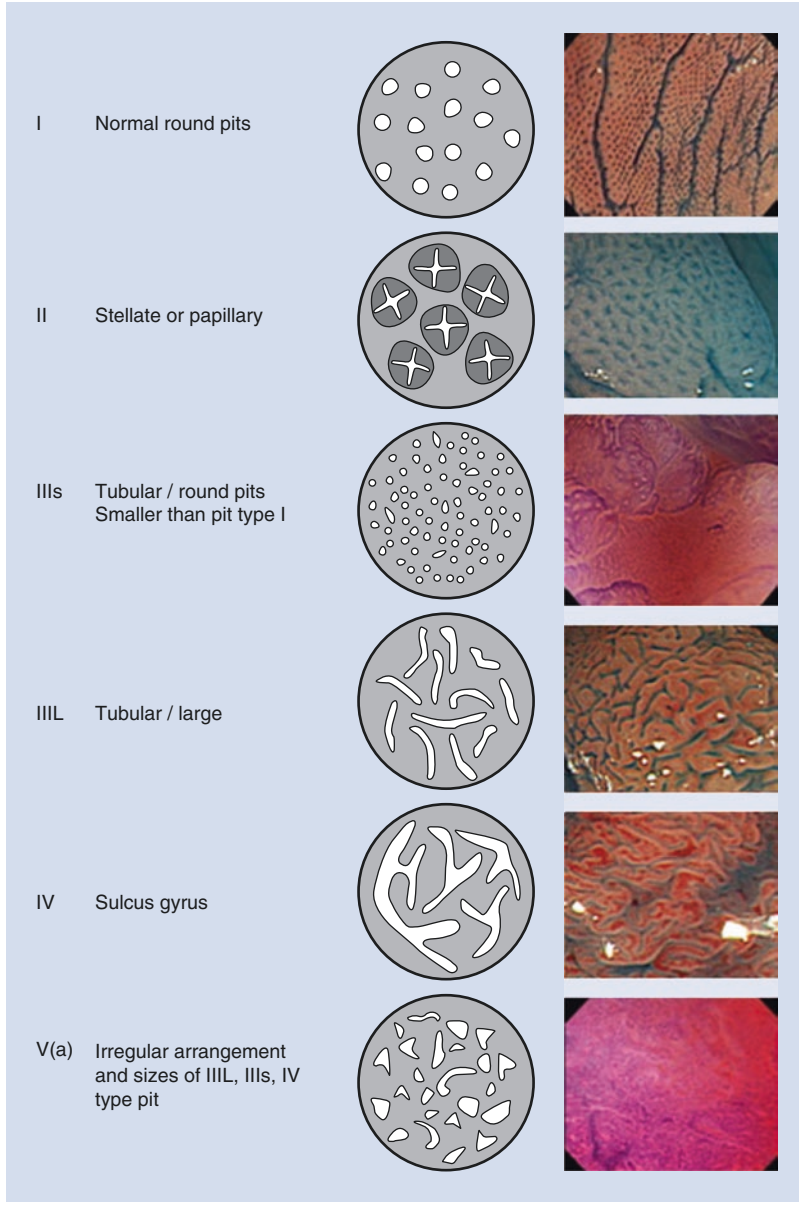

Fig. 1.1 Pit pattern classification according to Kudo

They don't replace (yet) the histopathological exam.

The need for pre-therapeutic biopsies is under debate. For the confirmation of the existence of a lesion and its basic entity, a biopsy is necessary.

On the other hand, the biopsy might be not representative for the entire lesion or the most advanced part of the tumor. It should be borne in mind that the result of a biopsy expresses the minimum degree of the lesion but not necessarily the final characterization.

Many authors comment about scarring and technical problems with resection after biopsies, but there is no evidence for this.

Another disadvantage is the possible initiation of enlargement of lymph nodes, which could falsify tumor staging by endoscopic ultrasound.

That is why the necessity of biopsies has to be decided on an individual basis. In particular, if the resectability of the tumor is recognizable, a biopsy is not necessary.

If there is a doubt about the existence of a tumor and if the tumor cannot be resected endoscopically, a biopsy is mandatory.

1.1.2 Coagulation

There is a general consensus that for all endoscopic manipulations of tissue including biopsies, minimal requirements for blood coagulation (quick test result of more than 65%, thrombocytes more than 100,000) have to be proved.

Medication with 100 mg acetic acid is no longer regarded as contraindication for endoscopic manipulations. For details, there is a special chapter at the end of this book. Also see the actual recommendations on the homepages of the scientific organizations.

1.1.3 Cleanness of the Examination Site

Pollution of the examination site by food and feces compromises the diagnostic value of the endoscopy. Furthermore, this may cause risks for aspiration and perforation. The examiner has to decide whether to abort the exam or to continue with cleansing by flushing and suction.

For endoscopic resections in particular, a clear action field is mandatory.

1.2 Polypectomy

Mostly in the left colon, adenomas typically form a pedunculated tumor with a less or more slim polyp. This observation is the background for the term «polyp,» which is not a proper medical description. At the start of endoluminal diagnosis with barium enemas and later with the first fiber endoscopes, this type of adenoma was the first which could be detected. Later, with the progress in diagnostic sensitivity, flat adenomas have also been discovered, but the unfortunate term «polyp» was retained. Nowadays, we know that colorectal adenomas have very different shapes ranging from pedunculated, sessile, and flat adenomas to those with depressions or ulceration (Figs. 1.2, 1.3, and 1.4).

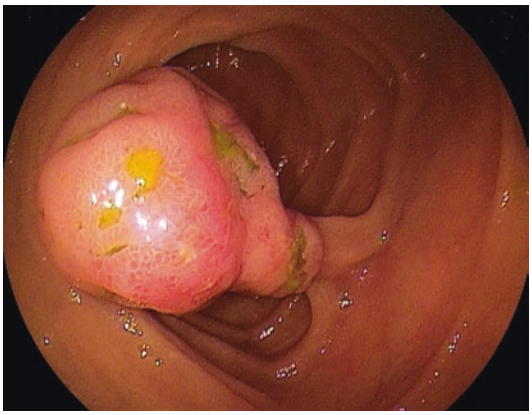

Fig. 1.2 Pedunculated «polyp»

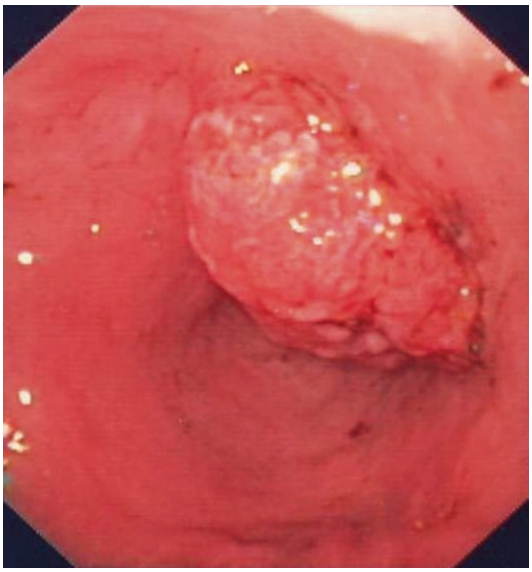

Fig. 1.3 Sessile «polyp»

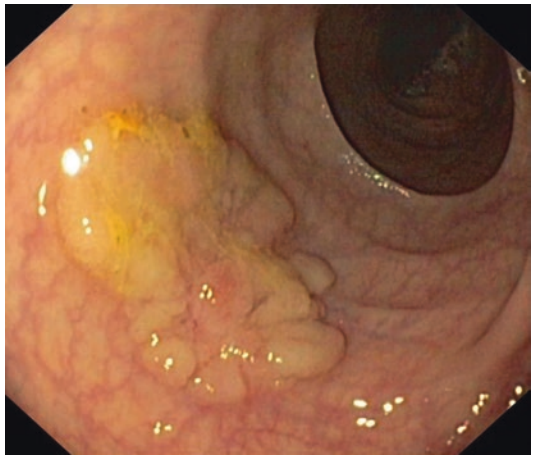

Fig. 1.4 Flat «polyp»

The most common and relevant tumors are adenoid tumors.

Indications

Most polyps in the gastrointestinal (GI) tract are adenomas and therefore real neoplasias. They require complete removal for diagnostic and therapeutic reasons.

Experienced examiners can rate the entity of the lesion by subtle inspection of its surface. If in doubt, a sample for histopathological exam is mandatory. Furthermore, an endosonography can clarify whether the lesion infiltrates the submucosal layer or deeper parts of the wall of the GI tract. In the majority of cases, and especially if the polyp has a visible polyp, an endosonography is not required.

A polypectomy is indicated for:

- Adenomas and polypoid adenocarcinomas
- Hamartomatous polyps
- Peutz–Jeghers polyps
- Juvenile polyps

Other polyps such as lipomas require removal only if they compromise passage, are ulcerated, or are bleeding.

After appendectomy, the stump can be inverted due to the operation technique. This mimics a sessile or pedunculated polyp. This impression is enhanced by changes of the mucosa at the tip of the appendix stump. To perform a polypectomy in this situation is unnecessary and dangerous due to possible perforation of the cecum.

Personnel Requirements

The attending physician has to be able to manage possible complications such as bleeding or perforation by injection therapy or clipping. One or better two assistants (in addition to the one for control of analgosedation) are needed. One of these has to be experienced in the abovementioned methods.

Technical Requirements

For a polypectomy, the following equipment is necessary in addition to the endoscope and its accessories:

- HF generator with endoscopy-specific settings (Fig. 1.5)

Fig. 1.5 HF generator (With kind permission of Erbe Elektromedizin)

Fig. 1.6 Neutral electrodes (With kind permission of Erbe Elektromedizin GmbH)

- Neutral electrode with cable (caution! small electrodes for children) (Fig. 1.6)
- Polypectomy snares of sufficient size (at least 5 mm larger than the lesion itself) (Fig. 1.7a–e)
- Connection cables between the snare and HF generator (caution! manufacturer-specific standards)
- Polyp trap (particularly if several polyps are located in the right colon)
- Instruments for retrieval of the polyps such as graspers and nets (Figs. 1.8, 1.9, and 1.10)

Accessories for Hemostasis

- Mandatory: clips (Fig. 1.11a–c), injection needles (Fig. 1.12), and saline or adrenaline solution
- Optional: coagulation grasper (Fig. 1.13), argon plasma coagulator, and endoloops (Fig. 1.14)

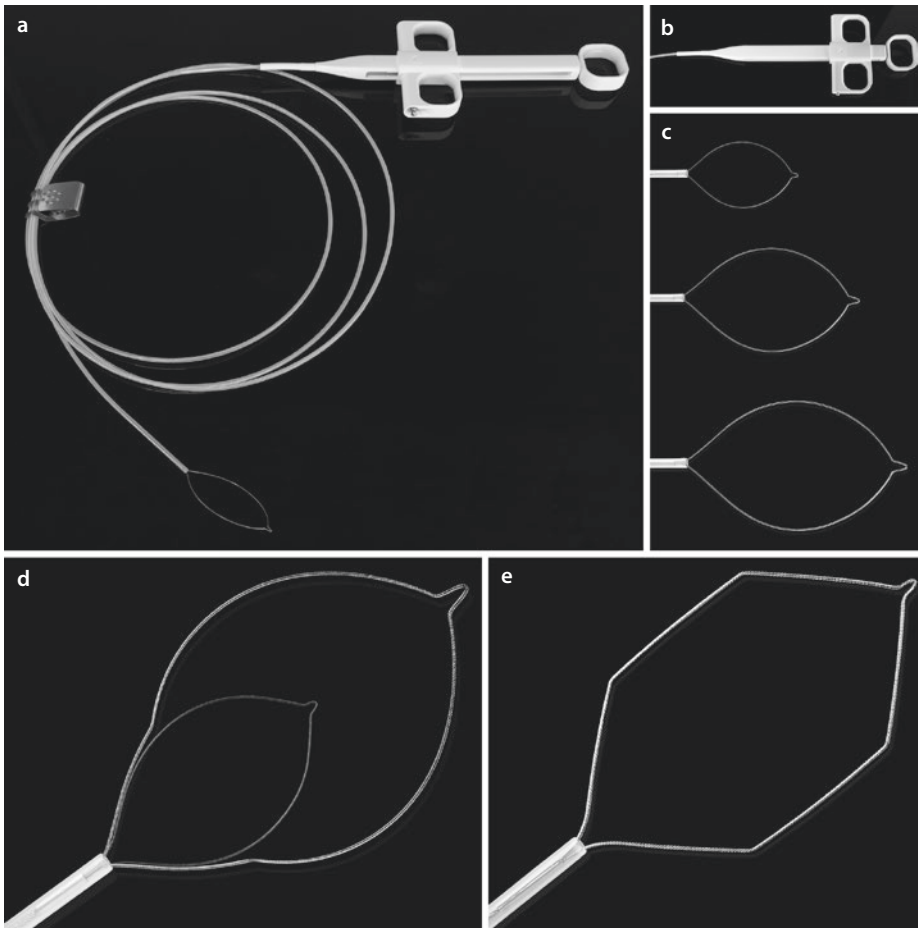

Fig. 1.7 **a–e** Polypectomy snares (With kind permision of medwork)

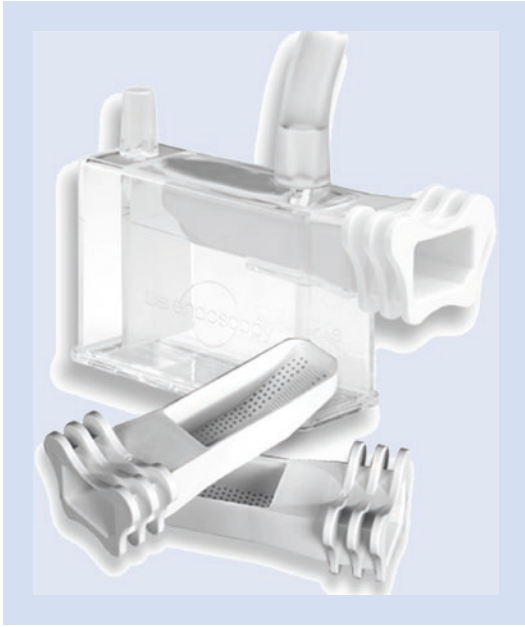

Fig. 1.8 Polyp trap (With kind permission of US Endoscopy)

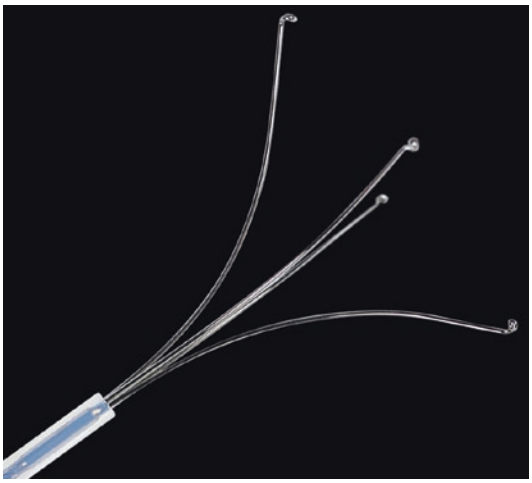

Fig. 1.9 Polyp grasper (With kind permission of medwork)

Administrative Requirements/Setting

The pre-endoscopic talk with the patient should include information and informed consent about a polypectomy and its complications, because every endoscopy can discover unexpected lesions which require removal for diagnostic and therapeutic reasons.

Under certain circumstances (patient's wish, urgent indication for anticoagulation, and low evidence for the existence of polyps), an examination without polypectomy is acceptable. Also, for very large lesions with risky removal, the resection should not be forced. For these cases, additional patient information and different settings for the removal including referral to specialized centers are recommended.

Fig. 1.10 Retrieval net (With kind permission of US Endoscopy)

Practical Execution

If there is no previous endoscopy, first a full examination should be carried out to get an overview concerning number, shape, and position of lesions.

In the colon, the resection should start at the highest (cecal) position and then in the direction of the anus. Because the resection site is a location of reduced resistance, unnecessary endoscopic passages should be avoided.

In the upper GI tract, the operation should be carried out from the aboral to the oral end.

Exceptions from this recommendation are very small or hidden polyps which can be removed by biopsy forceps immediately or can be marked within the first endoscopic passage.

If the exam reveals findings which require resectional surgery, the indication to remove further lesions depends on the following operation. If a right-sided hemicolectomy is planned due to a

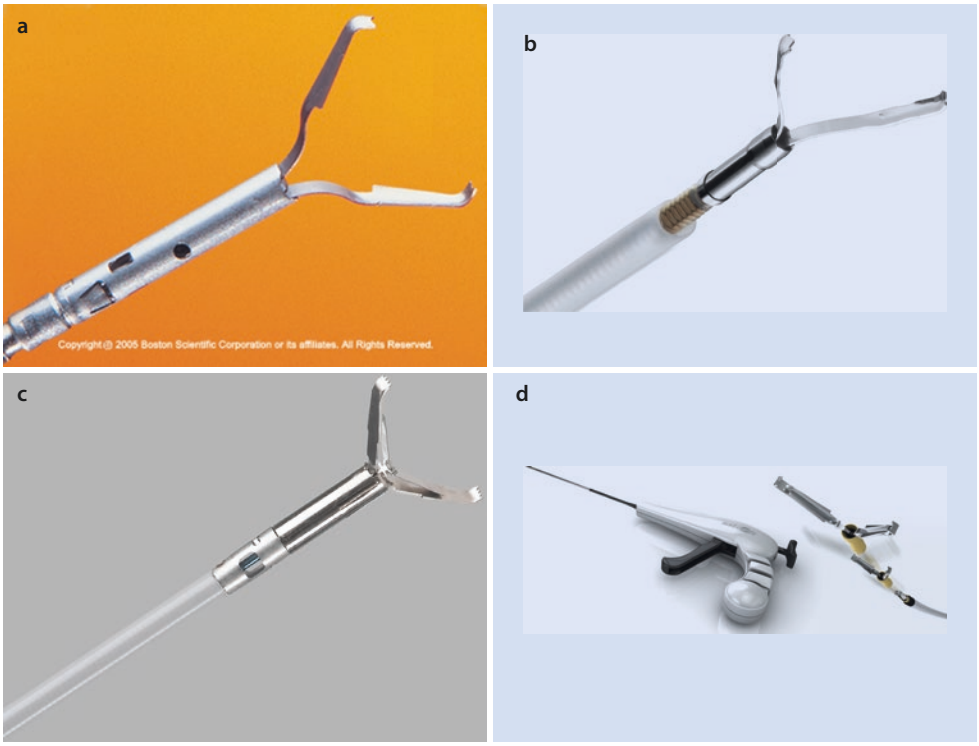

Fig. 1.11 **a**–**d** Clips. **a** Boston Scientific resolution clip. **b** Olympus hemoclip. **c** Cook Instinct clip. **d** medwork Clipmaster (With kind permission of Boston Scientific **a**, Olympus Deutschland **b**, Cook Medical Incorporated, Bloomington, Indiana **c**, medwork **d**)

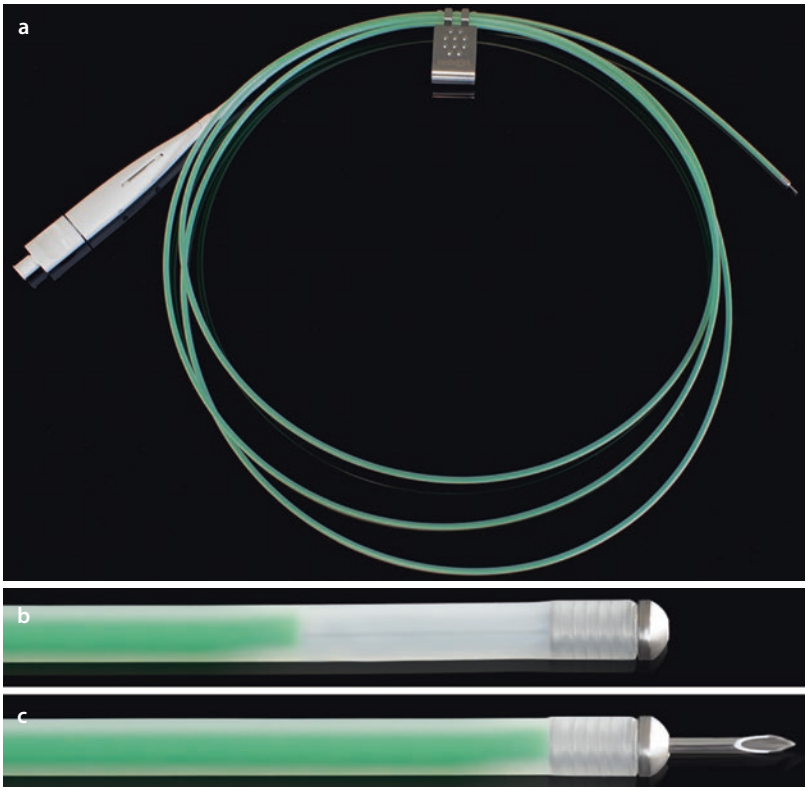

Fig. 1.12 **a** Injection needle overview; **b** tip with advanced and **c** withdrawn needle (With kind permission of medwork)

Fig. 1.13 Olympus Coagrasper (With kind permission of Olympus Deutschland)

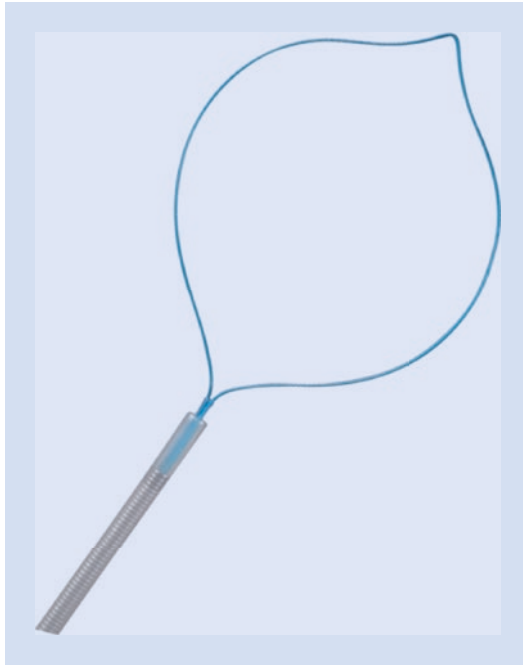

Fig. 1.14 Olympus endoloop (With kind permission of Olympus Deutschland)

cecal carcinoma in the left hemicolon, every polyp should be removed to clarify its malignancy status. For small lesions, an endoscopic tattooing is recommended to improve intraoperative recognition of the tumor. Avoiding intraoperative colonoscopy has some logistic advantages.

From the endoluminal aspect, it remains unclear in which part the colonic wall is covered by meso and in which it is not. Therefore, the tattooing should be injected in three corresponding parts of the colonic wall. Beginning with submucosal deposits of saline solution, these can afterward be marked with ink (Fig. 1.15) (Yeung et al. 2009; Bergeron et al. 2014; Haji et al. 2014).

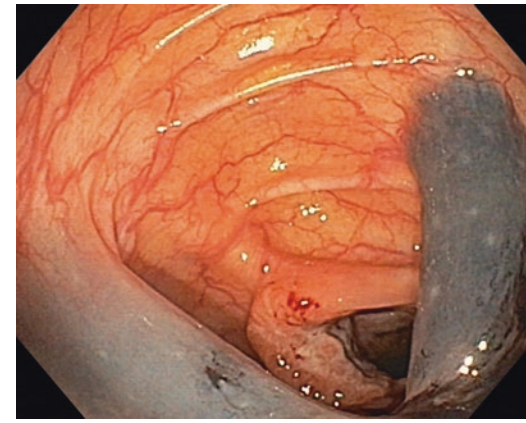

Fig. 1.15 Submucosal ink injection in the colon

Before starting the polypectomy proper, prophylactic hemostasis should be considered.

Therefore, ligation loops (as a single-use product or with reusable applicator) can be used. The placement of the ligation loop should ensure a sufficient distance to the margin of the lesion. A prophylactic injection of saline or diluted noradrenaline solution (1:10,000) to the basis of the polyp is cheaper. It has to be considered that the flattening of the polyp caused by injection may handicap the placement of the snare. Even prophylactic clipping could make further resection difficult.

In the author's experience, bleeding prophylaxis may be dispensed with, especially in pedunculated polyps. Priority should be given to a complete resection; post-resectional hemostasis is successful in nearly all cases.

Tip

The first examination after resection should be made on the resection side. Lesions of the GI tract wall or bleeding sources can best be seen immediately after resection. The specimen can be looked at later (Fig. 1.16).

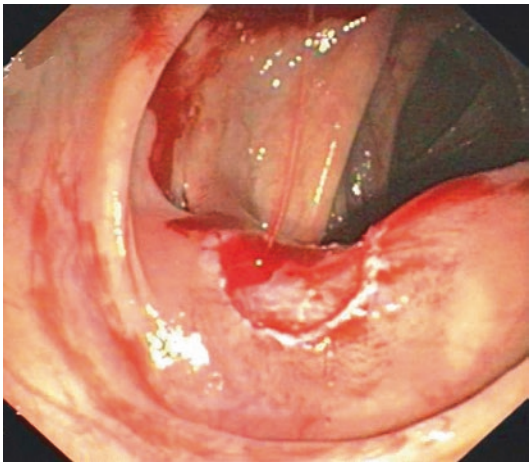

Fig. 1.16 Arterial bleeding after polypectomy

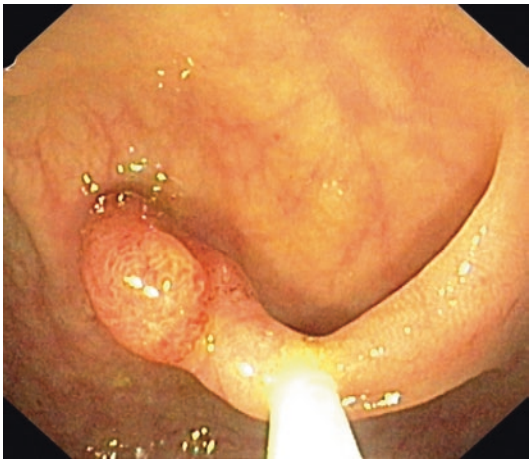

Fig. 1.17 Polypectomy of pedunculated polyp

To place the polypectomy snare, an excellent overview is mandatory. Remaining feces should be removed by flushing completely. The scope position should be stabilized. Balancing insufflation and suction and if necessary Buscopan i.v. administration can help to reach good visibility of the resection side.

In large polyps, the lesion should be passed. After complete opening of the snare, the polyp should be caught by withdrawing the scope with the open snare.

Closing the snare according to the order of the examiner is a very responsible task for the assisting person. If the snare is not closed strongly enough, the lesion can slip out. If it is closed too strongly, there is a risk of «cold snaring,» i.e., a cut without electrocautery which may cause bleeding in large lesions. Of course, experience and clear communication within the team support a successful procedure.

Furthermore, there are other risks associated with failed placements of the snare. Unnoticed grasping of healthy folds beyond the polyp can cause damage. If the snare is placed very close to the base, the risk of unintended resection of deeper layers of the GI tract wall as the muscular layer increases.

If in doubt, the snare should be reopened and the situation should be reviewed. Many textbooks recommend avoiding contact with the contralateral mucosa. In large polyps, this can be very cumbersome or impossible. Due to the improvements in modern HF generators, the risks of creeping electroenergy and consequent collateral damage have been significantly reduced (Fig. 1.17).

The cutting of the polyp base is carried out by moderate traction on the handle of the polypectomy snare. Modern HF generators provide special settings for polypectomy which consist of a defined alternating application of cutting energy and hemostasis. The correct setting and the use of the yellow pedal for cutting are important (this color code is a manufacturer-independent international standard).

The previously practiced so-called stutter cut (repeated short-time activation of the pedal) is not recommended anymore because this compromises the «endo cut» or other cutting modes. They contain a first-cut phase and then alternating cutting and coagulation modes.

This guarantees an optimal balance for effective prevention of bleeding and a small zone of electrocoagulation which allows an adequate histopathological exam.

Possible bleedings and visible lesions of the muscular layer (see also ▶ Sect. 3) can be managed easily with endoscopic clips. Small and diffuse bleedings can be treated by local injection or thermal therapy with argon plasma coagulation.

The use of the tip of the polypectomy snare for local coagulation is very quick and cheap. On the other hand, it is dangerous because there is no control with regard to the depth of the coagulation. Therefore, this should be done only in very small bleedings by experienced users.

To harvest the polyp, different methods can be used. Depending on its consistency, polyps up to 8 mm in size can be sucked through the instrumentation channel. For this purpose, polyp traps can be mounted between the endoscope and the

suction tube. This is very helpful, in particular if there are several polyps in the right-side colon (see Fig. 1.8).

If the polyps are too big for the transendoscopic suction, they can be grasped with the snare itself. This is sometimes difficult and the polyp can be divided by strong traction. Many manufacturers offer special polyp graspers with three or four arms or endoscopic nets. The latter are very useful, in particular for the harvesting of several polyps or fragments. They can be reopened to catch further polyps without loss of the previously caught polyps, due to their adherence to the net.

Another advantage of these devices is the ability to watch the mucosa while withdrawing the scope together with the net. Of course, large polyps can be sucked directly to the scope and transported by that. Because this compromises the endoscopic view, this method is recommended exclusively for the sigmoid colon and rectum.

Resected polyps sometimes move away from the resection site very quickly in both directions. From time to time, it can be very frustrating to search for them. The decision to continue polyp search or to sieve the stool may be made on the basis of an individual look at the relevance.

1.3 Endoscopic Mucosal Resection (EMR)

Indications

Endoscopic mucosal resection (EMR) is an evolutionary development of the polypectomy. It is used in non-pedunculated lesions. They are characterized by showing their largest diameter at the base. Given by nature, the shape of the lesion determines the resection method. This is not a preference of the physician.

Because EMR takes more time and more material and carries more risks, it is useful to describe it with another term than polypectomy. Meanwhile, the international classification OPS reflects this development.

As well as the polypectomy, EMR has a double character as a diagnostic and as a therapeutic measure. The complete resection can be regarded as a «total biopsy» and doesn't require a previous biopsy.

But nevertheless, to start a successful and complete resection, all requirements should be given. This includes patient conditions (informed consent, coagulation, adequate follow-up), the lesion (infiltration depth, size), and the related logistics (instrumental and personal equipment, time slot, experience). An intended incomplete resection is not recommended because this compromises later completion.

Of course, the infiltration depth can be detected by endoscopic ultrasound. This is well established for the rectum, esophagus, stomach, and duodenum; for the colon and small bowel, it is not. Because the exact measurement of the tumor staging, in particular the depth of infiltration to the submucosal layer, is not reliable, some experienced endoscopists abstain from endosonography. They estimate the tumor stage on the basis of subtle endoscopic inspection (Bergeron et al. 2014; Haji et al. 2014).

Nonetheless, the author recommends routine use of endosonography prior to resection in the upper GI and in the rectum because of the possible detection of additional findings such as lymph node enlargement, its risk-free performance, and its training effect.

Personnel Requirements

As in polypectomies, one or two persons for assistance are necessary in addition to the person for monitoring of analgosedation. Personal experience is more important than formal qualifications of the assisting person. Of course, the endoscopist bears the responsibility. He should be aware of his team leadership and has to take responsibility for clear communications.

Instrumental Requirements

Endoscopic mucosal resections are done by snare on principle. In particular in the esophagus, some modifications have been established which focus on a simplification of the procedure.

Instrumentarium for Endoscopic Mucosal Resection

Essentials

- Polypectomy snare
- Endoscopic injection needle
- Metal clips for hemostasis and possibly closure of defects
- Polyp trap, catching net, or polyp grasper

Optional Tools

- Transparent hood (Fig. 1.18)
- Asymmetric snare (Fig. 1.19)

- Second grasper for dual channel endoscope
- Ligation system (z.B. Duette, Cook) (Fig. 1.20)

Fig. 1.18 Mucosectomy cap (With kind permission of Olympus Deutschland)

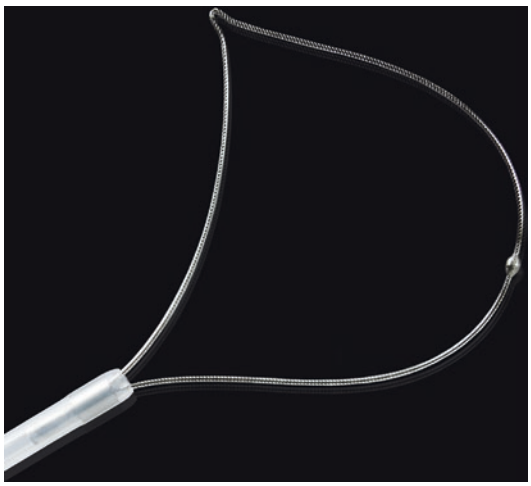

Fig. 1.19 Asymmetric snare (With kind permission of medwork)

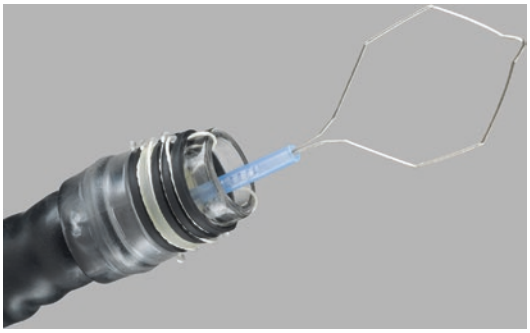

Fig. 1.20 Duette suck-and-cut system (With kind permission of Cook)

Organizational Requirements/Setting

Because partial mucosal resections cause local scarring, they seriously complicate the later completion and increase the risk of failure of the endoscopic therapy. Against this background, an endoscopic resection should be started only if completion can be achieved in the same session.

With regard to EMR, this means that a complete set of tools and patient-related requirements such as a check of blood coagulation, sufficient bowel preparation, informed consent, and analgosedation are required. Furthermore, backup management of possible complications should be organized including in hospital surveillance and surgical repair.

Practical Execution: Double-Channel Endoscopic Resection («Grasp-and-Snare»)

The use of a double-channel endoscope enables the examiner to insert a second grasping instrument via the second channel alongside the cutting instrument in the main channel. The idea is to pull the lesion into the snare with the help of the grasping instrument (forceps, grasper). Due to the limited availability of double-channel endoscopes, the method is not widely established. One of the main problems of interventional endoscopy remains unsolved. Every inserted instrument can be moved only with the entire scope. That is why the two instruments cannot be moved independently from each other. They don't allow the triangulation or application of traction and countertraction.

Even prototype endoscopes such as the R-scope from Olympus with two bending segments and two differently orientated Albarran elevators did not solve the problem. A new approach from the same manufacturer is the

Fig. 1.21 EndoLifter (With kind permission of Olympus)

EndoLifter. It enables the examiner to place a grasping forceps outside the scope and to draw it back independently from the scope movements (Fig. 1.21) (Imaeda et al. 2014).

Practical Procedure: Suction Cap Mucosectomy («Suck-and-Snare»)

Barrett's mucosa in the distal esophagus can be resected with a special method: the «suck-and-snare» technique.

Due to the restricted diameter in the esophagus, the angle of access of the scope to the esophageal wall is limited. Suction caps can overcome this obstacle. Suction caps are available in oblique and straight versions, with a maximum diameter of 20 mm. The size will be chosen according to diameter and position of the lesion. They have an internal ring in which the asymmetric snare is placed. This should be prepared before starting the insertion of the scope.

After careful endoscopic inspection of the lesion and electrical marking of the intended resection line around the lesion, the scope is withdrawn for the fitting of the suction cap to the tip of the scope. While passing the upper esophageal sphincter, the snare may dislocate from the inner ring of the cap. In this case, a repositioning against the stomach wall should be done.

After identification of the marked lesion, the tissue will be sucked into the cap. While continuing sucking, the snare will be closed with a mild pushing force. This will ensure that a maximum of tissue is caught in the snare.

An endoscopic control of the resection site reveals whether the markings are contained completely in the specimen. If not, the resection can be repeated. Here it is important to avoid suction of the muscular layer to the cap.

Especially in cases with large areas for resection, a special tool for serial ligated resections can be used. The Duette system (Cook) offers rubber bands on the transparent hood. They will be applied as in ligation therapy. Hereafter the newly created «polyp» can be resected by snare. The system offers a quick and safe resection technique (Pouw et al. 2010).

Practical Procedure: Snare Resection («Snare Alone»)

The solitary use of the polypectomy snare is the most common technique for EMR. In particular, in the stomach, duodenum, colon, and rectum, it is the standard for mucosal resections. With regard to the fact that the results of the endoscopic resection trigger the need of further surgical operations, the performance of EMR is a very sensible procedure.

The EMR has three simultaneous goals:

1. Complete resection of the lesion, ideally in one piece and with a healthy tumor-free margin
2. The avoidance of resections of the muscular layer, in particular those which cannot be closed by means of endoscopy
3. The avoidance of bleedings

In the author's opinion, the above list is an order of priority. It reflects the experience that bleedings can be managed endoscopically in nearly every case. Also, visible lesions of the muscular layer can be closed by metallic clips in particular if the serosa is not affected (covered perforation). In the long run, local tumor recurrence might be the greater problem.

This should not justify a careless resection technique, but the current clinical praxis opens a lot of space for improvements. Current statistics demonstrate that a lot of colorectal adenomas are treated by oncosurgical resections due to suspected malignancy or supposed endoscopic irresectability.

An effective submucosal injection is important for a successful EMR. This is to ameliorate the trapping of the lesion in the snare. Furthermore, the submucosal injection broadens the submucosa and prevents the involvement of parts of the muscular layer into the snare. Submucosal injection also prevents bleeding by compression of small vessels. Finally, the addition of a small amount of adhesive color (e.g., 1:1,000 Toluidine blue) to the injection fluid improves the visibility and the discrimination of the lesion. Especially in lengthy procedures with several steps, the coloration of the submucosa helps to maintain the overview (Fig. 1.22a–b).

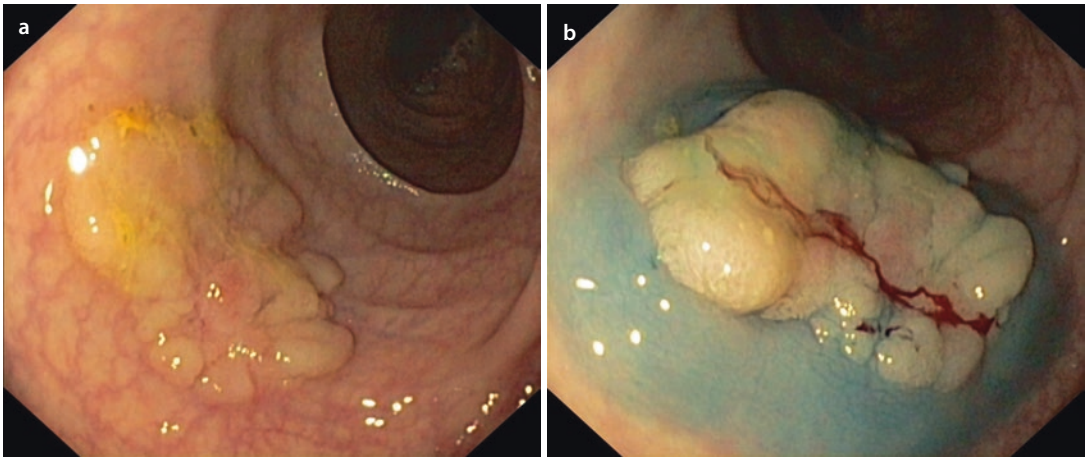

Fig. 1.22 Submucosal injection of an adenoma. **a** Flat native adenoma. **b** Flat adenoma after submucosal injection with Toluidine blue solution

The easiest and cheapest solution is isotonic saline solution. The addition of adrenalin to prevent bleeding is not recommended. Large bulky lesions in particular require a high volume for injection. In these cases, the cardiovascular side effects of large amounts of adrenalin may be problematic.

In cases with small manageable lesions, this may still be done by the endoscopist, but there is no evidence for effectiveness of vasoconstrictive additions.

Various other fluids have been tested for submucosal injection as well. Hyaluronic acid has been found to be very effective, but it is costly. Plasma expanders such as dextran and hydroxyethyl starch 6% are cheaper and cause a local volume traction effect. They provide longer-lasting fluid cushions than saline solution (Sold et al. 2008). One disadvantage is their high resistance in the injection process.

The fluid injection is carried out with a standard injection needle. A flat insertion at the edge of the lesion is recommended. While the assistant generates a continuous pressure flow with the syringe, the needle is withdrawn very gently. The examiner has to watch the region carefully and stops the withdrawal of the needle if the tip reaches the submucosal layer. This is verified by a clearly visible lifting of the mucosal layer. This maneuver is repeated around the lesion until the entire tumor and its surroundings are elevated. If necessary, the injection can be done also through the tumor.

Especially in narrow organs such as the esophagus and colon, it is helpful to start injection at the back of the lesion. Otherwise the lesion can tilt to the back and resection is handicapped.

Tip

As well as for preparing the injection for the resection, it can be very helpful to work with the tip of the scope in an inverted position. To invert the scope is easier with pediatric endoscopes. This should not be forced to avoid perforations.

Because this technique alters the chances for a complete resection, the use of pediatric colonoscopes as a standard is recommended (Fig. 1.23).

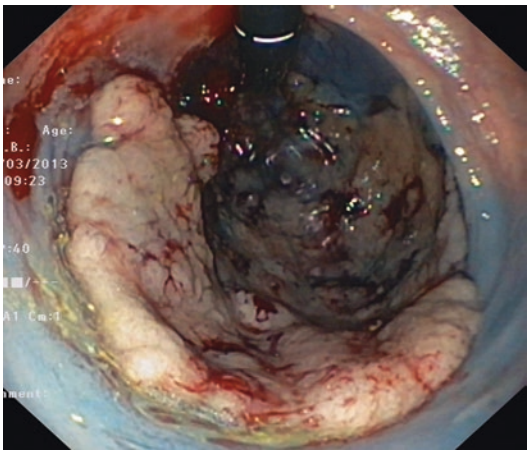

Fig. 1.23 Adenoid tumor in inverted scope position

1

Especially for the resection of adenomas larger than 25 mm, a special technique has been developed which uses water-jet technology. It is known from surgical dissection of parenchymatous organs such as the kidney, liver, brain, and others. A thin capillary is connected with a special pump and applied to the mucosal surface. In the tip of the capillary, there is a special crystal, which forms a coherent water beam. It penetrates the mucosa immediately due to its soft character. The submucosal layer of the GI tract wall consists of a three-dimensional nexus of fibrous fibers which reflect the beam in every direction. A fluid cushion selectively in the submucosal layer is the result (selective tissue elevation by pressure = STEP). Especially in large and complex adenomas, the technique is very helpful (Fig. 1.24a–b) (Kahler et al. 2007).

The actual resection is done with a polypectomy snare. Manufacturers offer a broad spectrum of snares, in terms of size (15–60 mm), shape (oval, hexagonal, asymmetric), material (nitinol, steel), and processing (mobile, braided). The users have different priorities. In the author's experience, a braided 30 mm oval snare is a good standard which covers a large majority of cases.

Most snares feature a shaped tip which helps to fix the snare in one point above the lesion. Beginning at this point, the snare is opened slowly and is positioned around the tumor. Now a harmonized coordination between the examiner and assistant is crucial to coordinate movements of the snare and the endoscope. Of course, the assistant needs a clear view of the monitor.

Before closing the snare, it is very important to reduce the tension of the GI tract wall by sucking out the air. This can mean a complete collapse of the lumen with loss of the view. Thus, even a flat lesion can fall into the opening of the snare. Throughout the closing of the snare, the examiner has to push the snare in the direction of the wall to cover the lesion completely. The assistant has to be aware that the final tension for closing the snare is much higher in EMR than in polypectomy. Strong tension is necessary to avoid the lesion slipping out of the snare. The risk of an unintended cutting («cold snaring») as in polypectomy is negligible.

Thereafter, the lumen is re-insufflated, and the tissue which is grasped in the snare should be controlled. The risk in this maneuver is to include parts of the muscular layer into the resection. If in doubt, a shaking movement of the snare can check if the entire GI tract wall is moving or just superficial parts of it. A careful opening of the snare allows deeper layers of the wall to slip out of the snare. Of course, this act requires a lot of experience. Finally, there remains some uncertainty.

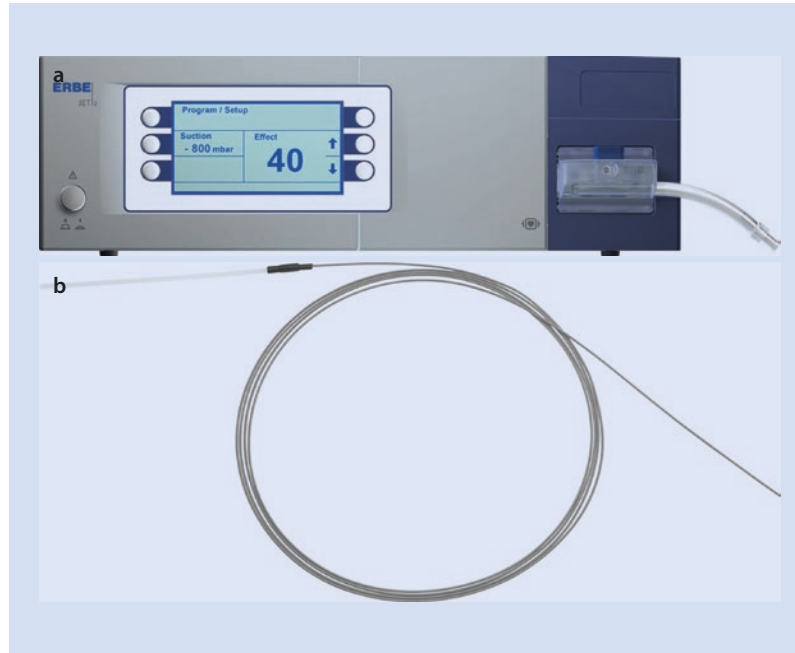

Fig. 1.24 **a–b** Instrumentarium for water-jet dissection. **a** Erbe-Jet. **b** Probe for Erbe-Jet (With kind permission of Erbe Elektromedizin, Tübingen, Germany)

Fig. 1.25 Pedal of the HF generator (With kind permission of Elektromedizin, Tübingen, Germany)

Now the actual resection is done by cutting with the high-frequency (HF) generator. All manufacturers have to provide yellow pedals for cutting and blue pedals for coagulation energy modes (Fig. 1.25).

Generators with special settings for endoscopic resections are strictly recommended. These special settings have (adjustable) sequences for cutting and coagulation modes. A continuous activation of the pedal is important for their function (no «stammer cutting»). An alternate activation of the yellow and the blue pedal would defeat the effect of the «endo cut.» For details, see the recommendations of the manufacturer of the HF generator.

Tip

After resection the first view should go to the resection side because possible lesions of the wall and bleeding vessels can be recognized optimally in the earliest moment after resection. Thus, they can be treated in a very targeted manner. Clips have to be ready for use.

In cases with large lesions, which cannot be resected in one piece, a fractional resection (piecemeal resection) has to be carried out. There is no strict recommendation to start with either the oral or the aboral part of the lesion, but the first cut should consider the entire and complete procedure. Prominent parts of the tumor are easier to get into the snare. Therefore, they are a good place to start the resection. This creates an abutment for further placements of the snare.

The resection should be continued to completion whenever possible. Later resections are compromised by scarring due to previous resections.

Clips should be applied after completion of the resection because they may disturb snare placement. To stop arterial bleeding, the use of a special grasping coagulation forceps («Coagrasper») is superior to clipping against this background.

Visible lesions of the muscular layer should be closed by clips even if they are covered by serosa (covered perforations) (Fig. 1.26a–b).

If the lesion's shape is not slit-like, it may be necessary to narrow it from the edges. For larger

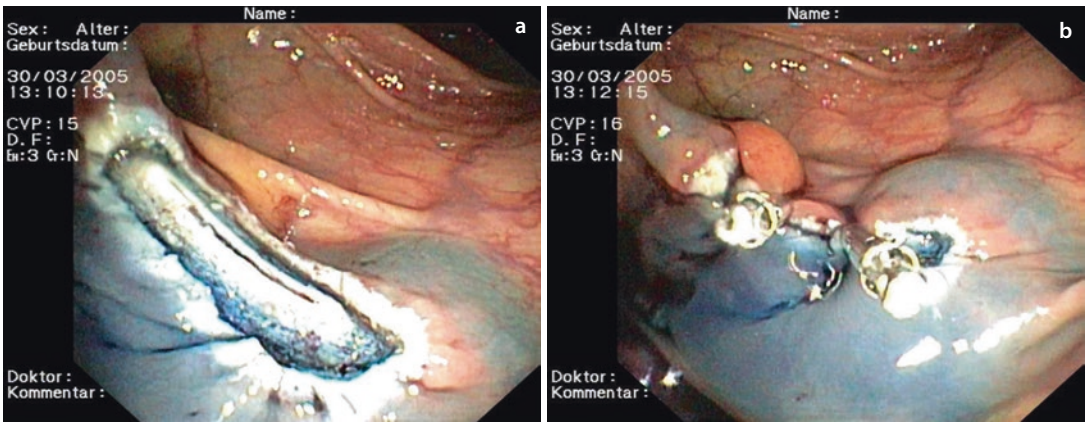

Fig. 1.26 **a**, **b** Covered perforation after EMR. **a** Lesion. **b** Clip closure of the lesion

lesions, a special over-the-scope clip is recommended. It can be applied with the help of special grasping instruments (anchor or twin grasper). They help to grasp the edges of the perforation and to pull the tissue into the transparent hood of the application system (Weiland et al. 2013; Magdeburg et al. 2013, 2008).

If the patient demonstrates a pneumoperitoneum, until the lesion is closed, it should be punctured or drained. The patient should receive antibiotics and careful clinical surveillance for minimally 48 h: if there is any doubt, obviously a readiness to intervene surgically is self-evident.

The decision concerning nonsurgical management of a perforation is very important and has to be made within a reasonable time period. Because the endoscopic examiner may be uncertain, this decision should be made in an interdisciplinary team. Of course, it is more important to avoid a severe peritonitis than a surgical intervention.

To harvest the specimen, there are several methods available. Small and soft polyps can be sucked through the scope. Therefore, a special trap between scope and suction device is necessary. Larger specimens can be grasped with the snare or with special polyp graspers. In cases with several specimens and in particular in the right colon, endoscopic nets are very helpful. According to the size, shape, and nature of the lesion, the examiner should consider fixing it on a flat material (cork, plastic) with pins to improve the histopathological exam.

1.4 Endoscopic Submucosal Dissection (ESD)

Indications

The indications for ESD follow the same principles as EMR. ESD is indicated in all mucosal tumors with confirmed or suspected malignancy due to the endoscopic feature (Fig. 1.27) (Barreiro & Dinis-Ribeiro 2013).

The infiltration depth in particular to the submucosal layer can be estimated by endosonography or by watching the submucosal injection. A good elevation is regarded as a «positive lift-off sign» and as an indicator for benign lesions. Conversely «negative lift-off» is regarded as an aspect of malignancy by many authors. In practice, it is difficult sometimes to make a safe distinction. Previous (incomplete) endoscopic resections, deep biopsies, and chronic inflammations also can cause scarring in the submucosal layer and thereby a negative lift-off.

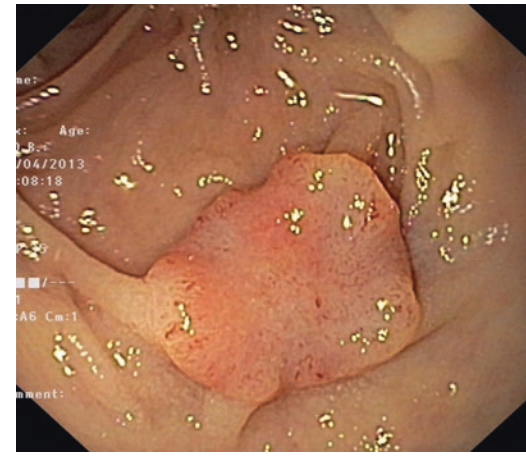

Fig. 1.27 Mucosal colonic cancer

Histopathological high-risk criteria such as microlymphatic (L+), microvenous (V+), perineural (Pn+), or poor tumor differentiation (G > 2) are clear contraindications for endoscopic resections with curative intent.

Personnel Requirements

For ESD, the entire team has to be aware that it is a lengthy procedure. In addition to the examiner and assistant, another assistant or a second physician is necessary to manage possible complications and the lengthy sedation. Full anesthesia is not necessary but can be useful in patients with coronary heart diseases or severe lung dysfunction. For details see the guidelines for analgosedation in endoscopy. If in doubt, contact the anesthetist.

Instrumentation Requirements

The following devices are necessary for ESD:

- HF generator with special endoscopy-related settings
- Instruments for injection: injection needle or hybrid knife with water jet
- Fluids for submucosal injection (for details see text)
- Endowasher with side adapter on the instrumentation channel (Figs. 1.28 and 1.29)

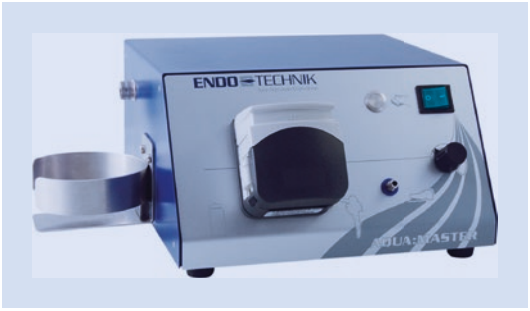

Fig. 1.28 Endowasher (With kind permission of Endo-Technik W. Griesat)

Fig. 1.29 Flush adapter for instrumentation channel (With kind permission of medwork/US Endoscopy)

- Needle knife optionally with insulated tip (IT knife) (Fig. 1.30a–d)
- Instruments for bleeding control (Coagrasper, clips)
- Instruments to harvest the specimen (grasper, net)
- Transparent hood for the tip of the scope (Fig. 1.31)

Optionally, the following instruments can be used:

- Large clip for full-thickness closure (OTSC) with grasper (anchor and/or twin grasper)
- CO2 insufflation for the endoscope (Fig. 1.32)
- Devices for puncture or drainage of free gas (e.g., suprapubic bladder puncture set) (Fig. 1.33)

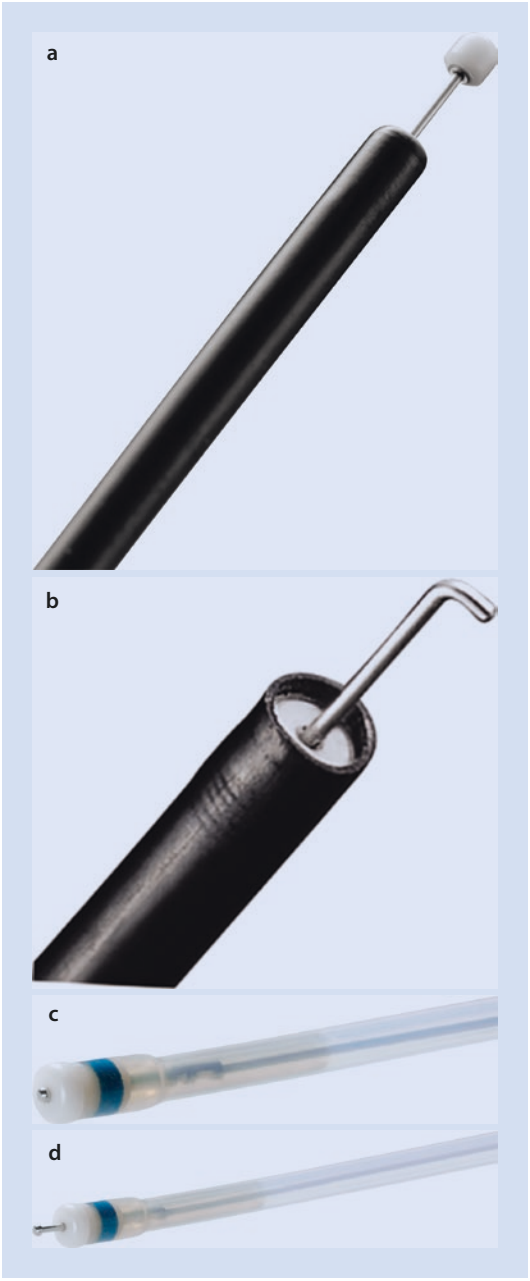

Fig. 1.30 **a**–**c** Needle knife. **a** HybridKnife I-Type. **b** IT knife. **c** Hook knife. **d** Dual knife (With kind permission of Erbe Elektromedizin **a**, MTW **b,** and Olympus Optical Co **c**, **d**)

Organizational Requirements/Setting

The setting for ESD is clearly more demanding than every other endoscopic procedure. Because the time duration is difficult to estimate, a sufficient reserve should be scheduled.

Fig. 1.31 Transparent distance hood for ESD (With kind permission of Olympus Optical Co)

Fig. 1.32 CO2 insufflation system (With kind permission of Olympus Optical)

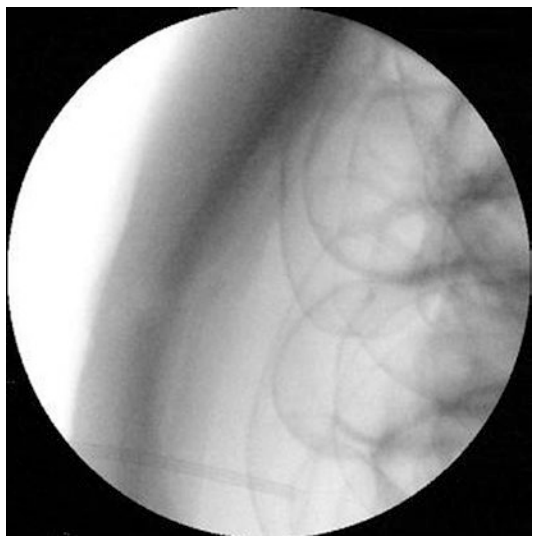

Fig. 1.33 Free gas and drainage in fluoroscopy

Mobile phones, pagers, and other deflecting factors should be banned from the room. The team should discuss the approach for possible complications, in particular if surgical repair is needed. Special team training before beginning with ESD is ideal.

Practical Procedure

Due to the long duration of complex ESD, some special aspects have to be respected as in surgical procedure. The bedding of the patient has to avoid cooling down as well as paresis, because of long-lasting compression of peripheral nerves. It has to be taken into account that changes of the patient's position for tactical reasons can be necessary.

The actual procedure starts after flushing and orientation about the lesion, with marking of the planned resection line by electrocoagulation or argon plasma coagulation (APC). These markings should be minimally 5 mm distance to the tumor. The visibility of these markings is crucial, because the overview reduces during the course of the procedure. Otherwise, the completeness of the resection is the basis for oncological success.

For marking the existing needle, knifes can be used. The use of APC is less traumatic for the mucosa but involves additional costs (Fig. 1.34).

For injection, a standard needle can be used. To create long-lasting fluid cushions, a viscous substance should be used. The addition of vasoconstrictive drugs is not recommended because high volumes may be necessary, and this can cause systemic side effects.

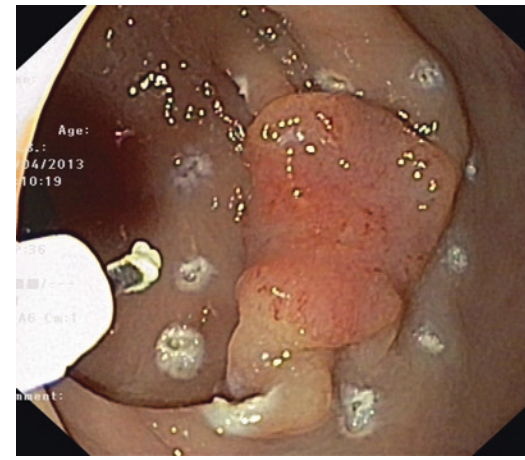

Fig. 1.34 Mucosal carcinoma with marking

Japanese authors prefer hyaluronic acid but it is expansive. Plasma expanders such as hydroxyethyl starch (HAES) or dextran are cheap and available everywhere. They also can be used to create durable submucosal fluid cushions.

Some ESD knifes provide the opportunity to apply fluid simultaneously. The FlushKnife (Fujinon) makes it possible to flush the target area with low pressure next to the cutting tip (Fig. 1.35). This is helpful if the mucosa is opened already. Hence, its use presumes the previous cut in the mucosa and thus a conventional needle injection.

The HybridKnife (Erbe Elektromedizin, Tübingen, Germany) contains a central channel. By this, a focused fluid beam can be applied which penetrates the mucosa and creates a fluid cushion in the submucosal layer selectively (see ▶ Sect. 3). This can be repeated in every phase of the procedure without changing the instrument (Neuhaus et al. 2009; Yahagi et al. 2009; Lingenfelder et al. 2009).

The knife is provided in three different tip shapes (Fig. 1.36a–c).

Some authors add ink for the coloring of the tissue. In the author's experience, an addition of low concentrated Toluidine blue (1:2,500) improves the recognition of tissue layers.

Afterward, the circumcision of the lesions starts outside the markings (Fig. 1.37).

According to size, shape, and position of the tumor, various tactics can be used. While some authors start with a complete circumcision, others

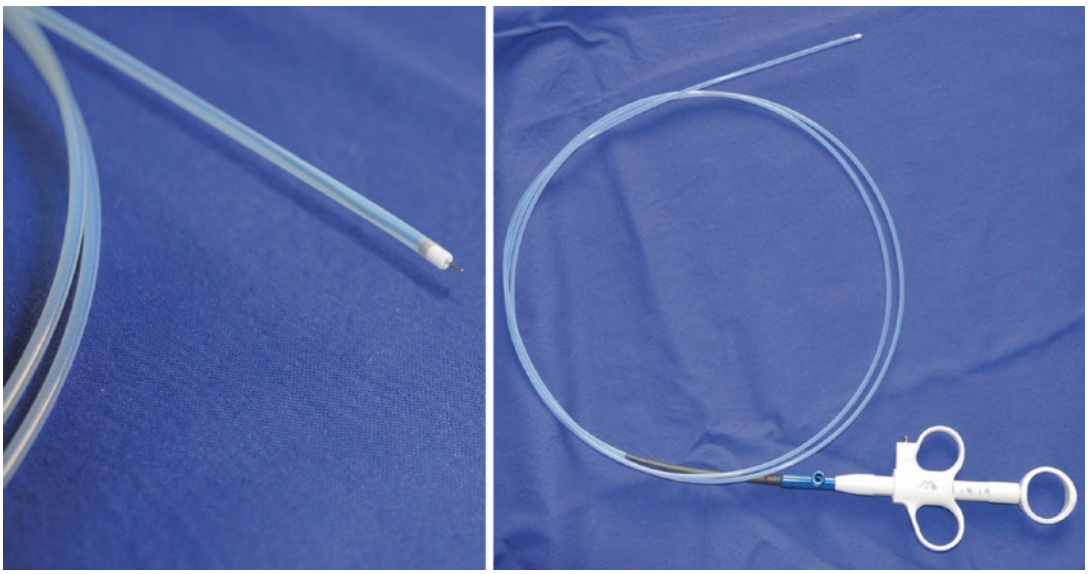

Fig. 1.35 FlushKnife (With kind permission of Fujinon)

Fig. 1.36 HybridKnife. **a** HybridKnife I-Type. **b** HybridKnife T-Type. **c** HybridKnife O-Type (With kind permission of Erbe Elektromedizin, Tübingen, Germany)

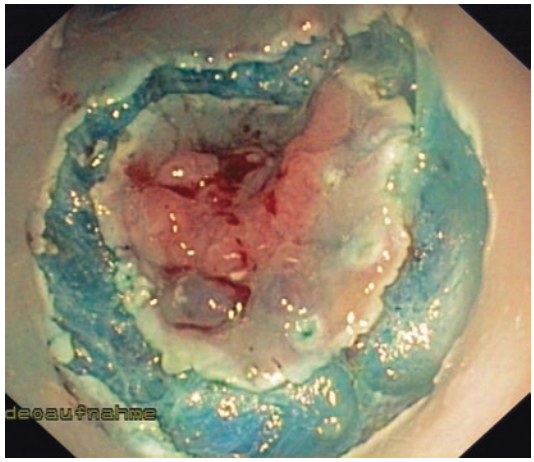

Fig. 1.37 Mucosal carcinoma after circumcision

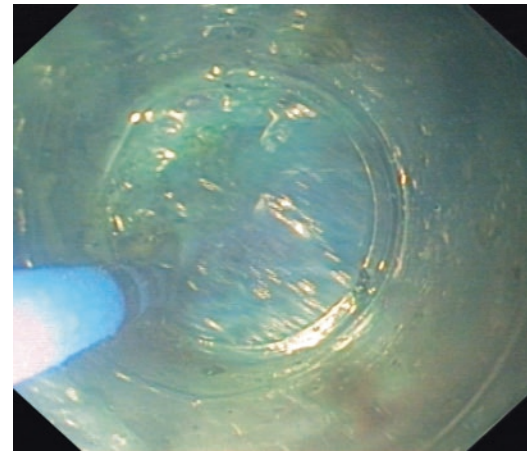

Fig. 1.38 Submucosal dissection with hood

leave a small mucosal bridge as a hinge. The resection tactic aims to use gravity to enlarge the submucosal gap between specimen and the GI tract wall, possibly with positional changes of the patient. The manufacturers offer different knifes, mostly with adjustable length of the knife. The tip of the knife should be advanced to the minimum length which is necessary to penetrate the mucosa. The absolute distance depends on the anatomical position of the lesion. In the stomach, the working distance is longer than in the colon. In addition, the angle of access to the lesion influences the advancement of the needle tip. Insulated-tip knives are especially recommended for the circumcision because they reduce the risk of uncontrolled violations of the muscular layer in this stage of the procedure.

The examiner should move the scope with his left hand, while the right hand guides the entire endoscope with a pushing, pulling, turning, or combined movement.

For the next step, the submucosal dissection, a transparent hood should be attached to the tip of the scope. It should overtop the scope by 5 mm to create distance between the optical lens and the target tissue. (Many endoscopists started to use these caps also for routine examinations because they may improve optical conditions.)

The submucosal dissection is the most difficult and demanding stage of the procedure. The dissection has to be done close to the muscular layer (Fig. 1.38). The knife has to be moved in a strictly parallel direction to the wall. The choice of the deep submucosal stratum is more due to the rarefaction of blood vessels than to oncological reasons.

If blood vessels can be identified, they should be coagulated preemptively with a Coagrasper or the knife. In the case of bleeding, an immediate bleeding control is necessary to maintain the overview and to lesser importance to spare blood. The permanent standby of a flushing device is essential to localize the bleeding source. Monopolar coagulation can be applied also under water.

While the dissection is done, the endoscopist always has to keep the orientation over the anatomical situation. Insufflated gas and flushing fluids have to be evacuated intermittently.

In the past, many techniques have been described for improving the submucosal dissection. As mentioned above, some authors change the patient position to use gravity of the specimen. Double-channel endoscopes, use of magnets, use of a second endoscope, or the fixation of an external grasping device (EndoLifter, Olympus Optical) have been tested to improve safety and speed of ESD. None of these were completely convincing. Thus, the user has to decide on one or the other of these technologies, depending on the circumstances of his patient.

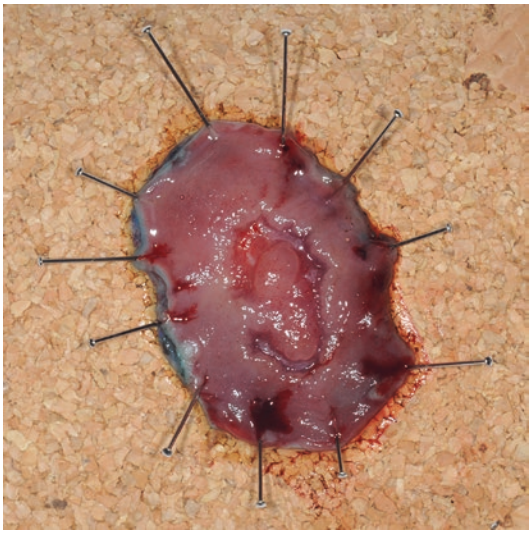

Fig. 1.39 Fixed ESD specimen

If the lesion is circumcised completely, there is a specific temptation for the examiner to use a snare to complete the resection. The endoscopist should be aware that this carries the risk of compromising the result of ESD by cutting through the tumor due to insufficient overview or control of the snare position.

To harvest the specimen is no problem. This can be done with suction to the cap, by snare, or by a net. The resection site should be controlled for small perforations. They can easily be closed with clips. Larger lesions can be closed with the over-the-scope clip (Ovesco Endoscopy AG, Tübingen, Germany). Visible blood vessels should be coagulated for prevention of later bleedings.

Especially after ESD, it is important to fix the resected specimen with some pins in a flat position to an appropriate material such as cork or plastic. This is necessary for a proper histopathological exam. Some endoscopists use this to orientate the specimen for later correlation between tumor and resection site (Fig. 1.39).

A routine endoscopic control of ESD sites is dispensable. Clinical surveillance for 24 h, better 36 h, is recommended. Administration of PPI supports ulcer healing in the stomach. Antibiotics are not necessary in the absence of perforations.

1.5 Endoscopic Full-Thickness Resection

In contrast to the above methods, endoscopic full-thickness resection is not a clinical standard yet. That is why we describe herein the principles of different published techniques. We want to point out that clear standards have not yet been established with regard to either indications or technique.

1.5.1 Closed Full-Thickness Resection

For lesions not larger than 2 cm, two techniques are described which are suitable in particular for lesions in the lower corpus of the stomach. In both, the procedure starts with the creation of a full-thickness plication and a following resection of inverted parts of the GI tract wall (Schmidt et al. 2014).

Flexible surgical staplers (which are not commercially available at the moment) can be introduced via the esophagus to the stomach. A slim endoscope can also be introduced alongside the stapler and can grasp the gastric wall into the opened branches of the linear stapler. When closing and firing the stapler, a resection is done after closure of the wall without a connection at any time to the abdominal cavity (Fig. 1.40a–c) (Kaehler et al. 2006).

Another technique has been described by K Caca et al. for submucosal tumors of the gastric wall. With the help of an endoscopic suturing device (GerdX; G-Surg GmbH, Traunstein, Germany), a double plication is created. Afterward, a snare resection of the full gastric wall can be carried out without perforation (Fig. 1.41) (Schmidt et al. 2014).

Recently, Ovesco Endoscopy presented a further development of its over-the-scope clip. It is connected with a large transparent hood. First, the lesion is grasped and/or sucked into the cap. Then the clip is fired, and a snare at the tip of the hood cuts the tissue which is grasped by the clip (Fig. 1.42) (Kaehler et al. 2006; Schurr et al. 2014). Currently, this device has approval only for use in the colon and the rectum.

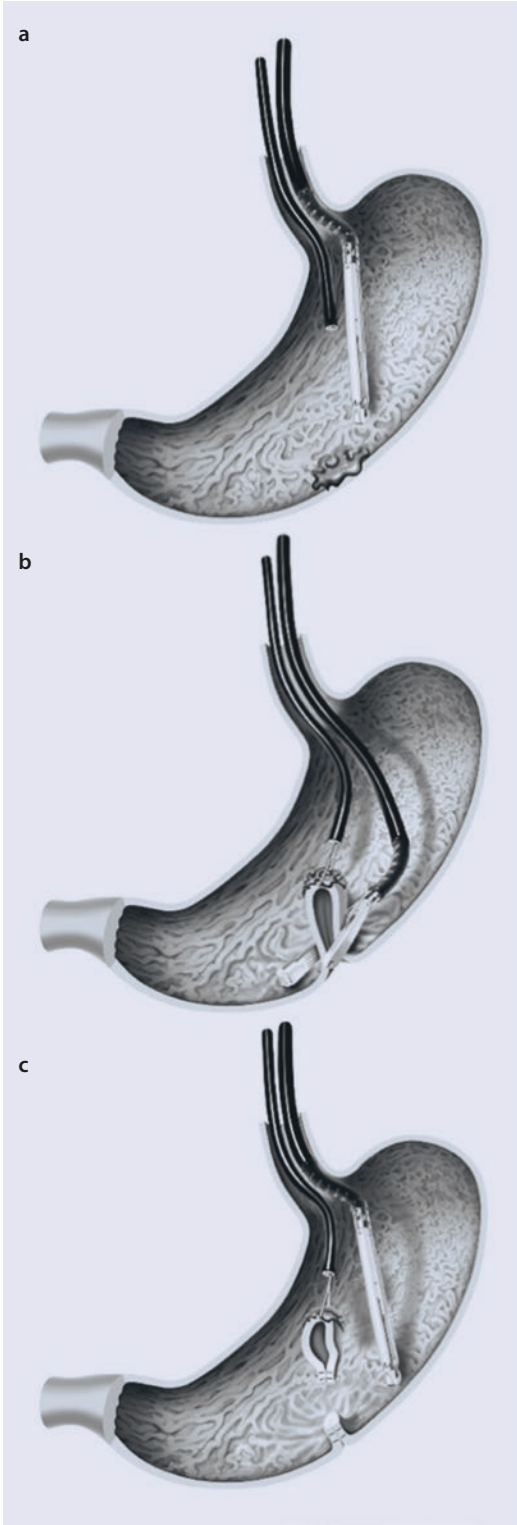

Fig. 1.40 **a**–**c** Full-thickness resection of the stomach with flexible linear staplers. **a** Introduction of the stapler and the endoscope into the stomach. **b** Pulling of the gastric wall with the endoscope into the branches of the stapler. **c** Resection by closure and cutting with the stapler

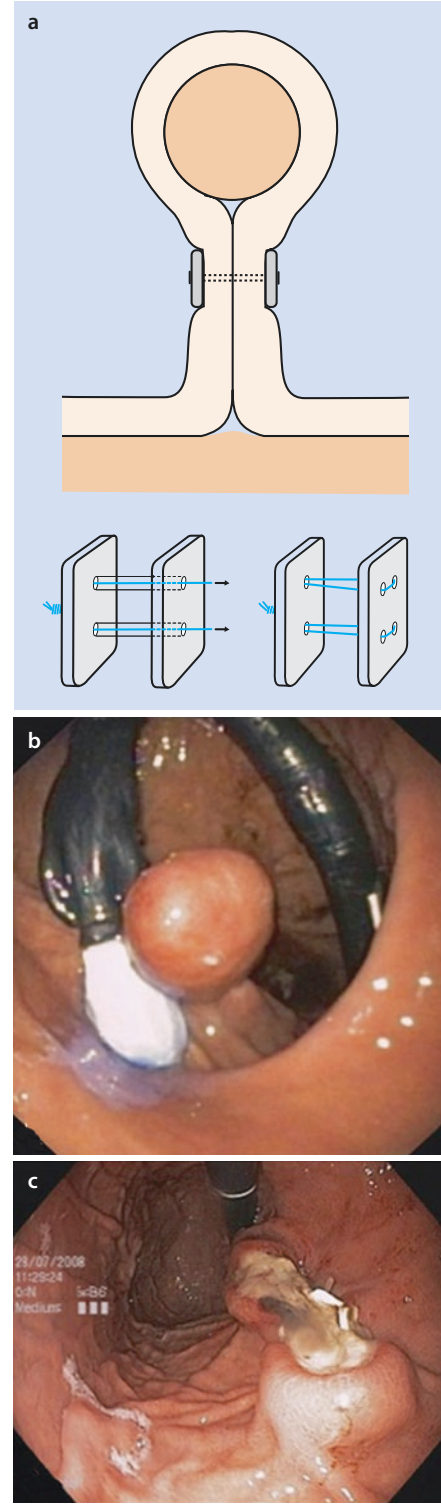

Fig. 1.41 **a** Schematic demonstration of the method. An arteficial polyp is created by full thickness suturing under the lesion. **b** Endoscopic view to the lesion after opening of the suturing device. **c** View after snare resection of the submucosal lesion as full thickness resection (With kind permission of Walz et al. 2011)

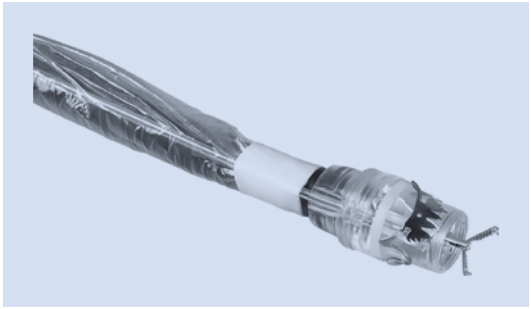

Fig. 1.42 Full-thickness resection with the OTSC (With kind permission of Ovesco Endoscopy)

1.5.2 Open Endoscopic Full-Thickness Resection

Adapted from the endoscopic management of perforations, some methods have been developed which provide a closure of the GI tract wall. In some degree, these methods can be used to close the wall after targeted circumcision of tumors.

In particular in slit-like lesions, a row of hemoclips is able to close the defect. This is limited by the opening width of the clips and the fact that hemoclips mostly can grasp just the mucosal layer. The previously mentioned OTSC can provide a full-thickness closure, but this is limited by its size to lesions smaller than 15 mm.

Some Japanese authors have published a technique with a combination of endoloops and clips. Therefore, an opened loop is fixed with several clips to the edges of the lesion. Finally the loop is closed. This technique can be used even in large defects, with the precondition that the GI tract wall is flexible at the targeted site (Fig. 1.43).

In all open techniques, it has to be taken into account that the following pneumo- or capnoperitoneum can cause problems for unfolding the wall and for respiration and blood circulation.

For all full-thickness resection methods, the indications must be balanced with surgical options. Because local surgical excisions have a very low complication rate, endoscopic full-thickness resections can be justified only if they can be carried out very safely. In cases of postinterventional pain, old patients with related comorbidities should be operated earlier, because their tolerance to peritonitis is lower than that of healthy individuals.

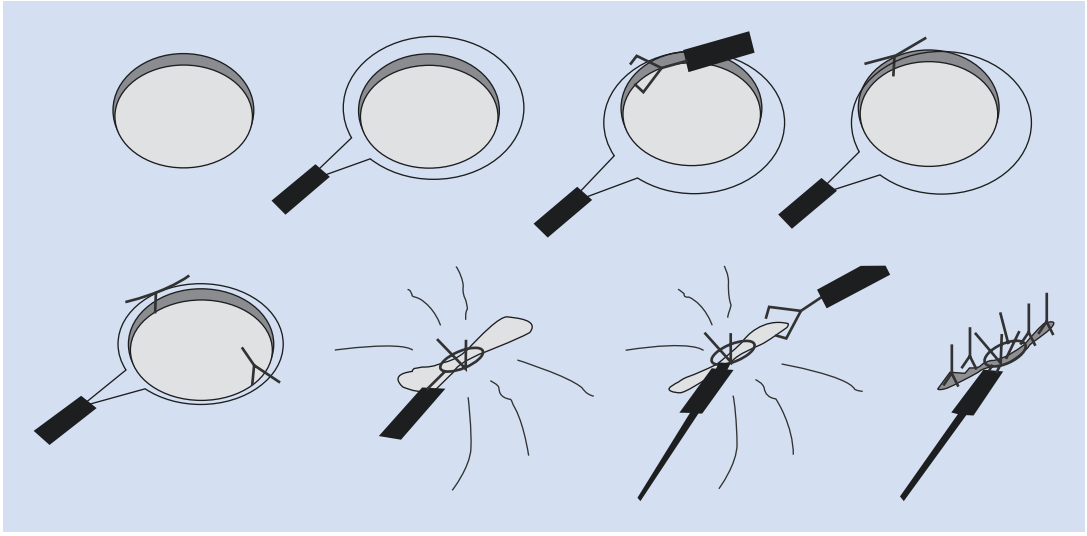

Fig. 1.43 Combination of endoloop and clips—schematic drawing (Matsuda T et al. 2004, with kind permission of Elsevier)

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Endoscopic Recanalization Techniques

Jan Krahn and Axel Eickhoff

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2

This chapter describes the large variety of endoscopic techniques that are available to reestablish or maintain luminal patency in the gastrointestinal tract. A comprehensive portrayal of various procedures is complemented by a concise overview of their respective indications and clinical outcomes. Since achalasia as well as Zenker's diverticula can pose a significant obstruction of passage in the upper GI (gastrointestinal) tract, advanced techniques such as endoscopic diverticulotomy or peroral endoscopic myotomy are depicted in this chapter as well. Endoscopic ablation techniques are described because of their impact on prognosis and recurrence rates of endoluminal tumors, thereby playing a significant role in maintaining patency of different segments of the gastrointestinal tract.

2.1 Introduction

Historical Aspects

Medical recanalization procedures were already being used in ancient times. For example, the dilation of urethral strictures was achieved with the help of feathers or papyrus stalks in ancient Egypt.

Girolamo Fabrizi d'Acquapendente reported the blind intubation of the esophagus with wax tapers in the sixteenth century, mainly as a treatment for food impactions and foreign bodies in the esophagus (French «bougie»: wax candle).

Sir Thomas Willis is usually credited with the first successful «bougienage» of the lower esophageal sphincter in an achalasia patient in 1672, which was performed using a whale bone with a sponge fixed to its apex.

The first esophageal stenting was reported by Sir Charles Symonds, who used an indwelling boxwood tube (which was fixed with strings emerging through the nose and tied behind the ears) in 1885.

In 1914 Guisez et al. performed the first tube implantations under endoscopic guidance, employing rigid esophagoscopy and Seldinger technique.

The remarkable technical progress in flexible endoscopy and minimally invasive therapy since the mid-twentieth century has now created a broad armamentarium of endoscopic recanalization techniques that are available to use in the gastrointestinal tract.

Epidemiology/Pathogenesis

Stenosis might occur anywhere throughout the gastrointestinal tract, and its pathogenesis can be categorized into mechanical/structural and neuromuscular/functional mechanisms.

Due to the marked heterogeneity in causes and localizations of gastrointestinal stenoses, data regarding epidemiology are extremely variable with regard to different etiologies and also change in the course of time. For example, the rate of peptic stenosis as a reason for food bolus impaction has declined from 75% to 41% since the turn of the millennium. At the same time, a rising prevalence of eosinophilic esophagitis was noted (Mahesh et al. 2013).

Causes of Gastrointestinal Obstruction

Mechanical/Structural

- Inflammatory strictures/scarring (e.g., Crohn's disease, primary sclerosing cholangitis (PSC), autoimmune cholangiopathy, radiation-induced or peptic stricture)
- Schatzki ring
- Postoperative/anastomotic stricture
- Neoplastic stricture
- Extrinsic compression
- Eosinophilic esophagitis

Neuromuscular/Functional

- Achalasia
- Sphincter of Oddi dysfunction

Clinical Symptoms

The clinical manifestations of symptomatic stenoses are as variable as its possible localizations and its dynamics of obstruction. For instance, the development of increasing dysphagia, regurgitations, and eventually loss of weight are the typical symptoms of progressing achalasia. Painless jaundice may be a harbinger of neoplastic biliary obstruction because of its slow progression, whereas colicky pain and cholangitis typically indicate more acute obstructions.

2.2 Dilation Techniques

Flexible bougie and balloon dilators are both used to treat strictures throughout the gastrointestinal tract. In gastroenterology, the term dilation refers to the application of balloon dilators, whereas bougienage describes the usage of bougies.

The balloon dilators exert radial force along the length of the stricture, thereby achieving dilation by tearing of tissue. Bougie dilators additionally produce axial shear forces, while the tapered end of the bougie is passing the stricture.

For various parameters that are of practical interest, e.g., the value and duration of maximal balloon pressure or time between repeat dilations, divergent recommendations exist by different work groups. On the basis of the available evidence, most of these recommendations appear to produce the same results.

2.2.1 Bougienage

Indication

Generally, indications for bougienage can be any symptomatic stenosis in the gastrointestinal tract, especially of benign etiology.

With regard to stenotic neoplastic lesions, bougies may be used as a preparatory measure for further interventions, since mere bougienage of malignant narrowings has a very short-lived effect. In practical terms, bougies can only be used in easily accessible segments of the GI tract or if the intended dilation diameter does not exceed the width of the working channel of the used endoscope.

In the following, the technique of esophageal bougienage will be described in a stepwise manner. Bougienage in other locations may be performed with the same technique by analogy. Biliary and pancreatic strictures are also amenable to smaller bougies used through the working channel of a duodenoscope.

Several controlled trials have compared bougies with balloon dilators for the treatment of esophageal strictures. In summary, no significant differences concerning clinical response or complication rates could be demonstrated. Thus, in situations where the use of both bougies and balloon dilators is feasible, the selection of the proper device depends on the individual expertise and experience of the operator. An argument for the use of bougie dilators is the operator's ability to better gauge the forces exerted on a stricture by tactile feedback.

Devices

Bougie dilators are flexible catheters with a tapered tip, available as push-type dilator (Fig. 2.1b) or wire-guided devices. The most commonly used bougie for the esophagus is the Savary–Gilliard dilator (Fig. 2.1a). These tapered, solid tubes of polyvinyl chloride are reusable devices, have a central channel to accommodate a guide-wire, and are available in calibers 1–20 mm (3–60 Fr).

In addition to endoscopic standard equipment, a fluoroscopy unit should be available, even though many esophageal strictures, especially in the case of repeat dilations at the same site, can be dilated without fluoroscopic guidance. Small-caliber (pediatric) endoscopes can be useful in transversing a difficult stricture.

Technique

The etiology, length, and further characteristics of the site needing dilation have to be well evaluated before therapy. If a stricture should prove to be impassable even with a small-caliber endoscope, contrast matter can be

Fig. 2.1 Tools for gastrointestinal dilation. **a** Savary–Gilliard dilator. **b** Maloney dilator. **c** balloon dilator

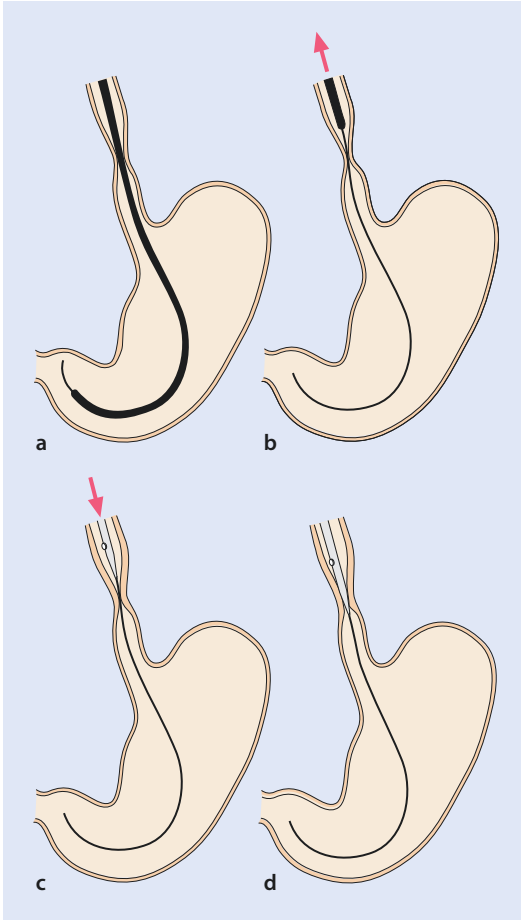


Fig. 2.2 Bougienage of an esophageal stricture. **a** Guide-wire placement. **b** Withdrawal of the endoscope. **c** Introduction of the bougie over the guide-wire. **d** Bougienage, repeat with larger bougies if indicated

applied via an ERCP catheter to depict the stenosis on fluoroscopy.

- For the treatment of an esophageal stricture, the endoscope is passed through the stenosis into the stomach. A guide-wire is placed into the antrum or duodenum under endoscopic control (Fig. 2.2a). In the case of an impassable stricture, the guide-wire can be advanced over the stricture into the stomach under fluoroscopic control. In this case, a soft guide-wire with a Terumo tip should be used.
- After withdrawal of the endoscope (Fig. 2.2b), the bougie dilator is introduced over the guide-wire using gentle pressure until the maximal caliber is passed over the stenosis (Fig. 2.2c, d). The bougie should always be well lubricated for a smooth passage. If no resistance is felt, no dilation of the stricture site has occurred. On the other hand, no excessive force should be used.
- The bougie is finally withdrawn carefully with simultaneous advancement of the guide-wire to prevent dislocation out of the stomach.

To prevent complications, usually the «rule of three» is applied for the selection of appropriate bougie sizes: the caliber of the first bougie should be equivalent to the estimated diameter of the stricture, followed by a stepwise increase in bougie sizes. After moderate resistance is encountered for the first time, no more than three dilators of progressively increasing caliber should be passed in one session (i.e., widening of the stricture by 3 mm in one session).

An exception to this rule is the treatment of a symptomatic Schatzki ring. The single passage of a large-diameter bougie (16–20 mm) has been advocated for this classic indication, as bougienage aims to disrupt the ring consisting of mucosa and submucosa.

Traces of blood on the withdrawn bougie dilator are a sign of expected mucosal injury (Fig. 2.3) and are not equivalent to a complication but should sound a note of caution.

In the case of persisting or recurrent dysphagia, a repeat procedure should be scheduled in 3–7 days.

Outcomes and Safety

Dysphagia usually can be relieved regardless of the type of stricture, if a widening of the lumen to at least 13–15 mm is achieved.

For peptic stenoses, clinical success rates of 85–93% are reported with bougie dilatations to diameters of 13–20 mm. Significant predictors for recurrent dysphagia are an initial small diameter of the stricture, a hiatal hernia >5 cm, persisting heartburn after the procedure, and a high number of dilation sessions necessary to relieve dysphagia.

The use of PPI can lower the risk of recurrence in peptic stenosis. In general, non-peptic strictures appear to have an increased risk of recurrence within the first year post-procedure.

The major complications of bougienage in the esophagus are perforations, significant bleeding, and aspiration. Perforation is the most clinically significant complication and is estimated to occur in 0.1–0.4% of cases. A perforation should be

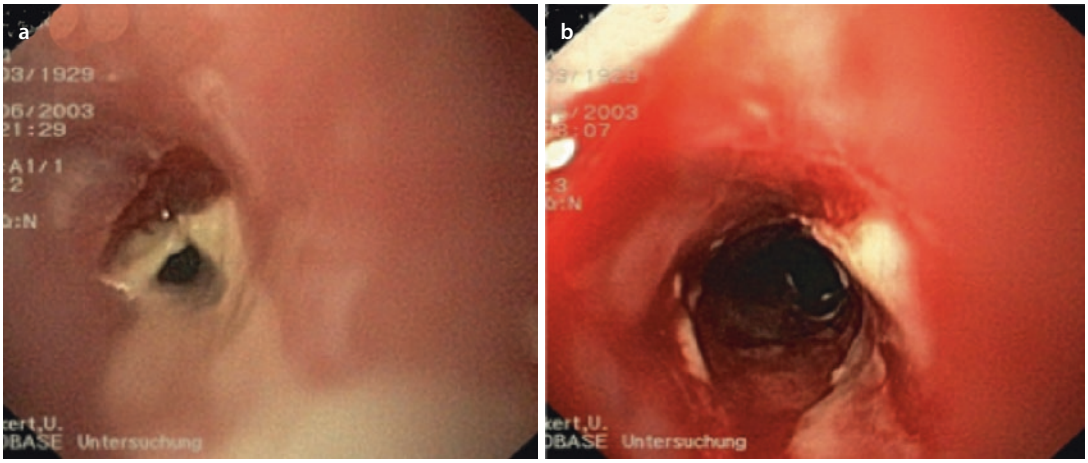


Fig. 2.3 Esophageal stricture **a** before and **b** after bougienage

Fig. 2.4 Hegar's dilators, sample sizes of 12, 14, and 16 mm

suspected if intense or persisting pain is reported post-procedure or if dyspnea, tachycardia, subcutaneous emphysema or fever is observed. In those cases, a thoracic CT or an esophagogram with water-soluble contrast should be obtained.

Even though dilatation procedures (together with variceal sclerosing) in the esophagus have been associated with a higher incidence of bacteremia than any other endoscopic procedures, it is rarely clinically significant. The current guidelines of the DGVS (the German gastroenterology association) do not recommend routine antibiotic prophylaxis, as there is no scientific evidence as to its benefit in preventing infectious endocarditis (Egan et al. 2006, Siddiqui et al. 2013).

Bougienage of Anal Strictures

Anal or distal rectal strictures (e.g., Crohn's-related or deep pelvic anastomotic) can be widened with the use of metal bougies.

A pre-procedure evaluation with a small-caliber endoscope is advisable to identify more proximal stenoses or inflammatory alterations. For bougienage in this setting, so-called Hegar dilators are commonly used. These are slightly curved stainless steel rods with a conic tip and a round profile (Fig. 2.4). They are available in sets of various sizes, ranging from 3 to 18 mm. They are introduced with gentle pressure without the use of a guide-wire; the initial diameter is estimated by means of the digital rectal examination;

the rule of three is applied accordingly. If the initial rectal examination is already painful, sedation during the procedure is recommended.

2.2.2 Dilation

Indications

Stricture dilation may be indicated in any accessible segment throughout the gastrointestinal tract if there is associated clinical impairment or if the passage of a larger instrument for further interventions is required.

Esophagus

Dysphagia is the indication for dilation of a benign esophageal stricture. Dysphagia secondary to a malignant stricture will usually only temporarily be alleviated by dilation and prompts further interventions (e.g., stent placement). The endoscopic standard therapy for achalasia is pneumatic balloon dilation.

Esophageal strictures can be categorized into two groups. Simple strictures are symmetric or concentric with a diameter >12 mm and allow for an easy passage of the endoscope. Complex strictures are tortuous, smaller than 12 mm in diameter, or cannot be passed with a diagnostic endoscope.

Empiric dilations of the esophagus without obvious structural pathologies have been reported. Taking into consideration the balance between possible major complications and questionable success rates, dilation for this indication cannot be recommended (Egan et al. 2006).

Stomach/Small Intestine

The most common indication in this segment is a gastric outlet stenosis due to various etiologies: peptic scarring, inflammatory conditions (Crohn's disease, pancreatitis, etc.), NSAID-induced, corrosive damage, or iatrogenic after endoscopic resections. The majority of these strictures are located in the pylorus or the duodenal bulb. Anastomotic strictures after surgery are another principal indication (Kochhar and Kochhar 2011).

Biliary System

Dominant strictures of the biliary tract in primary sclerosing cholangitis (PSC) are an indication for biliary dilation. Benign or postoperative biliary and anastomotic strictures after orthotopic liver transplantation are amenable to balloon dilation but have to be treated with further stenting for sustained clinical success. The widening of malignant stenoses to allow for the placing of a stent or balloon dilation of the papilla (preferably after sphincterotomy) in preparation for stone extraction is a further indication (Siddiqui et al. 2013).

Colon

Colonic stricture associated with obstructive symptoms should generally be evaluated for endoscopic dilation. The various etiologies include inflammatory bowel disease (IBD), ischemia, anastomotic or radiogenic scarring, NSAID, neoplasia, and diverticular disease.

Predictors of clinical success after dilation are short strictures, anastomotic stenosis, and tight strictures <10 mm. Multiple strictures, complete obstruction, stricture length of >4 cm, associated fistulas in the stenotic area, malignancy, or recent surgery are arguments for primary surgery (Lemberg and Vargo 2007).

Devices

Dilators are made of inflatable thermoplastic polymers fixed to a catheter and can be inflated to a cylindrical shape (Fig. 2.1c) using a handheld accessory device. By pressure injection of liquid (water/diluted radiopaque contrast) or air, the balloon is expanded to a specified diameter. Most balloon dilators are designed to pass through a 2.8-mm endoscopic working channel («through the scope,» TTS) with or without wire guidance. Large-diameter balloons for the treatment of achalasia are filled with air («pneumatic dilation») and cannot be passed through the working channel of an endoscope. They are placed using wire guidance.

TTS balloon dilators are available in various sizes and designs, usually with diameters 6–20 mm and balloon lengths 3–8 cm. Some designs allow for sequential dilation to multiple diameters, depending on the applied pressure. Achalasia balloons are available in standard sizes of 30, 35, and 40 mm.

From a practical point of view, it is a noteworthy detail that lower pressures are used for pneumatic dilation to treat achalasia than for the smaller TTS balloons. For this reason, pressures are commonly indicated in atmospheres (atm) on devices for TTS balloons and in «pounds per

square inch» (PSI) for achalasia balloons. Both coiled and monofilament/coated guide-wires can be used for dilator guidance if the design provides sufficient lateral stability (e.g., Jagwire).

Technique: Esophagus

Pneumatic dilation for achalasia: by dilation of the lower esophageal sphincter (LES), a disruption of LES muscle fibers is intended to lower the sphincter's resting pressure. A favorable diagnostic marker for clinical success is a post-procedure resting pressure of the LES of <10 mmHg, which can only be evaluated by manometry in the further clinical course. The dilation can be performed under direct endoscopic visualization or facilitated by use of fluoroscopic guidance, depending on the operator's preference and experience. It is imperative that a complete esophagogastroduodenoscopy with detailed inspection of the cardia has been performed before the dilation, to rule out pseudoachalasia.

The concept of «graded dilation» has proved effective and safe: The LES is first dilated using a 30-mm balloon. If there is an unsatisfactory resolve of dysphagia, a further dilation to 35 mm is performed 4–8 weeks later, with a final dilation to 40 mm after a similar interval if necessary.

With fluoroscopy the dilation is performed as follows:

- After placement of the guide-wire under endoscopic visualization and removal of the endoscope, the achalasia balloon (e.g., Rigiflex) is well lubricated and inserted over the guide-wire. Under fluoroscopic control, the balloon is advanced (Fig. 2.5a), until the double radiopaque markers (signifying the center of the balloon) are projected on the crest-like demarcation between the «dark» thorax and «light» abdominal area, i.e., the balloon is placed at the level of the diaphragm.
- First the balloon is inflated incompletely to adjust the position of the forming waist in the middle of the balloon (Fig. 2.5b).
- After appropriate centering over the stricture, pressure is applied preferably up to 7–10 PSI. The pressure is maintained until the waist is obliterated (the preferred endpoint) and optionally for a further 6–60 s (Fig. 2.5c). Care has to be taken to keep the balloon into place over the stricture, because there is a tendency for aboral dislocation.
- Finally, the balloon is completely deflated and removed together with the guide-wire.

Without fluoroscopy the dilation comprises the following steps:

- Placement of the guide-wire, removal of the endoscope, and introduction of the balloon as described above.
- Then the gastroscope is reintroduced and positioned above the cardia, so that the

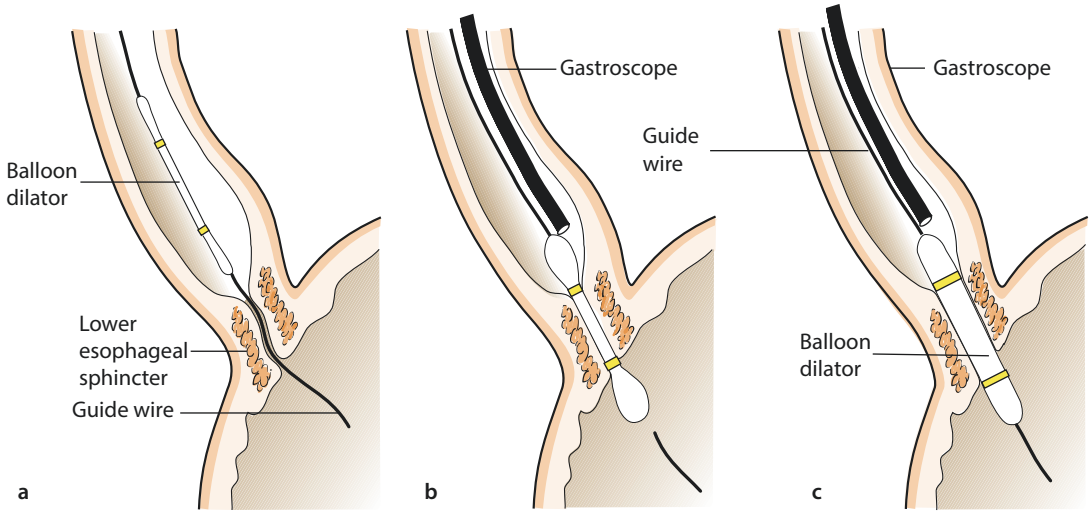


Fig. 2.5 Dilation of an esophageal stricture. **a** Introduction of the balloon dilator over the placed guide-wire. **b** Positioning of the balloon under direct visualization, alternatively with fluoroscopic control. **c** Balloon inflation until obliteration of the waist

balloon can be maneuvered across the stricture under direct visualization (Fig. 2.5b).
- The balloon is slowly inflated to 7–10 PSI. The dilated cardia can be observed through the balloon (Fig. 2.5c).
- The pressure is maintained until an ischemic ring at the tightest diameter of the cardia is noted (equivalent to the obliteration of the waist) or for 6–60 s.
- Finally, the balloon is completely deflated and removed after the endoscope.

Care has to be taken to completely deflate the balloon before extraction.

Technique: TTS Balloon Dilators

TTS dilators can be used in the esophagus as an alternative to bougienage. Their use is usually preferred for complex strictures. Bougienage is as effective and more cost-efficient for simple strictures (e.g., Schatzki rings).
- First, the length and further characteristics of the stricture are determined (with contrast via an ERCP cannula if required). Then a balloon dilator with appropriate size and length is selected.
- If the stricture cannot be negotiated with the endoscope, a guide-wire is advanced into the antrum using fluoroscopy to avoid kinking of the balloon catheter while passing complex strictures. With simple strictures, the balloon can be cautiously placed under direct endoscopic guidance without a wire, and fluoroscopy is not required.
- The balloon is inflated under vision. The appropriate inflation pressure (depending on the intended diameter according to manufacturer's specifications) is held for 30 s or until a sudden drop in pressure is noted on the pressure gauge of the inflation system. A slow increase of the inflation pressure and positioning of the dilator directly at the tip of the endoscope reduces the likelihood of balloon dislocation.
- Waist formation and its obliteration can be directly observed through the transparent balloon.
- Finally, the balloon is completely deflated and withdrawn with the endoscope (Fig. 2.6).

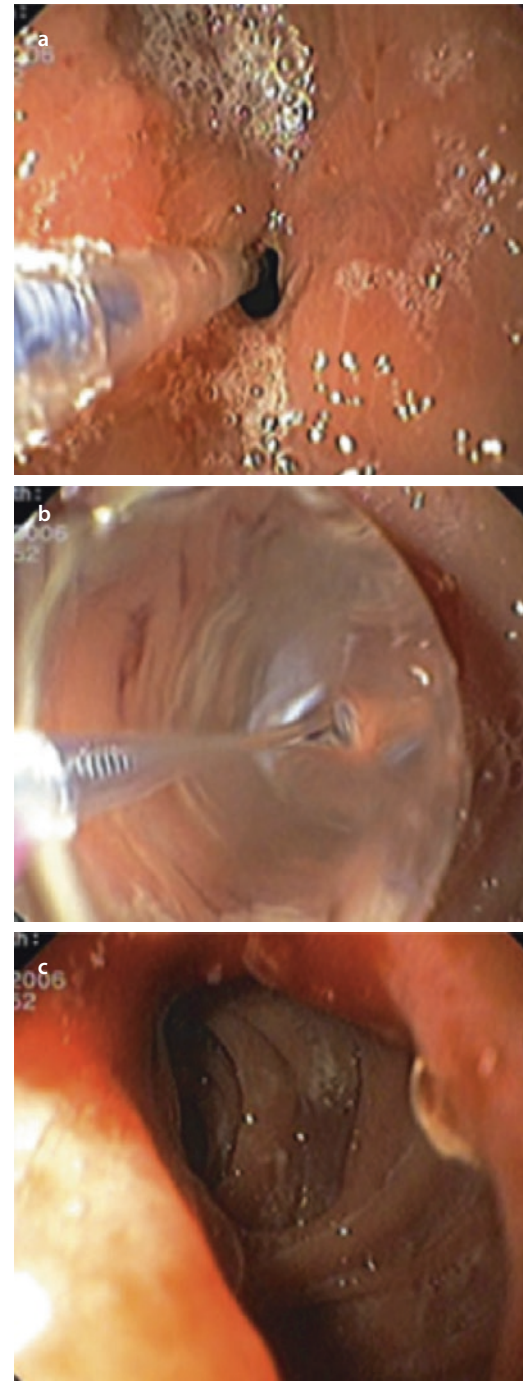


Fig. 2.6 Balloon dilation of pyloric stenosis. **a** Passage of balloon catheter over stricture. **b** Lnflation of balloon. **c** luminal view after dilation

Technique: Gastric/Enteral, Biliary System, and Colon

Dilation in these segments is performed in analogy to the technique described above. (For dila-

tions of biliary strictures, see ▶ Chap. 4). The larger the selected dilation diameter, the more sustained the clinical response seems to be, at the expense of an increased perforation rate.

Special aspects and recommendations with regard to different segments of the GI tract are listed in the following table.

Dilations in Different Segments of the Gastrointestinal Tract

Stomach/Small Intestine

- First dilation usually to 15 mm.
- Ulcerations and active inflammations should be treated medically before dilation.
- More cautious dilation in repeat sessions of tight strictures (interval approx. 7 days).
- No dilation within 8 weeks after chemical burns.

Biliary System

- Ampulla of Vater: balloon size depending on the width of the distal bile duct. Up to 15 mm possible after sphincterotomy.
- Proximal CBD: not over 6 mm.
- If no waist obliteration is observed after 30 s, repeat dilations may be attempted.

There is a risk of cystic duct dilation/perforation, especially in cases of low insertion of the cystic duct. The position of the guide-wire in the central bile ducts has to be ascertained before balloon inflation.

Colon

- First dilation for anastomotic strictures and Crohn strictures: 15 mm.
- More cautious approach for strictures induced by diverticulitis, ischemia, or radiation.
- (Neoterminal) ileum: 10–12 mm. Repeat dilation to 15 mm in case of insufficient clinical response.

Outcomes and Safety: Esophagus

Balloon dilations of benign esophageal strictures have excellent short-term clinical results. Nonetheless, recurrence of dysphagia within the first year post-dilation occurs frequently, especially in the case of non-peptic strictures. Clinical response and complication rates are comparable to those achieved with bougienage (see above).

Balloon dilation can be considered the standard therapy for achalasia, as an alternative to operative myotomy. Performed as «graded dilatation» as described above, a European multicenter trial observed a success rate of 82% after 5 years with no significant difference to laparoscopic Heller myotomy (LHM) with Dor fundoplication (Moonen et al. 2016). Irrespective of operative or endoscopic treatment (with a tendency toward more favorable outcomes for LHM), relapses may become apparent in the further clinical course and warrant repeat interventions. Rates of significant gastroesophageal reflux of about 20% are to be expected after dilation as well as LHM with fundoplication.

A better outcome for dilation is to be expected for patients >45 years of age. Young men in particular have a tendency toward lower success rates after balloon dilation. Further unfavorable predictors for clinical success after dilation are a dilated esophagus and Type I or III achalasia according to the Chicago classification (Pandolfino and Kahrilas 2013).

Outcomes and Safety: Stomach/Small Intestine

Dilations of the pylorus for treatment of a gastric outlet stenosis have favorable short-term success rates of 70–80%. Divergent results are reported for sustained clinical response, with success rates between 30% and 100%. A consistent therapy with PPI as well as eradication therapy of helicobacter pylori seem to be predictors for a successful outcome.

It is noteworthy that for this indication, strikingly high perforation rates of up to 7% were reported. For this reason we recommend cautious dilation, not over 15 mm. Dilations of gastroenteric anastomotic stricture seem to have good response rates. Case series for fibrotic Crohn's disease strictures report long-term success rates, with avoidance of surgery in 56–75% of patients.

Outcomes and Safety: Biliary System

Exclusive dilation of biliary strictures has no sustained clinical response and should be accompanied

by additional therapy like stent implantation. Only with PSC-induced dominant strictures is the placement of a stent of no additional use.

The dilation of the sphincter of Oddi as an alternative to endoscopic papillotomy is associated with an increased rate of pancreatitis. A large-caliber dilation after sphincterotomy has a success rate of 98% with regard to removal of large biliary stones, with a low complication rate (post-ERCP pancreatitis 1.2%).

Outcomes and Safety: Colon

Various uncontrolled case series have observed good effectivity of the dilation of benign colorectal strictures, with reported complication rates of 0–10%.

Excellent short-term results are reported for strictures in Crohn's disease, but data for long-term avoidance of surgery are similarly divergent as described above for gastric/enteral strictures (Endo et al. 2013).

Outcomes and Safety: Additional Techniques

Incisions Electrosurgical incisions of esophageal or colonic strictures using a sphincterotome or needle-knife have been described by different work groups. Performed in addition to balloon dilation, increased clinical success rates are claimed. Evidence for the superiority of this procedure is rare, with the exception of the incisional treatment of Schatzki rings. For this indication, incisional therapy seems to produce comparable results to bougienage.

Steroid injections There is an ongoing controversy over the role of adding intralesional steroid injection to dilational therapy. Data from controlled trials predominantly suggest a lowered relapse rate after additional steroid injection, especially with regard to strictures in Crohn's disease. On the contrary, steroid injections were not found to be effective with possible negative side effects in anastomotic strictures.

In our opinion, the injection of steroids in combination with dilation is a noteworthy treatment option for refractory benign strictures of peptic or inflammatory origin. A practicable approach to this technique is to dilute 40 mg/ml triamacinolone 1:1 with saline. Then, 0.5 ml aliquots are injected into each quadrant at the edge of the lesion (Di Nardo et al. 2010).

2.3 Stenting

In medical practice, stents are devices used to maintain or restore luminal patency of hollow organs, vessels, or ducts. In gastroenterology, semirigid plastic stents are distinguished from self-expandable stents. Tubelike plastic stents are generally only used in the biliary/pancreatic system and are placed over a guiding catheter or are pushed directly over the guide-wire in case of small-caliber stents. Plastic stents are available in different designs (e.g., straight or pigtail) and in sizes up to 12 French.

Self-expandable stents consist of mesh cylinders that are packaged in a compressed form on a delivery catheter. Once deployed, they exert self-expanding forces until reaching a predefined diameter (Fig. 2.7). Sustained high radial forces then effect an appropriate widening of strictures and anchoring to surrounding tissue. Self-expandable stents are most commonly composed of metal alloys (SEMS, self-expandable metal stents) such as nitinol.

A self-expandable plastic stent (SEPS) has been developed for the esophagus, allowing for easy retrieval but also showing high migration rates. Self-expandable stents made of absorbable polyester–polymer (biodegradable stents) are available in Europe. Stents coated with a chemotherapeutic agent (drug-eluting stents) have been tested only in preliminary studies.

To prevent ingrowth of neoplastic tissue through the mesh, SEMS may be wholly or partially covered with a plastic membrane or silicone (fully or partially covered SEMS). Esophageal stents are commonly flared at both ends to prevent migration and are available in various diameters (12–28 mm, >30 mm for leakage SEMS) as well as lengths (Fig. 2.8). Enteral and colonic stents are usually uncovered to achieve firm anchoring to the intestinal wall, to reduce the likelihood of migration despite peristaltic forces.

Esophageal SEMS are deployed over a guide-wire outside the endoscope; other stents have to be introduced via the endoscopic working channel. SEMS are marketed in various designs and sizes with different characteristics with regard to radial forces and the degree of foreshortening after deployment (Varadarajulu et al. 2011).

Indications: Esophagus

Esophageal SEMS are indicated for the palliation of malignant strictures or tracheoesophageal fistulas. Furthermore, SEMS are an important therapeutic

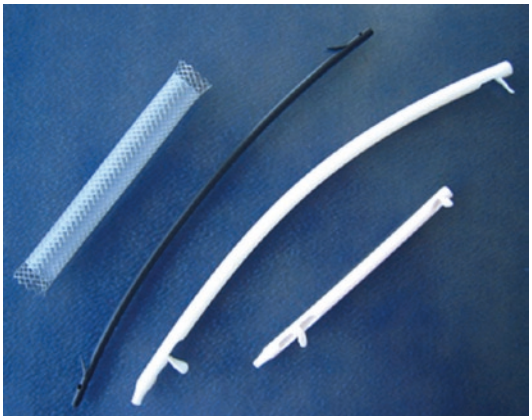


Fig. 2.7 SEMS and plastic stents

option for the treatment of esophageal perforations. SEPS and covered SEMS may be used for benign strictures.

Indications: Stomach/Small Intestine

Gastroduodenal SEMS are commonly used for palliation of malignant gastric outlet strictures. Further applications are possible, especially for advanced endoscopic transgastric procedures (e.g., EUS-guided biliary drainage, transmural necrosectomy, etc; see ► Chap. 5).

Indications: Biliary/Pancreatic System

An important indication for endoscopically placed stents is palliative drainage of malignant biliary obstructions. Because of lower occlusion rates, insertion of SEMS is preferred if the expected survival is >4 months.

The majority of benign strictures for which stenting is indicated are caused by postsurgical injuries or inflammatory disorders. Dominant strictures in PSC are usually treated by dilation only. Further potential applications are the therapy of biliary leakage, temporary stenting for bile duct stone that cannot be cleared initially, symptomatic pancreatic strictures, a symptomatic pancreas divisum, or the prophylaxis of post-ERCP pancreatitis (Pfau et al. 2013).

Indications: Colon

Colonic SEMS are mainly used as palliative therapy for malignant obstructions, mostly as a bridge to surgery. The closure of malignant fistulas may be attempted with covered SEMS in non-operable palliative situations.

Technique

Before stenting, the extent of the respective stricture has to be evaluated endoscopically or using fluoroscopy. The length of the stenosis can be evaluated using the distance markers on the shaft of the endoscope. Alternatively, the edges of the stricture can be marked with the injection of Lipiodol. The selected stent should be 3–4 cm longer than the obstruction, to cover a sufficient distance on both sides of the lesion. Examining the patient in supine or prone position has the advantage of better fluoroscopic overview of the anatomy.

Long-standing colonic obstruction with (sub-) acute ileus is frequently present in the case of malignant colonic strictures presented for stenting. Therefore, insertion of a nasogastric tube is strongly encouraged before endoscopy to minimize the risk of aspiration during sedation.

- The endoscope is advanced to the stricture. If the stenotic lesion can be easily transversed, a stiff wire of 0.89 mm (0.035 inch) is advanced about 20 cm over the stricture. If no passage is possible, the stricture is cautiously probed with a flexible, hydrophilic wire through a biliary catheter; contrast application through the catheter is used for fluoroscopic guidance. Once wire and catheter are passed over the stricture, the wire is exchanged for a stiff wire. Occasionally, dilation has to be performed to allow passage of the esophageal SEMS. In contrast, dilation should be avoided during colonic SEMS deployment.
- Over the wire: The endoscope is withdrawn, and the delivery catheter is advanced through the stricture over the wire. The endoscope is then reintroduced alongside the predeployed stent for direct visual control.
- TTS: A working channel of ≥3.2 mm (10F) is required, e.g., a therapeutic gastroscope or standard colonoscope. The delivery system can be advanced through the scope in this case.
- The middle of the stent is positioned over the stenotic lesion, and the constraint system is released, with subsequent radial expansion of the stent (from distal to proximal with most delivery systems) (Figs. 2.9 and 2.10).

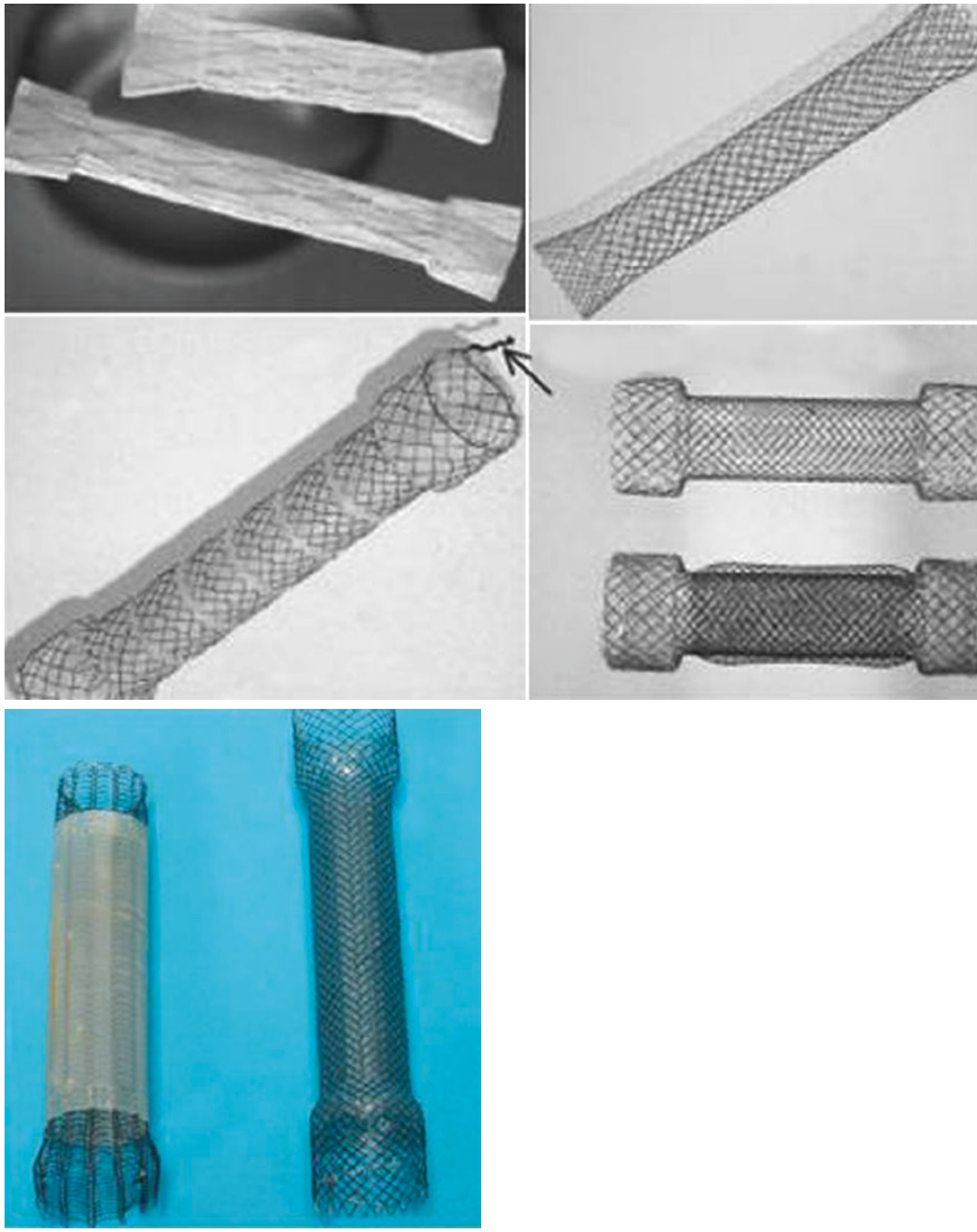


Fig. 2.8 Different variants of self-expanding esophageal stents

An important aspect of SEMS deployment is the variable degree of foreshortening that occurs with most stents upon release from the delivery catheter. A permanent adjustment of position under fluoroscopic or visual control is therefore essential.

- After the entire stent is released, its position should be evaluated using fluoroscopy. If no definite waist formation can be detected, or if one end of the stent appears to be compressed, the stricture is possibly not bridged. Repositioning or placement of a further stent (stent-in-stent) then has to be considered.

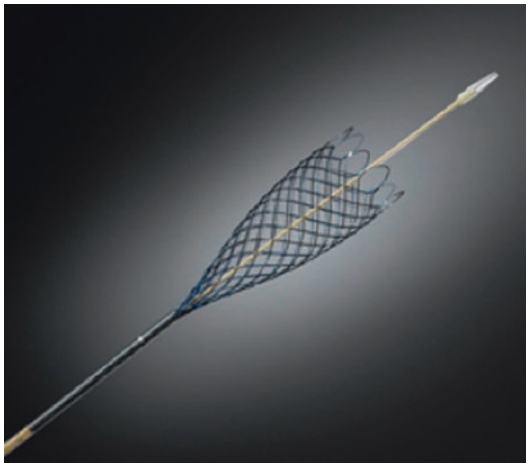


Fig. 2.9 Distal release SEMS

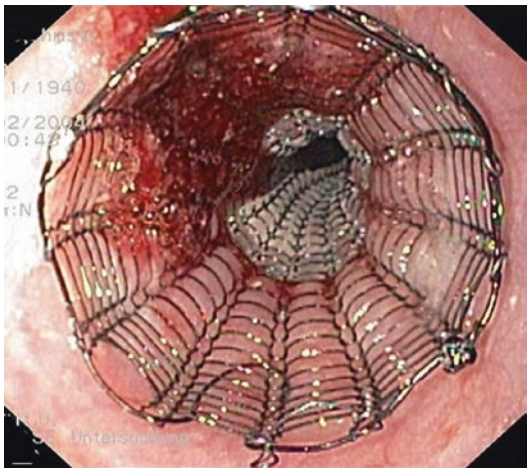


Fig. 2.10 Partially covered SEMS in the esophagus

When malignant gastric outlet strictures are evaluated for stenting, a simultaneous biliary obstruction is frequently either evident or impending. In these cases, a biliary SEMS should be placed before deployment of the duodenal stent to allow for biliary drainage. If biliary obstruction becomes evident after duodenal stent placement, dissection of the SEMS mesh can be attempted in the papillary area using APC. If the biliary system cannot be accessed through this route, a percutaneous transhepatic drainage is required.

Outcomes and Safety: Esophagus

SEMS can provide at least short-term relief of dysphagia due to malignant obstructions in over 90% of cases and therefore are an established procedure for the restoration of enteral nutrition in palliative care or as a bridge to surgery. Stent migration is a concern in the further clinical course, especially after neo-adjuvant therapy. Migration rates of 24–46% have been reported in these cases.

SEPS dislodge more frequently and are not recommended for use in malignant obstructions.

Of concern are strictures near the upper esophageal sphincter; here, SEMS with a smaller diameter are used to prevent complications as foreign body sensations, pain, tracheal compression, and pressure necrosis. Stents with a proximal release mechanism are beneficial in these situations to allow for a more precise positioning.

Placement of self-expandable stents for therapy of benign strictures has been reported in case series. Silicone-covered SEPS are easier to remove, especially after long placement periods; on the other hand, higher migration rates than for SEMS have been described.

For esophageal ruptures and leakages, covered SEMS are successfully employed with lower complication rates than for operative alternatives. For this indication, attention should be paid to extract the implanted stents after 2–4 weeks to prevent tissue ingrowth and a technically difficult removal.

Outcomes and Safety: Stomach/Duodenum

The technical success of stent implantation for the treatment of gastric outlet obstruction is reported to approach 100%. And for >80% of patients, subsequent oral intake of at least a soft diet is possible.

Stenting of malignant gastric outlet obstructions seems to be superior to bypass surgery with regard to short-term reestablishment of oral nutrition and improvement of quality of life.

Surgery is associated with lower rates of long-term recurrent obstructions because of possible stent occlusion by tumor ingrowth.

Severe complications of gastroduodenal stent placement occur in about 1% of patients. With a mean survival of 12 weeks after stenting for malignant obstruction, stent migration (≈5%) and restenosis (≈18%) are late complications.

Outcomes and Safety: Biliary System

Plastic stents as well as SEMS are successfully used for palliation of malignant bile duct obstruction, decreasing cholestasis and improving quality of life.

Occlusion of inserted plastic stents with a diameter of 10F occurs in 3–6 months. Longer patency could not be demonstrated for plastic stents with a larger diameter, with a possible increased risk of post-procedure pancreatitis.

SEMS have longer patency, but after some time uncovered stents are virtually impossible to remove because of tissue ingrowth.

Bridging drainage for the treatment of biliary or pancreatic leakages and irretrievable bile duct stones is possible in more than 90% of cases.

Clinical success in benign stenosis is strongly dependent on the etiology of the obstruction; insertion of multiple plastic stents side by side generally yields superior results compared to single plastic stents. In this context, general success rates for benign strictures are 94% and 54% for multiple and single stenting, respectively, with strictures due to chronic pancreatitis only 60% and 44%.

A predominantly distal migration occurs in 5–10% of cases after placement of plastic stents, whereas uncovered SEMS rarely migrate. Cholecystitis has been reported in up to 10% of cases after placement of a covered stent across the cystic duct ostium.

Temporary placement of a covered SEMS for benign strictures is a feasible alternative in selected patients. The problem of possible induction of hyperplastic tissue growth at the proximal end of the stent with subsequent difficult removal or new stricture formation has to be considered in these cases.

In chronic pancreatitis with pancreatic duct stricture, good short-term improvement of pain can be achieved by pancreatic duct stenting. Endoscopic long-term treatment often requires frequent stent changes over multiple months.

A reduction in post-ERCP pancreatitis rates has been reported for prophylactic pancreatic duct stenting for small plastic stents (3–5 French, 3–5 cm length) in the case of high-risk patients (e.g., difficult cannulations, accidental pancreatic duct cannulation; see ► Chap. 4) (Pfau et al.).

■■ Outcomes and Safety: Colon

Insertion of stents as a bridge to surgery in acute malignant obstructions is the principal indication for the use of SEMS in the colon, allowing for subsequent one-stage surgery in an elective setting with lower complication rates. Although a difference in overall survival in comparison to primary surgery has not been demonstrated to date, improved quality of life and cost-effectiveness have been reported (Varadarajulu et al. 2011).

Technical and short-term clinical success rates are above 90%. Main complications are perforations (about 4%) and migration (about 10%). Though SEMS may be placed successfully in all colonic segments, the advantages of primary endoscopic therapy have been demonstrated for left-sided stenting. Furthermore, the topic is controversial since recent controlled studies have produced conflicting evidence with unusually high perforation rates and inferior outcome of colonic stenting compared to emergent surgery.

In conclusion, placement of colonic SEMS may be used as a treatment option in patients with acute obstruction of left-sided cancer to avoid emergent surgery and in certain palliative situations. It should be performed by experienced endoscopists; balloon dilation before placement is not encouraged. Special caution should be applied if chemotherapy is planned, as an increased rate of delayed perforations has been reported in these cases (Garcia-Cano 2013, van Hooft et al. 2011).

2.4 Thermal Procedures for Recanalization/Ablation

2.4.1 Argon Plasma Coagulation

Argon plasma coagulation (APC) is a technology of electrocoagulation, i.e., ionized argon gas («argon plasma») is «sprayed» onto the target tissue from a monopolar probe, and this plasma is used as a medium to create an electric current, effecting thermal coagulation at the tissue surface. The extent and depth of the coagulation effects are influenced by application time, power setting (watt), settings of plasma flow (◘ Figs. 2.11 and 2.12), specific surface characteristics of the target tissue, and distance from the probe to the target tissue.

The dried coagulated tissue layer has an insulating effect, first routing part of the electrical current through the surrounding tissue. Continuing application of current then produces deep coagulation defects as well.

If the probe is too distant from the target tissue, no effective current density can be established. If the probe touches the mucosa, a diathermal effect is produced comparable to a monopolar coagulation probe, and argon gas is insufflated into the submucosa through the ensuing defect.

Fig. 2.11 Pulsed APC

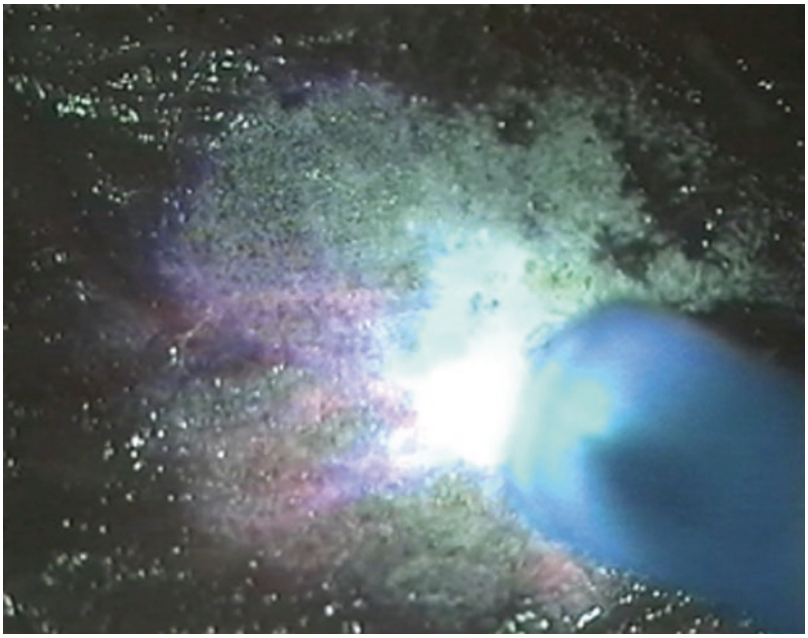


Fig. 2.12 Forced APC

Devices

Application of APC involves an appropriate applying catheter and an electrosurgical generator. Upon activation by a foot pedal, a synchronized flow of gas and current out of the tip of the catheter probe is generated. A neutral electrode patch is applied to the patient.

APC probes are marketed with various designs of openings at the tip, allowing for straight, circumferential, and sideways applications.

Indication

As a recanalization technique, APC can be used for tumor debulking throughout the gastrointestinal tract. Furthermore, it is used for restoring luminal patency of overgrown and obstructed stents. Cutting the mesh of SEMS may be possible using APC, presenting a helpful method for treating dislocated and obstructing stents.

Technique

- The endoscope is advanced to the target lesion. Residual soiling and surface fluid have to be cleared because they interfere with gas flow.
- The APC probe is inserted through the working channel, the tip placed approximately 2–8 mm from the surface of the target lesion. Because of possible thermal damage to the endoscope's video chip, it is recommended that the probe is extended at least 10 mm outside the endoscope (usually until the first black ring is visible in the endoscopic field).
- Power, gas flow, and mode settings depend on the location, structure, and size of the target lesion and should generally follow manufacturer's recommendations (Table 2.1).
- If the probe is at the correct distance from the surface, an electric arc is formed between the probe and tissue upon depressing the activation pedal. Coagulation is indicated by blackening of tissue and smoke formation. One should keep the endoscope and probe tip in motion to achieve a continuous treatment of the target area.

Duration of application is the most important factor to influence coagulation depth, even before power settings and distance from the probe to target tissue (Fig. 2.13).

Care should be taken not to apply coagulation current to one spot for too long (0.5–2 s) to avoid transmural damage, especially in the peripheral area of ablated lesions.

- One has to keep in mind that argon gas is insufflated during activation, so steady suctioning should be applied to minimize distension and clear smoke from the field of vision.

Outcomes and Safety

The evidence for APC as a method to restore luminal patency largely consists of case series. For inoperable esophageal cancer, clinical success rates of 84% have been reported after up to two sessions of APC treatment, with perforation rates of 8%.

Nowadays APC devices are standard equipment in endoscopy units; therefore, it serves as a useful adjunct to the other techniques mentioned above (Ginsberg et al. 2002).

Table 2.1 Recommended APC settings in the gastrointestinal tract (for ERBE-APC2-system with the VIO-generator system)

Procedure	Power settings	Mode
Devitalization		
Barrett's esophagus	30–50 W	Pulsed E2
Small polyps	10–30 W	Pulsed E1
Ablation of residual adenoma tissue after EMR	20–30 W	Pulsed E1
Zenker's diverticulum	40–50 W	Pulsed E1
Radiation proctitis	10–30 W	Pulsed E2
Hemostasis		
Vascular ectasia stomach/colon	10–30 W	Pulsed E2
Vascular ectasia duodenum/right colon	E4–E5	Precise
Bleeding ulcer, Forrest Ib-IIb	30–60 W	Forced
Tumor ablation		
Large(≥15 mm)	≥60 W	Forced
Small(<15 mm)	20–50 W	Forced
Stent management		
Stent ingrowth/overgrowth	20–30 W	Pulsed E2
Stent trimming	30–60 W	Forced

2.4.2 Nd:Yag Laser

Laser beams are highly coherent rays of light of a certain wavelength that are produced with the help of an active laser medium. Lasers of a high-power density can be applied for the ablation of lesions, as the absorption of laser light induces a photothermal reaction with ensuing destruction and vaporization of the targeted tissue. For this application in medicine, various lasing media can be employed, e.g., the neodymium-doped yttrium aluminum garnet crystal (Nd:YAG). Nd:YAG laser beams are invisible and produce coagulation up to 6 mm into the tissue with superficial vaporization.

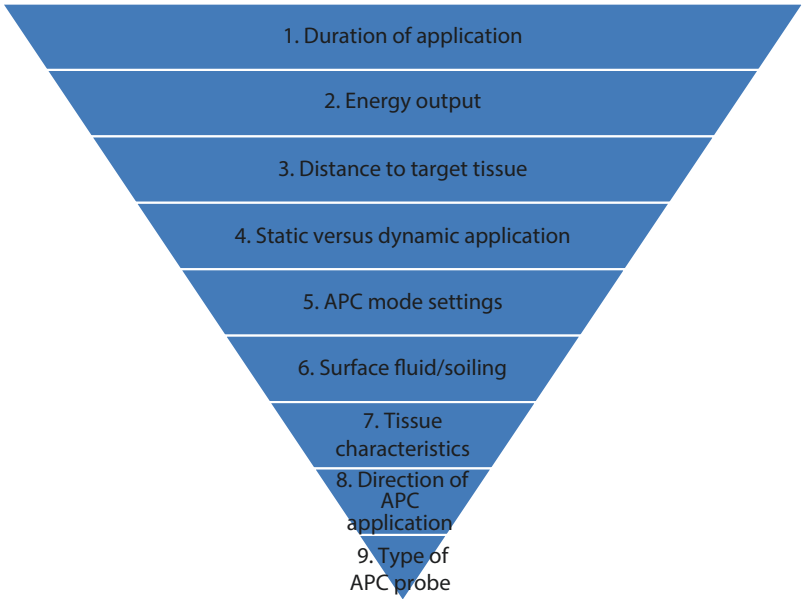


Fig. 2.13 Parameters of APC application, ranked according to impact on coagulation depth. *1.* Duration of application. *2.* Energy output. *3.* Distance to target tissue. *4.* Static versus dynamic application. *5.* APC mode settings. *6.* Surface fluid/soiling. *7.* Tissue characteristics. *8.* Direction of APC application. *9.* Type of APC probe

In clinical practice, additional complex equipment and a certain organizational effort are required; special qualifications to use medical lasers have to be obtained, and in German endoscopy units, a «Laser Protection Commissioner» has to be appointed.

Alternative methods as APC or RFA (radiofrequency ablation) are notably more cost-efficient, easier to apply, and have a more favorable risk profile. For these reasons, gastrointestinal endoscopic laser therapy for thermal ablation is rarely used nowadays.

2.4.3 Photodynamic Therapy

Photodynamic therapy (PDT) is the use of a photochemical reaction to destroy target cells. A light-sensitive drug (photosensitizer) is exposed to light of a certain wavelength, producing singlet oxygen which causes oxidative injury and destruction of cells.

Various substances are utilized as photosensitizers (e.g., aminolevulinic acid and hematoporphyrin derivates) that are usually administered systematically (i.v. or per os).

Medically applied photosensitizers differ in their respective half-life and duration of effectiveness and are preferentially retained by cells with a high metabolic rate (e.g., cancerous or precancerous cells).

For internal sites, a low-energy laser light of precise wavelengths is used, thereby avoiding direct thermal injury. Only cells that retain a sufficient amount of photosensitizer are destroyed, allowing for selective destruction of neoplasia.

Possible applications in gastroenterology are the palliative treatment of esophageal cancer and cholangiocarcinoma (CCC) as well as the ablation of Barrett's esophagus. For non-resectable CCC, a combination of PDT and stenting has been shown to be superior to stenting alone, with markedly improved survival. The evidence for the clinical benefit of PDT for other indications as compared to less complex treatment options is inconclusive. Furthermore, the optimal photosensitizers for the different indications have yet to be determined. Serious complications of PDT seem to be rare (Fayter et al. 2010).

2.4.4 Cryoablation

For cryotherapy, liquid nitrogen or compressed carbon dioxide (CO_2) is delivered through a catheter for tissue destruction. Liquid nitrogen has a temperature of −196 °C. Compressed CO_2 expands rapidly after exiting the catheter tip, freezing upon the sudden decrease in pressure (Joule–Thomson effect). Applied correctly, the induced freezing damage causes mucosal necrosis almost exclusively.

The device consists of a cryogenic system that delivers the gas or liquid via a flexible catheter through the accessory channel of the endoscope. The tip of the catheter is positioned 5–10 mm from the target tissue. The cryogenic substance is applied by depressing a foot pedal until whitening of the target tissue is witnessed (taking about 10 s). After the mucosal surface has thawed (returned to its original color), freezing is performed repeatedly, usually at 2–3 cycles. A nasogastric decompression tube is used to prevent damage from expanding gas.

This technology is available commercially for gastroenterologists only since 2007 but is already an established procedure in various centers for Barrett's ablation because of relatively simple application. Case series report an excellent safety profile and promising success rates for the treatment of Barrett's dysplasias (Chen and Pasricha 2010).

2.4.5 Radiofrequency Ablation

The term «radiofrequency» denotes a spectrum of electromagnetic wave frequencies above the spectrum of audible frequencies. Heat generated from high-frequency electrical currents is employed for the ablation of tissue. In gastroenterological endoscopy, the most common application of radiofrequency ablation (RFA) is the treatment of Barrett's esophagus.

An array of electrodes, each separated micrometers from each other, on a balloon (for circumferential ablations) or on a rectangular platform (for focal ablations) is used with two immediately adjacent electrodes functioning as a bipolar device. The electric current between these electrodes delivers heat to the surrounding tissue and produces an electrocoagulatory effect to a depth of 1 mm, limiting damage to the mucosa. In the areas of RFA-ablated Barrett's mucosa, a regeneration of squamous epithelium is induced.

The first commercially available RFA balloon devices required the use of a sizing balloon to gauge the appropriate size of the employed ablation balloon; now, self-adjusting balloon catheters are available as well.

After identifying and rinsing the target lesion (and measuring the esophageal diameter depending on the available system), the ablation balloon is passed into the esophagus over a guide-wire and positioned under endoscopic control, extending approximately 1 cm above the target mucosa; the length of the ablation electrode is usually 3–4 cm.

After balloon inflation and upon foot-switch activation, a circumferential ablation is induced by controlled radiofrequency application (usually for 1 s). This procedure is repeated with or without rinsing of the treated tissue surface; then, the balloon is advanced under direct vision for further ablation steps until the complete extent of Barrett's mucosa is ablated down to the gastroesophageal junction in an overlapping fashion.

In the case of focal lesions or areas of incomplete contact with the ablation balloon, a focal ablation array is used. This system contains a convex platform covered by electrodes on a catheter and is mounted on the tip of an endoscope; a smaller platform for TTS application is available as well. The mounted platform is oriented to the 12 o'clock position of the endoscopic image; ablation is performed analogous to the steps described above.

After Barrett's esophagus ablation, a maximal suppression of gastric acid is critical for the regeneration of squamous epithelium. High-dose PPI, H2-blockers, and possibly sucralfate should be prescribed for at least 2 weeks post-procedure.

After endoscopic resection of noticeable neoplastic areas, RFA has been reported to achieve a sustainable eradication of dysplastic Barrett's mucosa and prevent metachronous neoplastic lesions. Severe complications are rare, though mucosal lacerations are possible, especially in scarred areas after endoscopic resection (Haidry et al. 2013, Pouw et al. 2010).

RFA for the therapy of neoplastic biliary obstructions applying peculiar catheters has been demonstrated to be feasible with an acceptable safety profile. The evidence for this method is limited to case reports and small series, so little is known about its efficacy.

2.5 Zenker's Diverticulotomy

- **Indication**

Zenker's diverticulum is an outpouching of the mucosal and submucosal layer through the wall of the posterior pharynx in the area of the upper esophageal sphincter, most often directed to the left side. It is formed in between the oblique fibers

of the superior part and the circular fibers of the inferior part of the Pars cricopharyngea (the cricopharyngeal muscle) of the M. constrictor pharyngis inferior (a triangular area called Killian's dehiscence).

Zenker's diverticulum is observed almost exclusively in older individuals, with an estimated incidence of 2/100.000 at the age of 65–75. The widely accepted primary cause of Zenker's diverticulum is a neuromuscular dysfunction of the upper esophageal sphincter, but no consensus exists on the exact pathomechanism. This neuromuscular dysfunction leads to a hypertensive cricopharyngeal muscle which over time causes a pulsion diverticulum in the anatomic weak spot of Killian's triangle (◘ Figs. 2.13 and 2.14).

Main symptoms include dysphagia, regurgitation, chronic cough, and aspiration.

Flexible endoscopic Zenker's diverticulotomy was first described in 1995. This technique creates a common cavity and performs a myotomy at the same time, by dividing the septum between the diverticulum and esophageal lumen which contains the cricopharyngeal muscle.

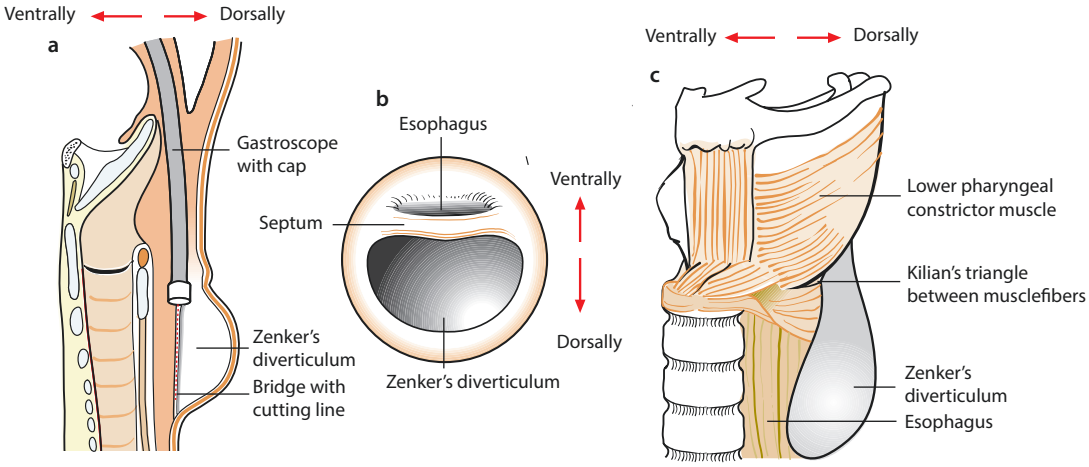
Devices

Diverticulotomy is performed using a standard gastroscope fitted with a transparent cap at the tip for better visualization. APC or a needle-knife is commonly used for myotomy; methods using bipolar cutting devices or the «harmonic knife» (developed for laparoscopic surgery) have been described. A soft overtube (the «diverticuloscope») may be used for better protection of surrounding tissue and optimizing the operative field, but its use in multimorbid patients is limited by the necessity for wide opening of the mouth and neck extension for insertion.

Technique

Patients are placed in a left lateral decubitus position, usually in intravenous analgosedation. General anesthesia with intubation is preferable for optimal conditions, especially in cases with difficult anatomic characteristics.

- First, a diagnostic gastroscopy is performed with detailed evaluation of the diverticulum. A nasogastric tube is inserted under endoscopic control to mark the esophageal lumen.
- Then, a transparent cap is attached to the tip of the endoscope. Some authors recommend inserting the needle-knife at this point and bending the protruding tip toward the center of the cap opening.
- The endoscope is advanced to the septum between the esophagus und diverticulum (◘ Fig. 2.15a), and the center point on the cricopharyngeal bar is marked with the needle-knife.
- Then, a stepwise, caudally directed diverticulotomy is cautiously performed (◘ Fig. 2.15). The needle-knife is maneuvered by rotating the shaft of the endoscope and by gentle tip deflection. Alternatively, APC is used for dissection of the cricopharyngeal bar. Pure coagulation current or



◘ **Fig. 2.14** Zenker's diverticulum. **a** Endoscopic diverticulotomy, lateral view. **b** Endoscopic view. **c** Lateral view of anatomy

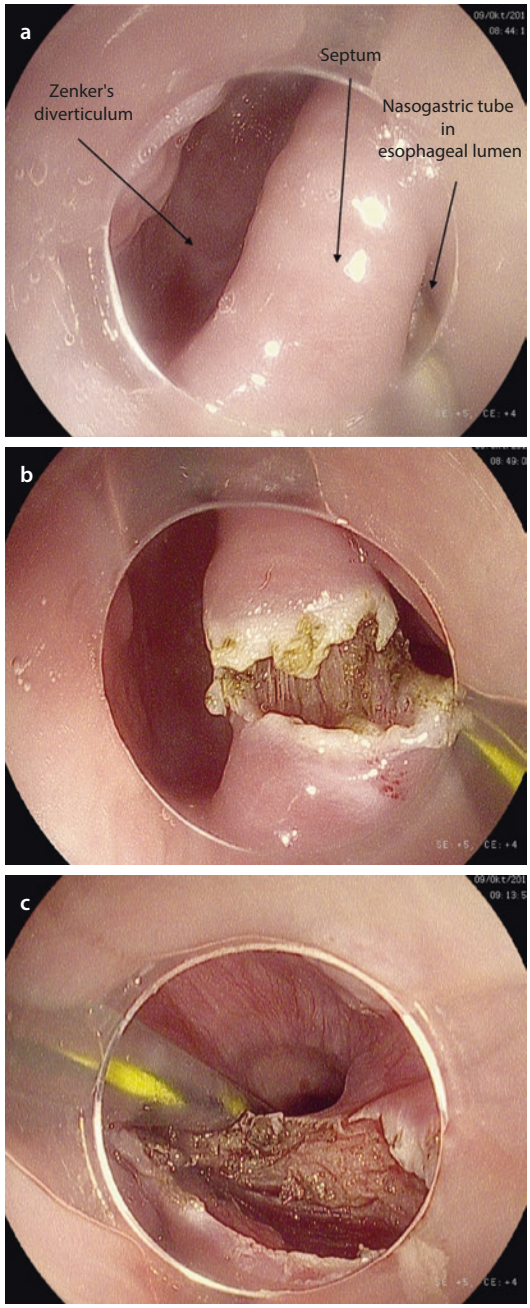


Fig. 2.15 **a–c** Medium-sized Zenker's diverticulum, endoscopic needle-knife diverticulotomy

blended currents can be used for the needle-knife (e.g., Endocut mode with ERBE generators); for APC power, settings around 50 watts are required.

- The last few millimeters of the cricopharyngeal bar should not be dissected, in order to minimize the risk of perforation.
- After finishing the dissection, an uncomplicated advancement of the standard gastroscope into the stomach should be possible.

After an uneventful recovery, the patient can be discharged on the following day with a soft oral diet for a few days.

A sore throat is to be expected after diverticulotomy, but strong pain or a subcutaneous emphysema should prompt further radiological diagnostics. If a perforation is diagnosed, conservative management with i.v. antibiotics is usually sufficient; the inserted nasogastric tube can then be used for enteral feeding.

Outcomes and Safety

Case series of flexible endoscopic Zenker's diverticulotomy have reported initial success rates of about 96% with persistent or recurrent symptoms in 8.5% of cases. Bleeding occurs in about 3% and perforations in 4% of described cases.

With similar success rates and less severe morbidity compared to rigid endoscopy or surgical approaches, flexible endoscopic diverticulotomy may become the preferred method especially for poor surgical candidates. However, there are no randomized controlled trials comparing the various treatment options (Dzeletovic et al. 2012).

2.6 Peroral Endoscopic Myotomy

Peroral endoscopic myotomy (POEM) is a comparatively recent technique for the treatment of achalasia, applying the concept of natural orifice transluminal endoscopic surgery (NOTES). With this procedure, esophageal myotomy is performed via an endoluminal access, in contrast to the thoracoscopic or laparoscopic routes used for the established Heller's operation. POEM on a human patient was first performed by Inoue in Yokohama, Japan, in 2008.

Indication

Achalasia is the original indication for POEM. In theory, achalasia type III (according to the Chicago Classification) in particular might be a good indication for extended endoscopic myotomy. Because of spastic esophageal motility encountered in this subtype, therapy targeted only at the lower esophageal sphincter (LES) (e.g., balloon dilation) has a poor clinical success rate.

POEM has the advantage of tailoring the extent of myotomy in this setting. For the same reasons, POEM has been proposed as a treatment option for hypertensive esophageal motility disorders such as distal esophagus spasm (DES) or jackhammer esophagus.

Devices

In principle, POEM is an advanced and challenging endoscopic procedure and should only be performed by operators experienced in ESD techniques at high-volume centers.

POEM should be performed under controlled circumstances with the patient under general anesthesia, with surgical backup because of the potential for severe perforations.

A gastroscope with a transparent cap attached to the tip is employed for the procedure and carbon dioxide gas instead of air for insufflation. For the dissection of the submucosal layer and for myotomy, various instruments may be used depending on the operator's preference (e.g., Triangle Tip knife by Olympus or HybridKnife by Erbe). The HybridKnife has the advantage of enabling submucosal injection and dissection without having to change instruments during the procedure. A mixture of saline and indigo carmine or colloid solutions may be used for submucosal injection and hemostatic clips for mucosal closure. A decompression cannula should be available in the event of (usually harmless) pneumoperitoneum occurrence.

Technique

- A submucosal injection on the right side of the esophagus is performed to lift the mucosa 10–15 cm proximal to the lower esophageal sphincter (LES). At this location an incision of 2 cm width is made, for example using the HybridKnife.
- Through this incision, the endoscope is inserted into the submucosal space. A submucosal tunnel along the right esophageal wall is created by sequential submucosal injection and dissection in an aboral direction. This tunnel is extended about 3 cm distal to the lower esophageal sphincter (LES) along the lesser curvature. The direction and progress of the tunnel is monitored regularly by withdrawal of the endoscope out of the tunnel and inspection from the esophageal lumen.
- The next step comprises the actual myotomy, which is started a few centimeters below the initial incision. The aim is to dissect the inner circular muscle layer without injuring the outer longitudinal esophageal muscle. Modifications, including the dissection of both muscles, have been described. Myotomy is continued distally until it is extended 2 cm into the cardia.
- Finally, the mucosal incision (the «tunnel entry») is closed with endoscopic clips (Fig. 2.16).

Outcomes and Safety

Various pilot studies have demonstrated the safety and effectiveness of POEM for the treatment of achalasia. A prospective multicenter trial reports a technical success rate of 100% without the need for surgery. Clinical success was observed in 97% of patients after 3 months and 84% after 1 year. The rate of post-interventional gastroesophageal reflux was 37%, slightly higher than in balloon dilation or LHM.

Future randomized controlled studies will have to further examine the efficacy of POEM in comparison to balloon dilation and Heller's myotomy with Dor fundoplication.

Considering the excellent safety profile and encouraging results of existing studies, POEM may become an established alternative to LHM in experienced centers (von Renteln et al. 2013).

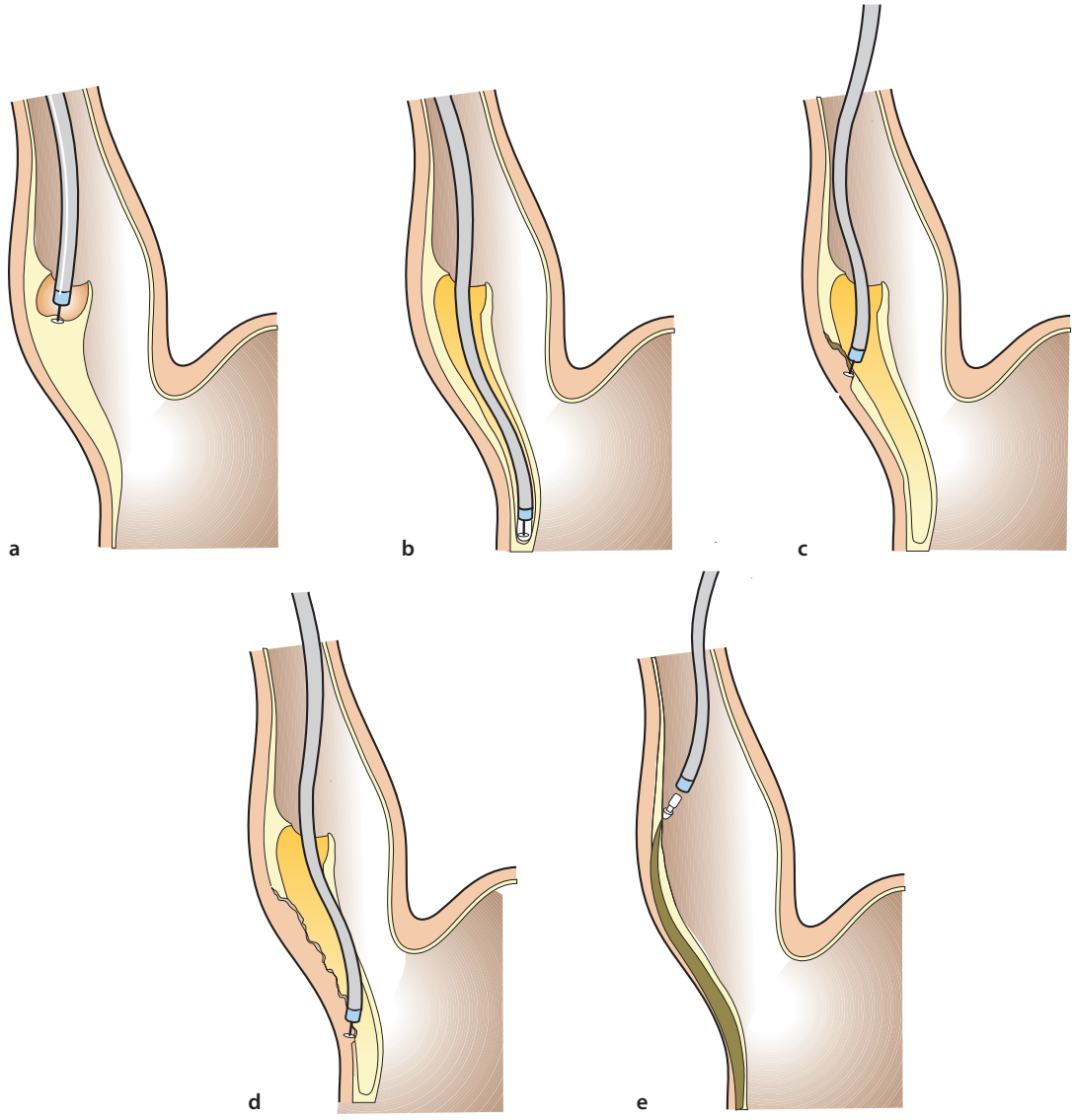


Fig. 2.16 **a** Incision after mucosal lift. **b** Creation of submucosal tunnel. **c** Incision of muscle fibers. **d** Extension of myotomy. **e** Closure of the tunnel

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Endoscopic Bleeding Control

Johannes Wilhelm Rey, Arthur Hoffman, Daniel Teubner, and Ralf Kiesslich

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Gastrointestinal bleeding (GIB) can occur at different locations and different intensities throughout the intestine. Gastrointestinal bleeding is subdivided based on the location (upper, lower, middle GIB). The upper GI tract comprises the esophagus, stomach, and duodenum (up to the papilla of Vateri). Middle GIB relates to that part of the GI tract located below the papilla Vateri up to the terminal ileum. Lower GIB is defined as a bleeding within the colon and rectum. Upper GIB is diagnosed with esophagogastroduodenoscopy, middle GIB with capsule endoscopy or enteroscopy, and lower GIB with colonoscopy.

3.1 Introduction

Upper gastrointestinal bleeding (GIB) has an incidence of 50/100,000 persons and is a common gastroenterological emergency. Endoscopic techniques for bleeding control as well as intensive care treatment have greatly evolved in recent years. However, the mortality of GIB is still high at 5–14% (Czernichow et al. 2000). Bleeding ulcers of the duodenum are the most common causes of upper GIB. They account for up to 50% of all cases with GIB (Thomopoulos et al. 2004). Ulcers within the stomach and duodenum are more often seen in the elderly. They are induced by infection with *Helicobacter pylori* or the use of nonsteroidal anti-inflammatory drugs (NSAIDs). Most of the ulcer bleedings stop spontaneously. If not, immediate medical treatment is required. Endoscopic, radiological, or surgical techniques are available for bleeding control. The most commonly used intervention is endoscopic therapy.

A special entity is the so-called Dieulafoy's lesion. It is difficult to diagnose, because an aberrant vessel reaches the mucosa and can lead to strong arterial bleeding based on erosion of the superficial vessel. The typical endoscopic feature is a bleeding vessel without surrounding mucosal damage (Fig. 3.1).

Mallory-Weiss lesions, esophageal varices, and malignancies within the upper GI tract are other sources of GIB (Table 3.1).

Lower GIB shows a strong association with aging. The incidence is 20.5–27/100,000 persons per year. Lower GIB is less common than upper GIB. Common causes of lower GIB are diverticula, malformation of vessels (angiodysplasia), polyps, cancer, and inflammatory bowel disease (IBD). Most GIB (85–90%) is self-limiting. However, strong bleedings can also rapidly occur with hypotension and shock (Longstreth 1997).

The least common form of GIB is middle GIB. Middle GIB accounts for about 10% of all GIB. Causes are malformations of vessels, ulcerations, neoplasia, and IBD. Diagnosis of middle GIB can be challenging. Here, capsule endoscopy and balloon-assisted enteroscopy (single or double) are used to identify the source of bleeding. Capsule endoscopy is more used for occult bleeding, whereas balloon-assisted enteroscopy is used for diagnosing and treating overt bleedings.

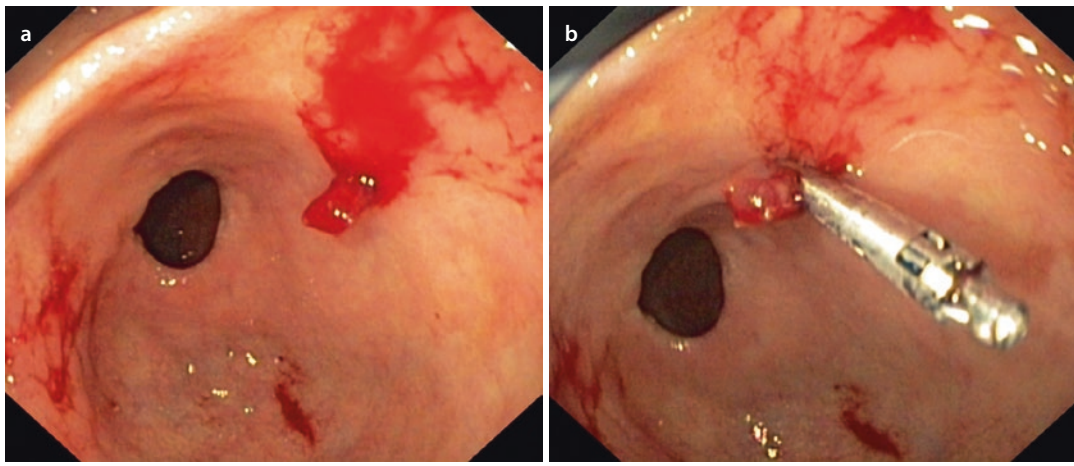

Fig. 3.1 **a** Visible vessel within a Dieulafoy's lesion of the antrum. **b** Endoscopic bleeding control with clip application

Table 3.1 Causes and frequencies of gastrointestinal bleeding

	Etiology	Frequency (%)
Upper GI bleeding	Peptic ulcers	50
	Erosions	16
	Variceal hemorrhage	10
	Mallory-Weiss lesion	5
Lower GI bleeding	Diverticula	42
	Hemorrhoids	16
	Colitis	18
	Post-polypectomy bleeding	13
	Vessel malformation	3

3.2 Ulcer Bleeding

Classification of peptic GI bleeding is based on Forrest classification (Table 3.2). The classification differentiates between acute, recent (with risk of re-bleeding), and almost-healed ulcerations. The goal of the Forrest classification is the immediate judgment of the risk of re-bleeding and the need for endoscopic intervention (Forrest et al. 1974).

Risk Stratification and Pharmaceutical Options of Therapy

First, thorough clinical evaluation is needed to define the health situation of the patient. Several scores can be used to define the need for hospitalization and treatment under intensive care. Measurement of vital parameters is the first and most important step of clinical evaluation. Hemodynamic instable patients require infusions and transfusions. However, red blood cells should only been given in otherwise healthy patients if the hemoglobin value is below 7 g/dl. Patients with coronary heart disease might require transfusions earlier, and the expected hemoglobin level should be above 10 g/dl.

Tip

Blood transfusions should be initiated in otherwise healthy patients if the hemoglobin value drops below 7 g/dl.

Table 3.2 Forrest classification of peptic ulcer bleeding

Forrest classification		Morphology of ulceration	Risk of re-bleeding
Forrest I	A	Active bleeding (pulsating)	High 5–20%
	B	Venous bleeding	
Forrest II	A	Visible vessel	
	B	Blood clot	
	C	Hematin based	Low 3–10%
Forrest III		Fibrin-based ulceration	

Active bleeding from the upper GI tract has to be considered as a medical emergency. Typical clinical signs are hematemesis and melena. Strong upper bleeding might lead to perianal bleeding with red color (hematochezia). Occult bleeding leads mainly to fatigue, dizziness, weakness, and cardiac symptoms (Peura et al. 1997).

Prognostic Scores

Differential risk stratification can be achieved with different prognostic scores (e.g., Rockall score, AIMS65 score; see Tables 3.3 and 3.4).

The different scores are scientifically evaluated. However, they are not all embedded into clinical practice. Here, simple parameters can be used to judge the overall blood loss. Melena is associated with an average blood loss between 50 and 100 ml. Hypotension develops after blood loss between 10 and 25% of the overall blood volume. Stable vital signs are seen if less than 10% of the blood volume is lost.

Medical Therapy of Gastrointestinal Bleeding

Endoscopic therapy of peptic ulcer bleeding should always be combined with medical treatment. Here, proton pump inhibitors (PPI) are the drugs of choice. The imbalance between aggressive and protective factors within the gastric mucosa can be treated with PPI. PPI therapy should be initiated prior to endoscopy. This regimen will lead to less active bleedings and will ease endoscopic therapy. PPI therapy after endoscopy is associated with lower re-bleeding. PPI can be given intravenously or orally. Patients with ulcer bleeding of the

Table 3.3 Rockall score: score below 3 is associated with a good prognosis, and scores above 8 predict high mortality risk

Variable	0 Points	1 Point	2 Points	3 Points
Age	<60	60–79	>80	
Hemodynamic	Normal	Pulse > 100 bpm Sys. RR >100 mmHg	Sys. RR <100 mmHg	
Comorbidity	None		Heart/circulation	Organ failure
Diagnosis	Mallory-Weiss	Other sources	Malignancy	
Forrest	III		I, II	

Table 3.4 AIMS65 score

Risk factor	Value
Albumin	<3 g/dl
INR	>1.5
GCS (mental status)	<14
Sys. RR	<90
Age	>65

Mortality risk:
No risk factor: 0.3%
1 risk factor: 1%
2 risk factors: 3%
3 risk factors: 9%
4 risk factors: 15%
5 risk factors: 25%

small bowel without intake of NSAIDs do profit from immediate eradication of *Helicobacter pylori* (Chan et al. 2007; Kahi et al. 2005).

Tip

Endoscopic therapy of peptic ulcer bleeding should always be combined with PPI treatment. Re-bleeding will be reduced.

Rapid pH elevation is mandatory for stabilization of blood coagulation and leads to reduced recurrence of GI bleeding. Cellular and plasmatic coagulation is only sufficiently active if pH values are between 4 and 5. There is inconsistency with regard to the route of administration of PPI (orally or intravenously) to be used. Oral administration may be sufficiently effective in patients with stable bleeding. Eradication of *Helicobacter pylori* if present is an additional benefit. The recurrence of ulcerations of the stomach and duodenum is accordingly reduced (less than 5%). Prokinetic agents such as erythromycin and metoclopramide can be of benefit in preparing for endoscopic diagnosis and therapy (Altraif et al. 2011). The stomach will be freed of blood clots by prokinetic therapy, and the visibility of blood lesions will be improved. In contrast, the vasoconstriction of the splanchnic vessels which can be achieved with somatostatin does not play a role in endoscopic bleeding management or therapy (Imperiale and Birgisson 1997).

Tip

Prokinetic agents prior to endoscopic examination ease the visibility of the mucosa and improve endoscopic diagnosis and therapy.

Surgery does not play an important role in treatment of GI bleeding nowadays. Endoscopy, radiological interventions, and medical treatment have almost replaced surgical interventions. Resection methods such as Billroth were performed in the past but are no longer necessary. However, surgery is needed if recurrent bleeding is present. Complications such as perforation or stenosis still require surgery.

Co-medication with anticoagulation increases the risk of GI bleeding and can lead to more severe bleedings. However, cardiovascular mortality can be increased if anticoagulation is stopped based

on GI bleeding. Thus, close interaction between cardiologists and gastroenterologists is needed to define optimal treatment of the patients.

Endoscopic Therapeutic Methods

The main diagnostic step for diagnosing upper GI bleeding is EGD. EGD should be performed within 24 h after onset. Ideally, EGD should be done right after stabilization of the patient. Early endoscopy is associated with a higher diagnostic yield, and almost 90% of upper GI bleedings can be identified with EGD (Zuccaro 1998). Endoscopic therapy depends on size, severity, location, and experience of the examiner. There are several endoscopic therapy options:

Endoscopic Therapy Options for Upper GIB

- Injection therapy:
  - Epinephrine
  - Histoacryl
  - Aethoxysklerol
  - Fibrin glue
- Thermal therapy:
  - Electrocoagulation
  - Heater probe
  - Laser coagulation
  - Argon plasma coagulation (APC)
- Mechanical therapy:
  - Rubber band ligation
  - Hemoclip
  - Over-the-scope clip
- Hemostatic powder:
  - Hemospray
  - EndoClot (Hegade et al. 2013, Huang et al. 2014)

It is mandatory to use two types of endoscopic therapy to sufficiently treat GI bleeding (Sung et al. 2007). Most commonly, injection therapy is combined with clipping.

Indications

Upper endoscopy is recommended in every patient with GIB. Informed consent should be obtained if possible (stable patient). Emergency upper endoscopy is needed in clinically unstable patients. The lab parameters should be analyzed. However, it should be taken into account that dilution due to infusion therapy might play a role.

Personnel

Sufficient and experienced personnel are required to perform high-quality endoscopic diagnosis and therapy. EGD is performed on the left lateral position, or the patient is intubated and can stay on the back. Patient with severe bleeding and hematemesis requires intubation. This minimizes the risk of aspiration. Emergency EGD should be performed by an experienced examiner and experienced nurse. Ideally, the team is highly familiar with all endoscopic techniques for stopping GI bleeding. The team should already have performed all kinds of endoscopic interventions in elective patients. Intensive care treatment is needed if the patient is highly unstable. A physician and a nurse who are familiar with intensive care treatment should be part of the team to treat the patient properly and sufficiently. Endoscopy can be performed in the emergency room, the endoscopic suite, or within the intensive care unit. Interdisciplinary interaction is needed to receive the best results.

Tip

Acute GIB is an emergency, which requires interdisciplinary interaction to achieve best treatment for the patient.

Organizational Requirements

Organizational requirements depend on the severity of the bleeding. It has to be ensured that indication is clarified and informed consent is obtained. Coagulation parameters and vital signs have to be measured and optimized (if possible). In general, any endoscopic service should be able to offer diagnostic and therapeutic endoscopy. The structure of the team and the suite has to be adapted to the needs of the patients. Therapeutic algorithms and post-interventional follow-up have to be defined — within the endoscopic suite as well as in the hospital.

Knowledge of the working method as well as the technical application of endoscopic therapies is mandatory to perform sufficient endoscopy and proper endoscopic hemostasis. Medical device requirements and law have to be taught to the team, and reliable handling of the different devices has to be ensured. Maintenance of the equipment is also mandatory.

Instrumentation Requirements

In general, the use of therapeutic endoscopes with larger working channels (3.8–4.2 mm) is recommended. A second endoscope should be available in case malfunction of the used endoscope occurs or if the working channels become blocked due to the aspiration of blood clots. Intensive care treatment should be available depending on the severity of the bleeding. Monitoring of the patient is essential. Here, noninvasive measurement of the blood pressure, continuous measurement of the oxygen saturation, and pulse oxymetry are recommended.

Necessary Preparations for Endoscopic Diagnosis and Therapy

- Absorbent sheets
- Detergent flushing fluid (e.g., Dimethicone and Aqua) (Fig. 3.2)
- Lubricant
- Adequate amount of container for suction and exchange material
- Suction pump
- Adequate amount of rinsing fluid for the optical system

Fig. 3.2 Lubrication cream and antifoam agents are standard for endoscopic care

- Two i.v. cannulas with safe fixation and large diameter
- Mouthpiece
- Oxygen applicator with humidification
- Emergency chest (with regular controls) nearby
- Endoscopic injection needles
- Saline solution 0.9%, adrenaline solution(1:10,000)
- Clips (according to the manufacturer)
- Devices for thermal hemostasis

Types of Intervention

The highest level of success can be achieved if the endoscopic team is experienced and has performed the interventions many times before. Ideally, emergency interventions should be performed by the most experienced examiners. The different forms of endoscopic interventions are now explained.

Injection Therapy

Injection therapy is performed with different agents (see Table 3.5). Here, mechanical compression of the vessel is the main mode of action. Vasoconstriction might play an additional role. Compression lowers the blood flow and thus activates the coagulation system (Fig. 3.3).

The use of diluted epinephrine solution is most common. Several circumstances are in favor for this type of agent:

- High tolerance
- Low costs compared to fibrin glue
- No tissue destruction or damage

Table 3.5 Substances for injection therapy of peptic ulcer bleeding

Substance	Mode of action
Epinephrine solution 1:10,000–1:100,000	Vasoconstriction and compression
Polidocanol	Sclerosing and scar formation
Fibrin glue	Multiple component activator of coagulation
Saline	Compression
Alkyl cyanocrylat	Polymerization

Fig. 3.3 Substances used for injection therapy. The dilution of epinephrine is carried out using saline solution

Injection with diluted epinephrine (1:10,000) is highly effective. The source of bleeding is treated by injecting several doses (1–2 ml) of epinephrine toward the bleeding vessel. Complication rates are below 1%. Bleeding control can be achieved in 75–90% of cases.

Technical note: The catheter covering the needle is gently passed over the working channel of the endoscope. The nurse moves the needle forward out of the catheter if the distal tip of the catheter becomes clearly visible. The syringe with the diluted epinephrine is connected with the catheter. The examiner moves the needle forward into the tissue. Ideally, injection is done within four quadrants surrounding the bleeding vessel. The nurse states aloud the amount of applied epinephrine and also whether the injection can be done easily or resistance occurs; the examiner can reposition the needle based on this information.

The diluted epinephrine can be further diluted, or pure saline can be used in patients with coronary heart disease to further minimize the risk for systemic side effects.

Injection therapy is an easy and basic endoscopic intervention and can be learned quickly. It can be performed also by less experienced examiners.

Tip

Injection therapy with diluted epinephrine is aimed mainly at mechanical compression of the bleeding vessel. Pharmacological vasoconstriction might play an additional role. Epinephrine can be further diluted, or pure saline can be used in patients with known coronary heart diseases. This will further minimize the risk of systemic side effects.

The mode of intervention is similar for polidocanol, alkyl cyanoacrylate, and fibrin glue. However, the preparation of compounds using components such as fibrin glue requires special attention. The eyes and mouth of the patient and the examiners should be protected.

Fibrin glue has been stated to be superior in single studies (compared to epinephrine injection). However, further studies and meta-analysis could not confirm this observation. Additional injection of sclerosing agents for peptic ulcer bleeding has no additional benefit. Indeed, it is associated with a higher complication rate due to risk of necrosis and is not recommended.

Combination of injection therapy and thermal ablation or treatment has also shown no convincing benefit. Mortality, risk of re-bleeding, and need for surgery were comparable. However, mechanical treatment (hemoclip) in combination with injection therapy has shown advantages. Here, re-bleeding is less frequent mainly because of the prolonged compression of the bleeding vessel.

Figure 3.4 shows an 88-year-old patient with melena. The endoscopic examination revealed a continuously bleeding ulcer (Forrest I b) in the duodenal bulb. Hemostasis was done with two hemoclips Fig. 3.4b.

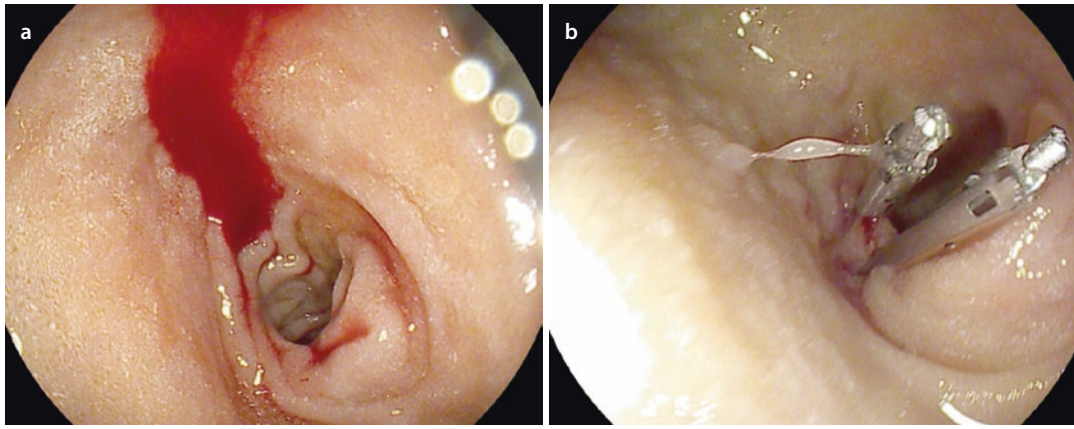

Fig. 3.4 **a** Bleeding ulcer in the duodenal bulb. **b** Hemostasis with two hemoclips

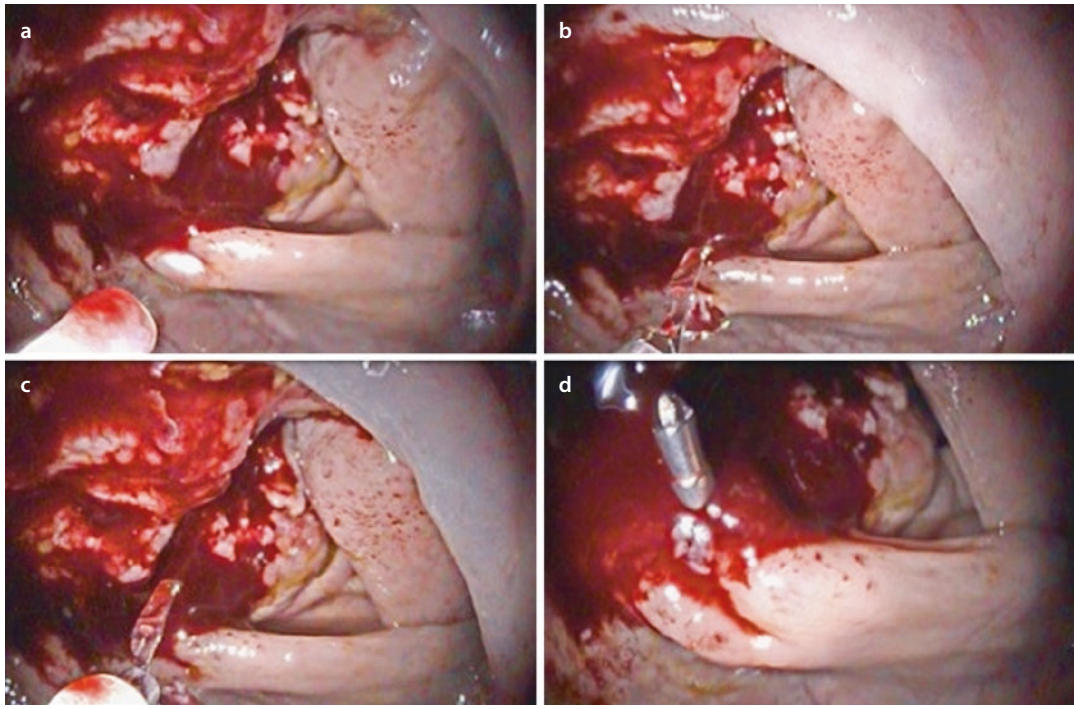

Fig. 3.5 Preoperative marking with hemoclip in a patient with colonic cancer. First the clip is advanced **a**, **b**, and then it is tautened **c** and finally applied **d**

Furthermore, hemoclips have also proved themselves useful for marking (Fig. 3.5) and for closure, for example, of small fistulas and perforations. All studies to date have demonstrated the significant superiority of hemoclips compared with injection methods with regard to primary hemostasis.

Nowadays, different single-use and reusable clips with different designs are available. The QuickClip (Olympus Medical Systems) is a single-use metallic clip which can be rotated within the endoscopic examination. The clip is available with varying opening angles and lengths of branches. In contrast to others, it cannot be reopened.

A reloadable system is available for more than 20 years. Another single-use product, the TriClip (Cook Medical), is a metal pin with three branches which can be closed only once after placement.

The manufacturer regards rotation as unnecessary due to the trilateral application.

The Resolution clip (Boston Scientific Corporation) is suitable for hemostasis, for closure of small perforations, and for the fixation of jejunal nutrition tubes according to the manufacturer's instructions. Furthermore, this clip can be reopened after closure.

The Over-The-Scope Clip (Ovesco Endoscopy AG, Tübingen, Germany) has been available for interventional endoscopy since 2007. While all other clips are introduced through the instrumentation channel of the scope, this clip is fitted at the tip of the scope (Schurr et al. 2008). Due to its design, it can grasp much more tissue and apply a higher pressure than conventional clips. This allows a targeted placement of the clip.

For proper and safe placement, the tissue can be sucked out, or a special tissue anchor can be used which is provided by the same manufacturer.

Case Study

Figure 3.6 shows a 69-year-old man with melena and vomiting of blood as an emergency case. Due to leg thrombosis, he was under Marcumar medication.

A gastric antrum ulcer with Forrest Ia bleeding was diagnosed. The endoscopic treatment was done with an OTS Clip solely (no injection). Testing for *Helicobacter pylori* was negative.

Therapy was successful, and no re-bleeding occurred. Patient was discharged 5 days after OTSC treatment.

Figure 3.6c, d demonstrates endoscopic controls after 3 days and after 6 weeks.

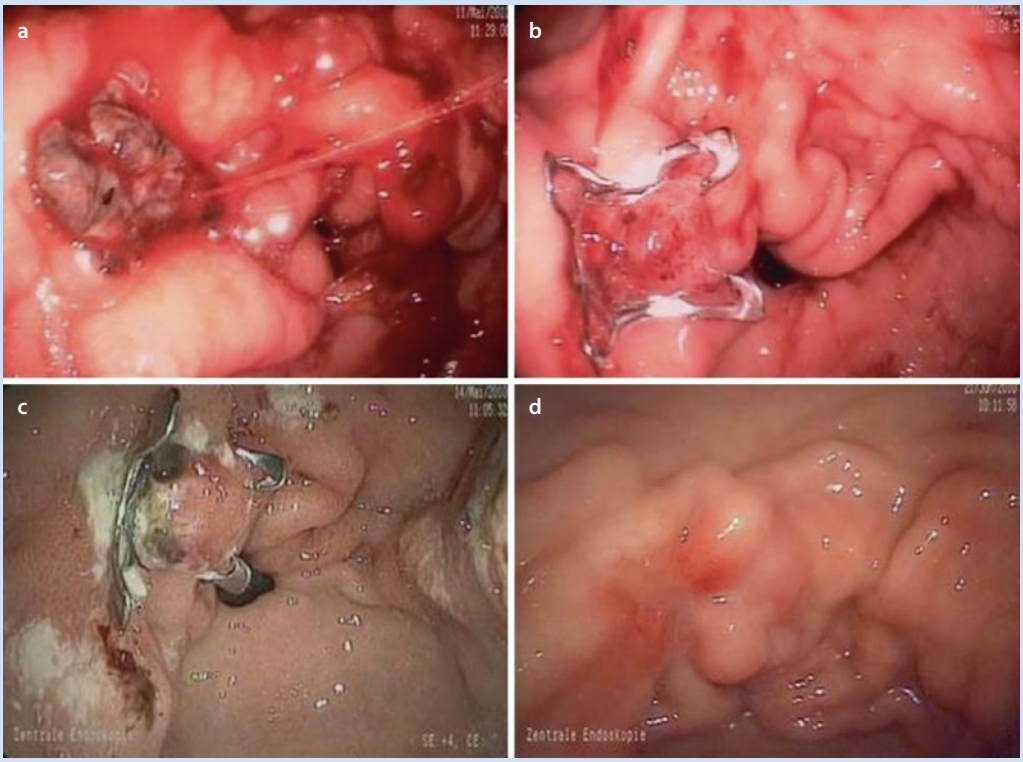

Fig. 3.6 **a** Forrest 1a bleeding in the gastric antrum. **b** Endoscopic therapy with OTSC without further treatment. **c** Postoperative day 3, **d** 6 weeks after intervention (With kind permission from Dr. Thomas Kratt)

The use of hemoclips in endoscopy provides a lot of advantages. All the abovementioned systems combine the positive aspects of low rebleeding rates and are superior to most of the injection methods. The handling and the related success rate depend on the experience of the endoscopist. Recommendations concerning follow-up endoscopies are conflicting. An international consensus from 2010 does not give a general recommendation for a control.

Mineral Powders

Just recently, endoscopic Hemospray (Cook Medical, Ireland) became available as an alternative to traditional methods (Holster et al. 2014; Smith et al. 2014; Yau et al. 2014). EndoClot (MicroTech Europe) is another mineral powder which can achieve homeostasis in GI bleeding. Hemospray (Fig. 3.7) is an inorganic silicate crystal (powder) which is provided in a cartridge. It is applied with a catheter through the instrumentation channel of the scope directly to the bleeding source.

The mode of operation of the powder is not clear in detail. In addition to a mechanical barrier, there seems to be another really significant component. On one hand, the powder causes a plasma separation and thereby an increased concentration of coagulation factors; on the other hand, electrostatic loading of the crystals activates intrinsic blood coagulation.

This noninvasive mode of functioning also works in patients with full anticoagulation. This is a clear advantage, in particular in emergency situations.

Few data exist about the use of Hemospray. In 2011, the first published study demonstrated a high level of safety and no side effects due to Hemospray.

With the exclusive use of Hemospray, after 72 h a hemostasis could be achieved in 89% of cases. In a European Register study (SEALS), the superiority of Hemospray was registered in particular in those cases in which other methods failed. Here, a hemostasis rate of 70% could be achieved.

The use of this method for peptic ulcer bleeding is promising (Fig. 3.8). In addition, it can be used in tumor-related bleedings and in patients with gastrointestinal bleeding and medical anticoagulation. In Europe, Hemospray is approved for nonvariceal upper GI bleeding. In Canada, it is approved also for lower GI bleeding (Fig. 3.9).

Even thermal treatment methods can be used in gastrointestinal bleedings, in particular the heater probe and argon plasma coagulation (APC) (▶ Sect. 3.4).

Complications

Aspiration of blood and overdosage of sedative medications are the most common complications before and during endoscopic therapy. A decrease in blood pressure can be caused not only by a hemodynamic complication by the bleeding itself but also by the sedation. Furthermore, perforations are possible complications. The complication rate is higher with aggressive monotherapy, in particular with thermoablation, compared with a combination of thermal ablation with clipping. For rare cases with failing of endoscopic hemosta-

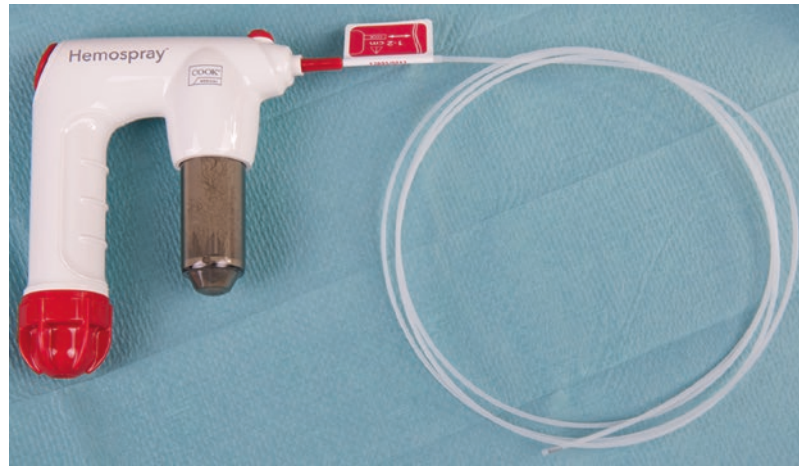

Fig. 3.7 Hemospray: the powder is applied by twisting the red button at the handle and opening of the outlet channel (*red lever*)

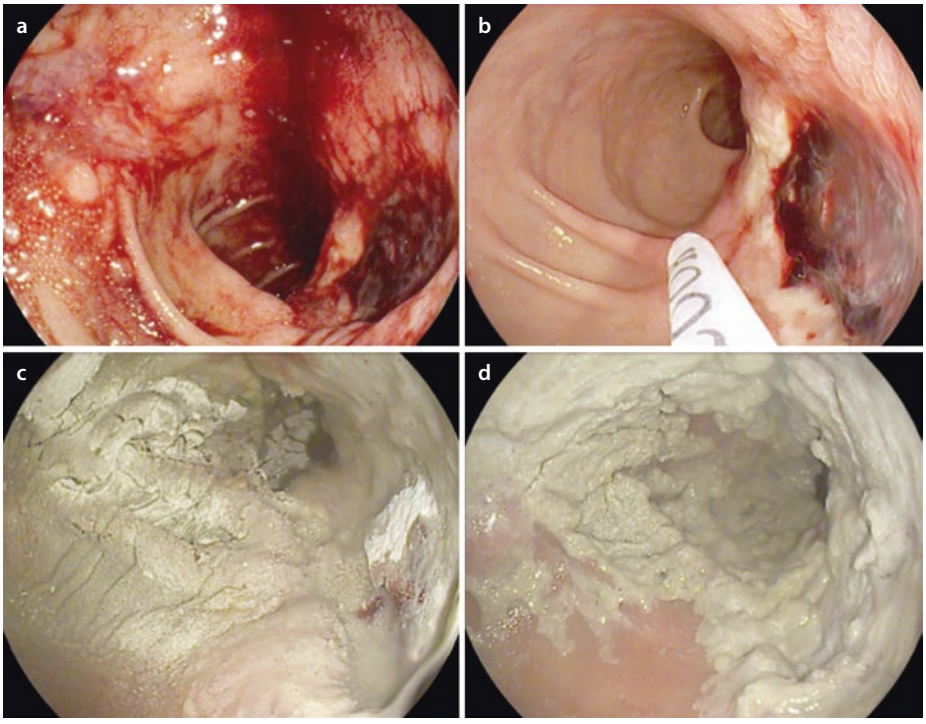

Fig. 3.8 A 76-year-old man with melena and hemorrhagic shock. The patient had a partial gastrectomy (Billroth I) with a non-bleeding ulcer with visible vessel stump (Forrest II a) (**a**). The endoscopic therapy was done with Hemospray and intensive care. Hemostasis could be achieved and the patient could be stabilized (**b**–**d**)

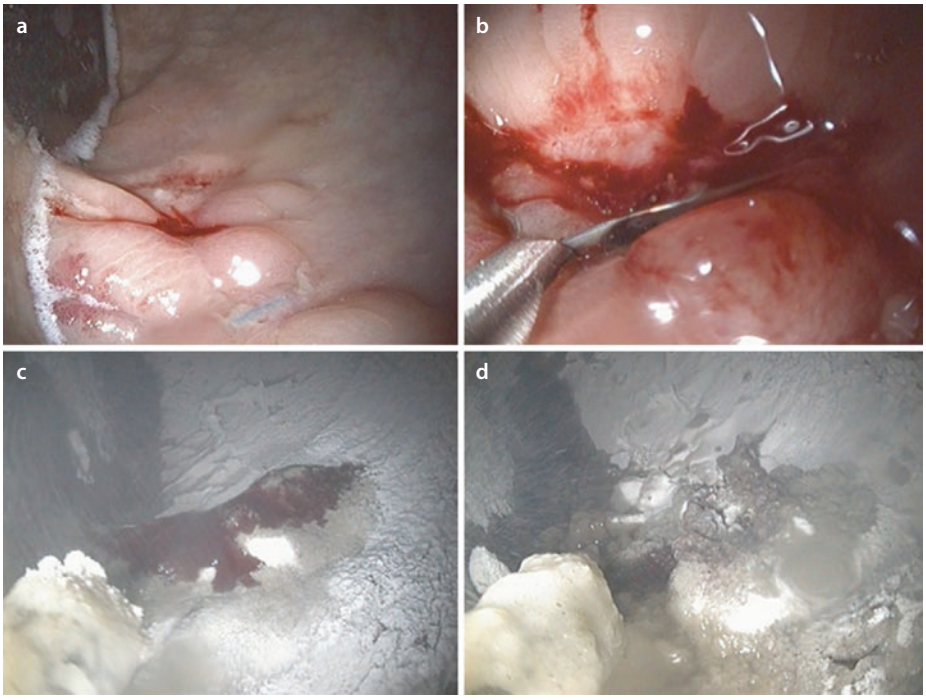

Fig. 3.9 A 71-year-old female with continuous perianal blood loss after (outpatient) hemorrhoidectomy some days before. **a** Endoscopic finding: bleeding from operation site. **b** Applied clips could not fix the mucosa. **c**, **d** Hemostasis after repeated Hemospray application till final surgery

sis, a transarterial chemoembolization should be undertaken (if appropriate radiologic expertise is available) before surgical therapy.

An overdosage of analgosedation can cause severe complications during endoscopy.

Tip

Analgosedation with propofol (e.g., Diprivan) should be started by titration. Administration of 0.5–1 mg/kg KG is usually sufficient to start sedation.

3.3 Variceal Bleedings

Esophageal and gastric varices are indicators of portal hypertension, which is the consequence of a pressure gradient between the portal vein and hepatic veins exceeding 12 mm Hg. Approximately one third of patients with liver cirrhosis succumb to variceal bleeding. In these patients, this variceal bleeding is responsible for 50–90% of upper gastrointestinal bleeding episodes. A spontaneous stop of variceal bleeding is observed in less than 50% of cases. Bad coagulation capacity also favors bleeding. Following variceal bleeding, the patient runs a high risk of re-bleeding within the first 6 weeks, the risk being highest during the first 24–73 h after the bleeding event. Therefore, the 30-day mortality from variceal bleeding ranges up to 20%.

Risk Factors of Acute Variceal Bleeding

- Age >60 years
- Kidney failure
- Large variceal convolutes
- Initial hemoglobin <8g/dl

In order to predict a variceal bleeding, other than due to localization, clinical circumstances, and intra-variceal pressure, the size of the varices and the morphology are relevant. Apart from the endoscopic therapy of bleeding-prone varices, primary prophylaxis by beta-blockers (carvedilol) represents the most important medical action.

Medical Therapies

Before attempting endoscopic diagnosis and therapy, a supportive medical treatment for the variceal bleeding must be started (Gawrieh and Shaker 2005; Schepke et al. 2004). Even if there is only a suspicion of a variceal bleeding, taking account of potential contraindications such as severe coronary disease, a vasoactive therapy should be started immediately, e.g., by 1 mg terlipressin intravenously every 4–6 h in a normal-weight patient. It should be continued in hemodynamically stable patients for 2–5 days. Furthermore, in addition to the hemodynamic stabilization of the patient, prevention and treatment of complications are integral parts in a therapeutic concept for variceal bleedings. A frequent monitoring of hemoglobin is essential. If values fall below 7 g/dl, the administration of an erythrocyte concentrate should be considered. However, hemoglobin levels should not exceed 9 g/dl because this could trigger re-bleeding episodes. Crystalloid liquids should be infused at a speed which maintains a urinary output of 50 ml/h; an excess infusion should be avoided. Correcting coagulation and thrombocytes may be useful.

Patients should be regularly checked for signs of sepsis. In patients with liver cirrhosis, infections are frequent, and a prophylactic administration of antibiotics has shown a survival advantage in most studies. Therefore, in these patients, an antibiotic therapy (gyrase inhibitors) even before endoscopic intervention is recommended. The currently available data suggest that both mortality and recurrent bleeding rates are thereby lowered. Depending on the clinical situation, airway safety must be guaranteed. Intensive care surveillance of pulmonary and cardiac function and a regular metabolic monitoring of potential electrolyte disturbances and base/acid imbalances are also integral parts of the therapeutic management.

Tip

In variceal bleeding situations, careful management of volume and blood transfusion is advisable; the hemoglobin value should not exceed 9 g/dl.

Tranexamic acid, which is already a well-established part of the emergency room management, was able to show an improvement of mortality in meta-analyses. However, it has failed to show this benefit in cases of upper GI bleedings.

Table 3.6 Grade of varices according to the endoscopic finding

Grade	Endoscopic finding
I	Small, flat varices
II	Enlarged tortuous variceal convolutes, comprising less than 1/3 of the esophageal lumen
III	Large, snail-shaped variceal convolutes, comprising more than 1/3 of the esophageal lumen

Endoscopic Therapeutic Procedures

The endoscopic ligation of varices (multiband ligation) not only is a successful step in the treatment of acute bleedings but also serves as primary prophylaxis of repeat bleedings. Endoscopically, the varices are classified into three different grades of severity (Table 3.6, Fig. 3.10).

Endoscopic primary prevention, however, has not shown superiority as compared to medical beta-blocker therapy as of today. A combination of both modalities has not been investigated yet. An endoscopic sclerosing therapy of varices is no longer recommended, since pulmonary embolism and sepsis have been reported. But it may still be helpful as an action of last resort.

Endoscopic multiband ligation is the treatment of choice in acute esophageal variceal bleedings. As soon as the suspicion has been raised of this type of bleeding, it should be rapidly prepared for and carried out in all patients. Long-term studies have revealed that rubber band ligation is superior to sclerosing therapy. This ligation procedure, since its first description in 1986, has been further developed and may today be regarded as a routine measure in the treatment of patients with esophageal varices.

One of the biggest steps forward was the development of the multiband ligator (Six-Shooter and Speedband) which made the treatment easier and safer. Esophageal variceal ligation is achieved by occlusion of the varix and subsequent thrombosis. This leads to necrosis of the tissue which then—after some days to weeks—will be discharged while the mucosa is healing. Unlike with sclerotherapy, injuries to the deeper layers of the esophagus are rare.

Recently, soft endoluminal stents have been used for compression of the varices. There is, however, only limited experience with this novelty, and case reports are rare. Acute variceal bleeding is always a life-threatening situation, where the bleeding and other complications endanger the patient's life (Table 3.7).

Endoscopic therapy of varices of the gastric fundus has to be looked upon separately from the treatment of esophageal varices. Here, for primary hemostasis, histoacrylic tissue glue is used. The application is done by injecting the histoacrylic solution via an injection needle which is forwarded through the working channel of the endoscope. By doing so, an immediate clotting of the blood inside the varices is achieved (Fig. 3.11). There is a

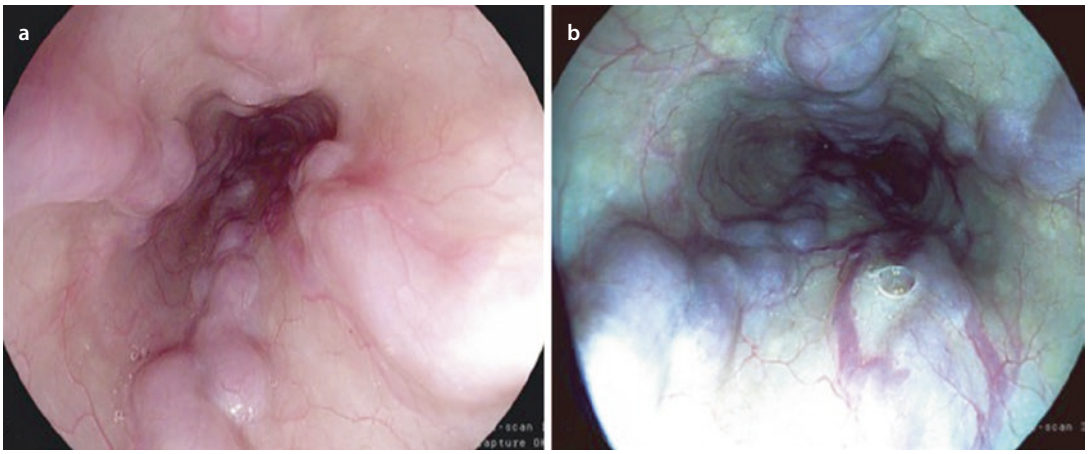

Fig. 3.10 Endoscopic aspect of esophageal varices II° without stigmata of imminent bleeding or red colour signs. **a** i-scan 1 mode. **b** i-scan 3 mode in virtual chromoendoscopy

Table 3.7 Potential complications of endoscopic therapy for variceal bleeding

Type	Complication
Local	Ulcerations, bleedings, strictures, motility disorders, pain, odynophagia, lacerations
Regional	Perforation, mediastinitis, pleural injuries
Systemic	Sepsis, aspiration, ARDS, spontaneous bacterial peritonitis, hypoxemia, portal vein thrombosis
For the physician	Eye injuries during sclerosing action

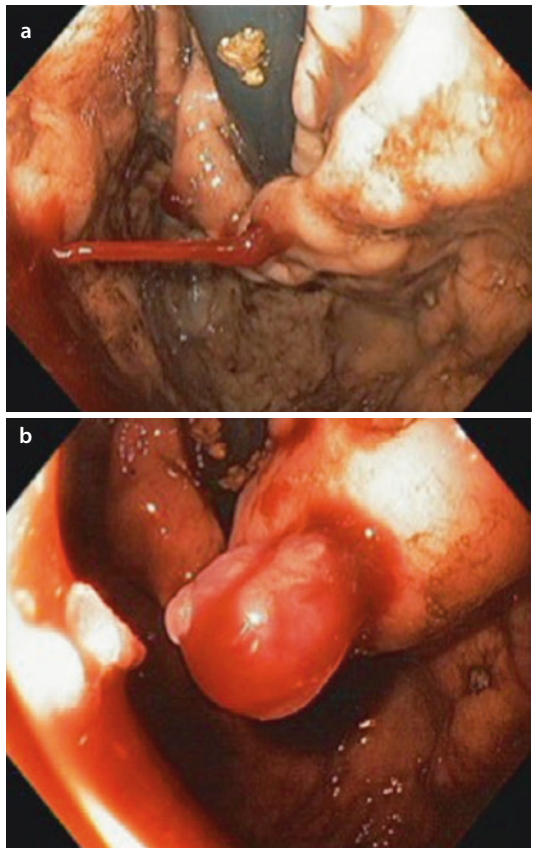

Fig. 3.11 **a** Endoscopic view in retroflexion onto an active spurting fundal variceal bleeding. **b** The bleeding stopped after the injection of n-butyl-cyanoacrylate

great variation as far as volume of the glue and frequency of injections are concerned. We usually take 1–2 ml of morrhuate sodium 5% per single injection, with a total of 12–20 injections per session. It is mandatory to wear protective goggles for eye protection. In addition, during retraction of the catheter, it is important to avoid the working channel of the endoscope being damaged or occluded by residual histoacrylic glue.

In those patients where endoscopic attempts to stop the acute variceal bleeding are unsuccessful, there remains the possibility of a transjugular intrahepatic portosystemic stent shunting (TIPSS). Placement of this shunt type makes it possible to avoid an emergency shunt operation in most patients.

Indications

The indication for an elective variceal band ligation is made following a diagnostic esophagogastroscopy in patients with large third-degree varices or varices ready to bleed («cherry-red spots»). The elective variceal band ligation is supposed to prophylactically reduce bleeding complications in these patients, while studies show a similar effect as compared to medical primary prophylaxis. Informed consent of the patient is obligatory. As of today, however, uncertainty exists concerning the post-ligation time frame until the next prophylactic endoscopy. Expert opinion recommends a repeat endoscopy, possibly with further band ligations, within 7–10 days. An additional interval therapy is helpful after 3/6/12 months.

Personnel Requirements

The requirements are similar to those necessary in patients with non-variceal gastrointestinal bleedings which were described previously. In the case of an elective variceal ligation, a standardized sequence of events should be prepared and carried out. Endoscopist as well as assisting personnel should be experienced in ligation and injection therapy. The elevated risk for significant blood loss during the intervention should be in everybody's mind.

Organizational Requirements

The organizational requirements for the elective treatment by variceal ligation are by no means

completely different from other endoscopic procedures and interventions. After a correct indication, the localization of the intervention and the personnel should be chosen according to their ability to react to possible complications in an adequate and timely fashion. For the event of an emergency intervention because of an acute variceal bleeding, every endoscopy unit should work out clear procedural rules which not only focus on endoscopy but well beyond on consequences for interaction in the whole hospital. Among these there are not only commitments of the intensive care unit and the blood transfusion lab but also the identification of adequate transportation services.

Instrumentation Requirements

The instrumentation requirements are also similar to those necessary in patients with nonvariceal gastrointestinal bleedings. In case of a rubber band ligation, nearly every standard endoscope has an additional device which may be mounted on the tip of the scope. The rubber bands are hung up under tension and may be mechanically released by the endoscopist.

The instrumentation requirements for histoacrylic glue injection are similar to injection therapy with adrenaline. Care has to be taken to prepare the correct mixture.

During injection of tissue glues, self-protection is always mandatory. The endoscopist must wear protective masks and goggles.

Practical Execution

In the case of an acute variceal bleeding, the endoscopic examination should commence fast, even if coagulation might be impaired (Fig. 3.12).

Parallel to that, achieving optimal coagulation parameters should be an essential goal. In order to avoid any aspiration of blood, patients should lie on their side. In acute bleedings, a protective intubation might be required. The first step of the endoscopy is a diagnostic esophagogastroscopy to identify the type and localization of the bleeding.

The treatment of esophageal variceal bleeding should start at the distal end, since the placed rubber bands will narrow the esophageal lumen. Practically, a varix for ligation is identified, the scope positioned, and the varix then sucked into the tip of the augmented scope. Then the rubber band is released (Fig. 3.13). It is important to suck in sufficient mucosa in order to avoid a slippage of the rubber band provoking an additional bleeding. In order to avoid exactly this issue, sufficient distance between ligations should be planned. Although theoretically there is no upper limit for the number of placed rubber bands, during index endoscopy, the number should be restricted to maximally ten. Studies have shown that more than six ligations placed during the first endoscopy have no benefit anymore for the course of the disease.

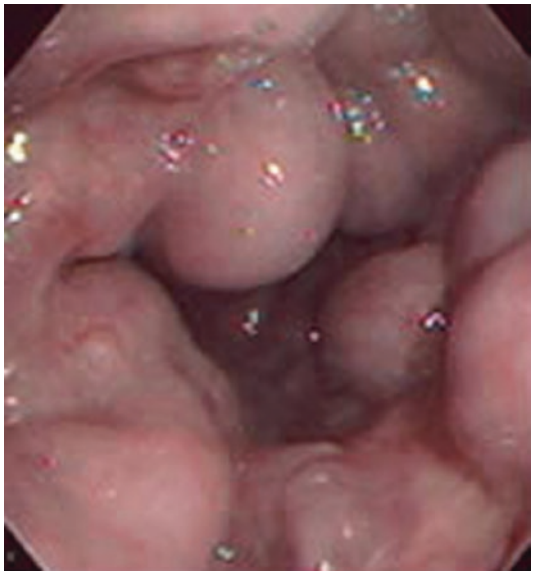

Fig. 3.12 Esophageal varices with signs of imminent bleeding

Tip

Variceal ligations in the esophagus should always start distally and move proximally.

There is a risk of iatrogenic variceal bleedings caused by endoscopy.

When the bleeding site is unclear, the blind attempt to place one or more ligations in the region of the gastroesophageal junction might reduce a more proximal bleeding. Studies have shown that rubber band ligations may achieve hemostasis in 80–100% of cases.

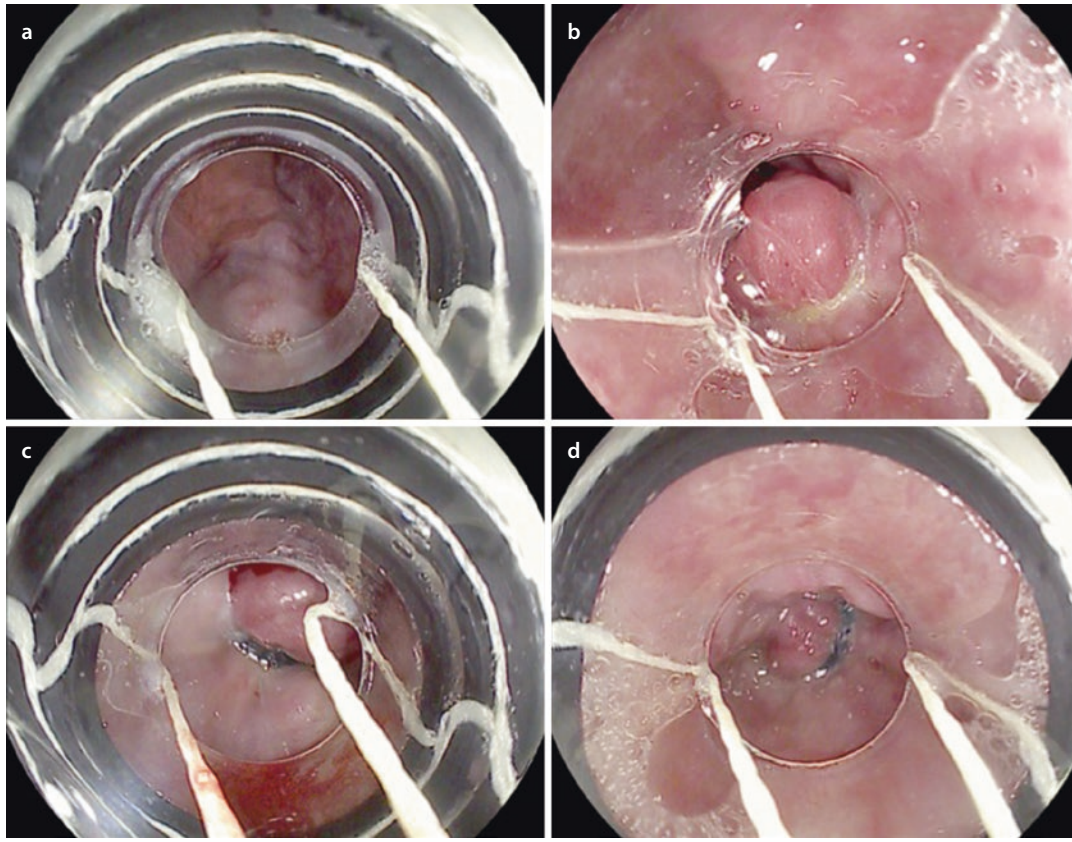

Fig. 3.13 Variceal band ligation with a cap into which the varix is suctioned **a**, **b** before the rubber band is released at the base of the pseudopolyp **c**, **d**

Currently, the following rubber band ligation sets are available: Conmed (Steigmann-Goff endoscopic ligator and Clearvue ligator), Boston Scientific (Speedband Super View Super 7), and Wilson-Cook (four, six, and ten multi-shooter speedband ligators). In acutely bleeding varices, the multi-shooter has definite advantages, whereas single shooters may be used in elective ligations. A combination of ligation and injection has not yet shown a better course in several studies. Furthermore, the combination of ligation and thermotherapy has not been sufficiently investigated and cannot be recommended for routine use. There are early reports on the successful use of Hemospray to treat variceal bleeding (Mostafa et al. 2015) although the license is pending.

Tip

In the treatment of variceal bleedings, antibiotic prophylaxis has to be carried out.

Complications

On the basis of current evidence, the complication rate of ligation therapy is less than that of injection therapy, most likely a transient bacteremia may be observed in patients with variceal ligation. As a consequence of the closure of esophageal varices the hypertensive gastropathy may aggravate. With regard to the instruments, the ligation device of the endoscope may lead to a poorer view within the esophagus. In addition, coagulated blood in the suction chamber can reduce orientation, thereby increasing the risk for secondary bleedings. Quite often, following ligation, the patients complain of retrosternal pain. Esophageal stenoses, strictures, or motility disorders—especially after multiple ligations—are only rare events. A transient bacteremia may be observed. The closure of esophageal varices may worsen the hypertensive gastropathy.

It should be recommended to fast during the following day and to eat soft food only for a couple of days. The healing process of the naturally

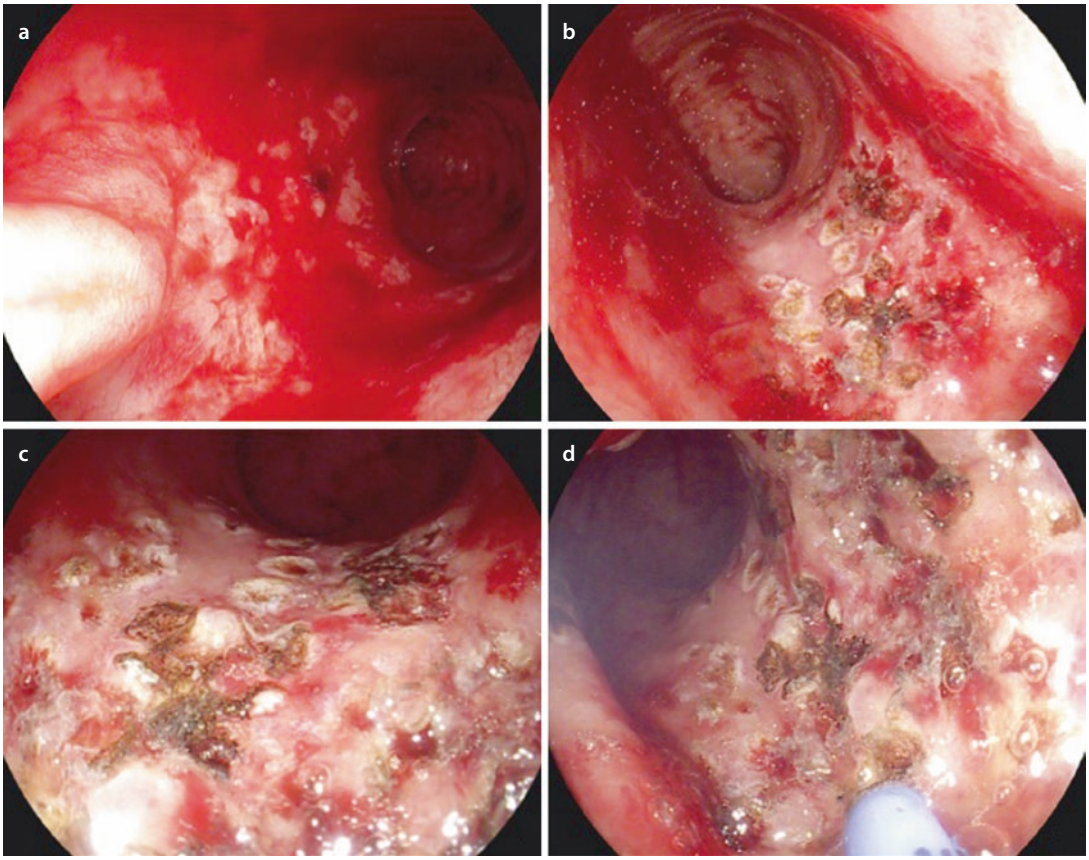

Fig. 3.14 A 72-year-old patient presenting with hematochezia after irradiation of an ovarian cancer. **a–c** Endoscopic finding of broad oozing from multiple rectal and sigmoid erosions. **d** Hematostasis achieved by APC

occurring tissue necroses in the esophagus may be supported by proton pump inhibitors.

3.4 Diffuse Bleedings

The endoscopic therapy of diffuse bleedings from mucosal defects in the gastrointestinal tract is a challenge to the endoscopist. Quite often they are the result of endoscopic mucosa resection or large polypectomies. Ischemic colitis, postirradiation colitis, and tumor bleedings may also contribute to diffuse upper and lower gastrointestinal bleedings (Fig. 3.14).

Here, patients with advanced carcinomas, e.g., of the colon, may develop severe bleedings due to erosions and ulcerations at the tumor surface (Fig. 3.15). So far, the endoscopic possibilities for hemostasis have been limited, since established procedures such as clipping bear an increased risk of perforation and often the tumor surface appears to be too hard. Thermotherapy for hemostasis is an alternative. The biggest potential may be given to the Hemospray, although our positive experience is primarily based on case reports rather than on prospective studies.

▪ Endoscopic Therapies: Thermotherapy for Hemostasis

Diffuse bleedings may be successfully stopped by thermal methods. Here, monopolar and bipolar (BICAP) electrocoagulation, argon plasma coagulation (APC), heat coagulation (heater probe), and laser coagulation are currently available methods (Table 3.8).

Contrary to laser or argon plasma coagulation, which is executed without direct contact to the bleeding site, in electrocoagulation, the mechanical compression of the bleeding vessel is relevant. The coagulation by electric current is only the second step. To reduce the danger of a deeper lesion in the mucosa with subsequent perforation, frequently bipolar electrocoagulation methods are in use today. Here the well-defined flux of the current from one electrode to the other at the tip of the instrument allows for a limitation

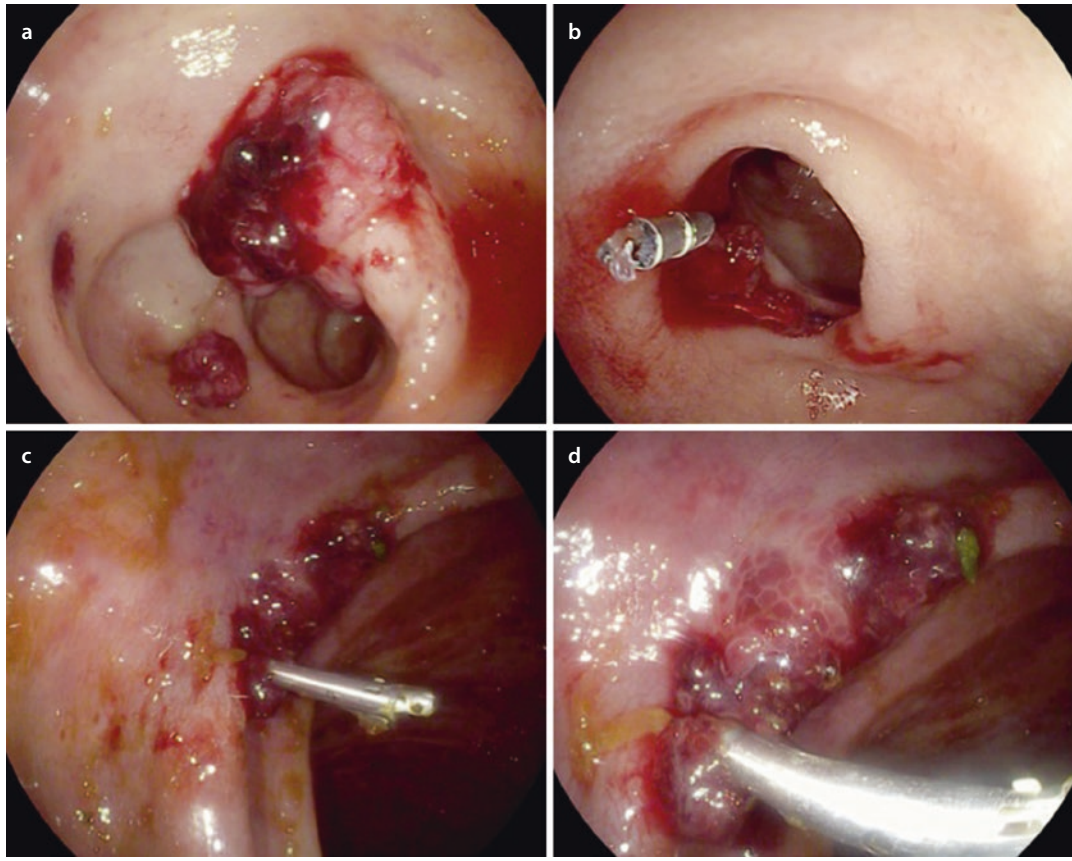

Fig. 3.15 **a–d** Bleeding from a tumor that was treated by application of a single hemoclip

Table 3.8 Different thermic procedures for endoscopic hemostasis

Type of procedure	Function
Electrocoagulation	Heat Coagulation with electricity (mono-/bipolar)
Heater-probe	Coaptive coagulation with high-frequency generator
Laser coagulation	Heat coagulation by energetic lasers
Argon plasma coagulation	Coagulation by ionized argon plasma

of the heated area and the depth of the heating effect. The use of hemostatic powders is comparable to its use in ulcer bleeding (▶ Sect. 3.2).

Indication: Argon Plasma Coagulation (APC)

Argon plasma coagulation was first described in 1994 to control bleeding in gastrointestinal tumors. Further use of this method has since been extended to diffuse superficial mucosal bleedings. Following polypectomy of sessile polyps in piecemeal technique, the application of APC provides a prophylaxis against re-bleeding and might coagulate potential residual polyp tissue. In cases of angiodysplasia, a hemostasis success of 85–100% is described in the literature (Fig. 3.16) (Kwan et al. 2006). The repeated treatment of the GAVE syndrome by APC is able to reduce the need for blood transfusion. The clinical appearance of postradiation proctitis is characterized by telangiectasias and hemorrhagic changes in the mucosa of the rectum. APC may serve here both therapeutically and prophylactically.

Indication: Thermal Contact Coagulation

Heat coagulation by electric current (mono- and bipolar) and coaptive coagulation by means of a high-frequency generator (heater) are in use for stopping acute bleedings. The currently available studies do not show an advantage of one method over the other. In patients with cardiac pacemakers, bipolar coagulation may have the least influence on pacemaker function and should therefore be preferred.

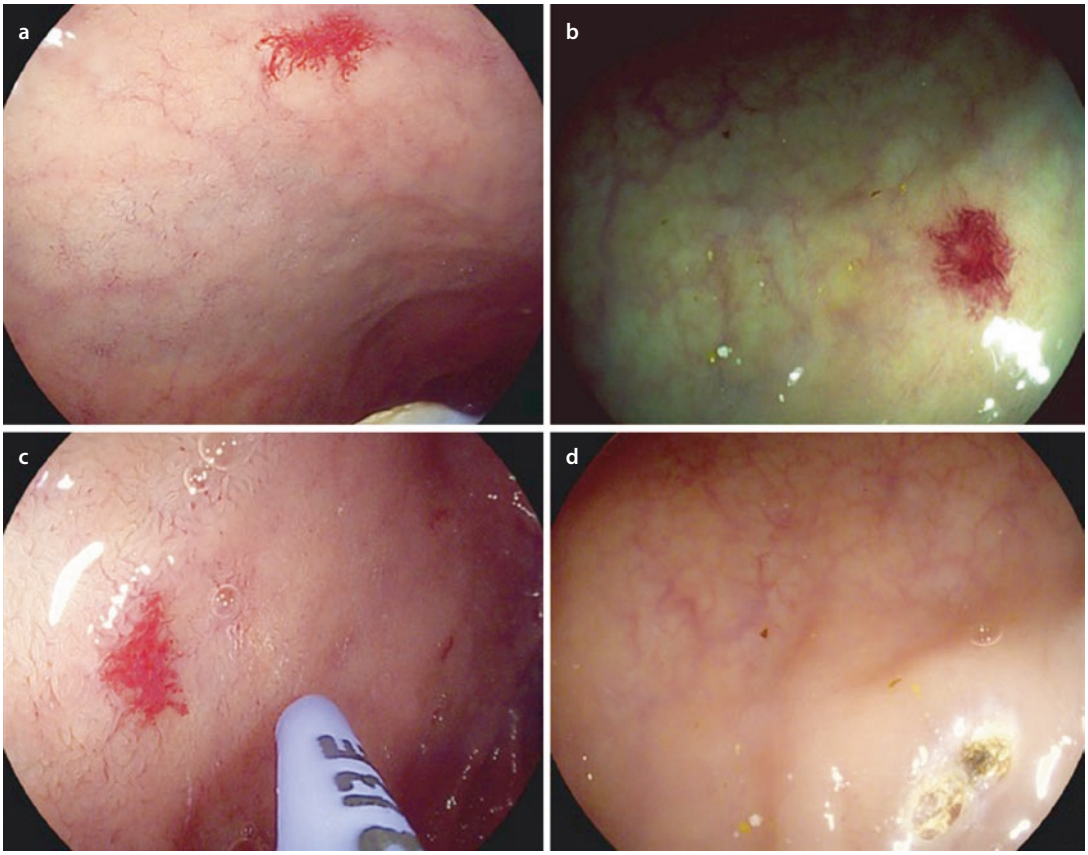

Fig. 3.16 Angioodysplasias are potential sources of gastrointestinal bleeding **a**, **b**. Preventive APC application **c** results in coagulation **d** of the superficial vessel

Personnel Requirements

For the use of all procedures, respecting the recommendations for sedation in endoscopy, next to the investigator, one experienced assistant should be sufficient. Both should be familiar with both preparation and execution of the chosen procedure. Our personal experience indicates that APC and Hemospray in particular are easily manageable after a few applications, provided there was sufficient guidance during the learning phase.

Tip

APC and Hemospray are suitable for inexperienced endoscopists, too, and may be used swiftly and safely.

Organizational Requirements

The organizational requirements are equivalent to those previously described for treatment of variceal and non-variceal bleedings in the gastrointestinal tract.

Instrumentation Requirements: APC

For APC, depending on the localization within the gastrointestinal tract, several sizes of catheters should be at hand. They are available in three different diameters (1.5 mm, 2.3 mm, and 3.2 mm) and two different lengths (220 cm and 300 cm). Following a pre-setting procedure, the further maneuver is steered by a pedal. After starting the instrument, a self-test is usually run automatically. Of course, a sufficient filling status of the argon gas reservoir has to be secured before the examination (► Chap. 2).

Instrumentation Requirements: Thermal Contact Coagulation

For this procedure, a therapeutic endoscope with a large-bore working channel should be used. Alternatively, an endoscope with two working channels serves the same purpose. This allows for simultaneous coagulation and rinsing of the procedural

field. The different probes for a mono- or multipolar electrocautery system (MPEC) or the so-called heat probe have to be at hand, together with the electrosurgical instruments that are typically required. The diameters of the probes are 3.2 mm or 10F. Since thermal contact coagulation procedures are often used in combination with other methods, additionally, hemoclips, loops, injection needles, and diluted adrenaline solution 1:10,000 should lie ready for use.

Practical Execution: Argon Plasma Coagulation

Argon plasma coagulation, in comparison to other thermal methods, is easy to use. Its specific advantage is that the mucosa does not require direct contact to the device. Argon gas is put under high voltage and sprayed onto the mucosa, invading it to a depth of 2–3 mm. As soon as a lesion suitable for APC has been identified, a grounding patch is glued to the thigh of the patient. The catheter for coagulation is then forwarded through the working channel. The generator is started, and a flux rate of the argon gas of 0.8–1 l/min is adjusted. The gas is applied periodically, not continuously. Depending on the extension of the lesion, the magnitude of wattage is chosen. In thinner parts of the gastrointestinal tract, it will range from 20 to 30 W and in thicker areas from 30 to 50 W. The depth of invasion depends both on duration of gas application and on the wattage. Usually the generators have programs in their software which adjust to localization and type of intervention. A visible mark at the end of the APC catheter indicates when the correct position is reached, so as to avoid damage to the endoscope. Successful use is only possible if the distance between catheter tip and mucosa is not more than 1 cm. By repetitive use while varying the catheter position, a calibration by the endoscopist is feasible. As during the whole process, any direct contact to the mucosa must be prevented by all means since this may lead to deep lesions with perforations. The currently available device leaves the choice between three application modalities.

Thermal interventions with too intense punctual coagulation may cause perforations in the gastrointestinal tract.

Practical Execution: Thermal Contact Coagulation

Unlike APC, here a direct contact with pressure on the target area is required. The combination of this direct contact with electric coagulation will affect hemostasis. Frequently, this method is used in combination with injection therapy. This may have the advantage of a more precise coagulation, since adrenaline can achieve hemostasis by itself, thereby clearing the vision for the endoscopist. This effect is similarly desirable in an acute bleeding. Already, pressure onto the bleeding source may reduce the bleeding intensity. The additional coagulation has a higher chance to achieve definite hemostasis. We choose in acute bleedings of average intensity an energy application of 15–20 W over 10 s, repeated 3–5 times. In less severe cases, lower wattage of 10–15 W may be tried first.

When using coaptive coagulation with a high-frequency generator (heat probe), an energy of 20–30 joules is used with similar duration and frequency to that for heat coagulation.

Complications: APC

The APC is a safe method with few complications. When used at the right colon, a perforation risk of 0.2% has to be considered. Further potential complications comprise subcutaneous emphysema and pneumoperitoneum. In one case report, an argon gas explosion triggered a colon perforation.

Complications: Thermal Contact Coagulation

In addition to secondary bleedings caused by the intervention itself, perforations are possible. The complication rate depends on the experience of the endoscopist and the depth of penetration of the thermal procedure. A so-called post-endoscopic submucosal dissection electrocoagulation syndrome (PEECS) is observed if the thermal application reaches down to the muscular and serosal layers without the signs of perforation with fever, muscular defense, and leukocytosis being apparent. In patients with ESD, this complication has been reported in up to 40% of procedures. Risk factors appear to be lesions >3 cm and all localizations outside the rectosigmoid colon.

In the case of combined therapies with adrenaline injections, systemic side effects such as tachycardia and arrhythmia are possible.

3.5 Summary

Today, the treatment of gastrointestinal bleedings is the preferred domain of gastrointestinal endoscopy. Depending on localization, the bleedings

Table 3.9 Type of bleeding and preferred endoscopic hemostatic technique

	Bleeding type	Endoscopic hemostatic technique
Upper GI	Ulcer	Injection, clipping, powder
	Esophageal varices	Ligation, injection, powder (off-label)
	Gastric varices	Injection, powder (off-label)
Lower GI	Diverticula	Injection, powder, thermal, clipping
	Hemorrhoids	Ligation
	Post-polypectomy	Clipping, thermal, powder (off-label)
	Angiodysplasias	Thermal
	Diffuse	Thermal, powder (off-label)

are classified as upper, middle, or lower gastrointestinal bleedings. Further differentiations group the bleedings as peptic, variceal, and diffuse or as tumor bleedings. Several endoscopic hemostatic techniques are available which are often used in combination (Table 3.9). The success rate of endoscopic hemostatic techniques is 80–100%.

Gastrointestinal bleedings are interdisciplinary challenges requiring endoscopic, medical, and intensive care therapies. Knowledge about the total spectrum of available diagnostic and therapeutic procedures is essential to provide a targeted and effective therapy to patients involved.

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ERCP

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Contrast-based endoscopic cholangio- and pancreatography has become possible after the development of side-viewing duodenoscopes in conjunction with methods to cannulate the papilla in the 1970s. This was soon complemented by therapeutic interventions, starting with endoscopic sphincterotomy in 1974 (Classen and Demling 1974). Endoscopic retrograde cholangiopancreatography (ERCP) differs from many other endoscopic procedures, as its intention is usually primarily therapeutic. Diagnostic ERCP has mostly been replaced by less invasive methods such as (endoscopic) ultrasonography, computed tomography, or magnetic resonance tomography/MR cholangiopancreatography (MRCP). In contrast, therapeutic ERCP for treatment of biliary or pancreatic stones and strictures and for palliative therapy of malignant diseases has been growing rapidly.

4.1 General Aspects

4.1.1 Indications for ERCP

ERCP shows a higher rate of complications and a longer learning curve in comparison to other endoscopic techniques. This mandates the conservative use of ERCP (Cotton 2001) and thorough training. The following paragraph only lists indications for therapeutic ERCP. Indications for ERCP should be as specific as possible and aim at interventions in either biliary (ERC) or pancreatic (ERP) ducts. As in all endoscopic interventions, the indication for ERCP should take into account patient-specific factors such as position (prone or supine) and time requirements and sedation considerations in relation to the patient's general state of health. This is especially important in emergency indications (e.g., in septic cholangitis) (Table 4.1).

The overall most common biliary indication is suspected choledocholithiasis, with or without concurrent cholangitis and biliary pancreatitis or prior to planned cholecystectomy. Benign strictures occur in primary or secondary sclerosing cholangitis (PSC, SSC), postoperatively after cholecystectomy or liver transplantation, and can be treated by ERC. Malignant biliary strictures are often treated in a palliative setting. Postoperative or traumatic leakage of the common bile duct (CBD) or intrahepatic bile ducts is amenable to bridging or drainage. In sphincter of Oddi dysfunction (SOD), types I and II [dilated bile duct (I) and/or (II) elevated serum liver tests] respond to sphincterotomy in some patients.

Pancreatic interventions are less frequently required, especially since pancreatic contrast has been associated with a risk of post-ERCP pancreatitis. In chronic pancreatitis, dilatation of pancreatic duct stenosis and extraction of pancreatic stones are sometimes necessary. Some pseudocysts can be drained using a transpapillary «natural way.» Postoperative or traumatic pancreatic duct

Table 4.1 Indications for therapeutic ERCP

Biliary interventions	**Therapeutic intention**
Choledocholithiasis	Stone extraction Lithotripsy Restoration of biliary drainage
Cholestasis	Restoration of biliary drainage
Biliary pancreatitis	Stone extraction
Cholangitis	Restoration of biliary drainage
Stenosis	Dilatation Bougienage Stenting
Leakage	Stenting Sphincterotomy/lowering of transsphincteric pressure gradient
Bile duct tumor	Restoration of biliary drainage Photodynamic therapy Radiofrequency ablation
SOD	Sphincterotomy
Pancreatic interventions	**Therapeutic intention**
Pancreas divisum	Lowering of transsphincteric pressure gradient/ minor sphincterotomy
Chronic pancreatitis	Dilatation Bougienage Stone extraction Pseudocyst drainage
Leakage	Stenting Sphincterotomy/lowering of transsphincteric pressure gradient
Intraductal tumors	Drainage

disruption can be treated in a multidisciplinary setting by endoscopic drainage.

Contraindications to ERCP are similar to other endoscopic interventions and pose relative contraindications in most patients. Careful weighing of the odds–risk ratio is mandatory, and written informed consent must be obtained in all cases.

4.1.2 Informed Consent, Adverse Events, and Prophylaxis

Adverse events are intrinsic to therapeutic endoscopy, and ERCP carries a specifically high risk relative to other endoscopic interventions. For consent, patients should be specifically informed about pancreatitis, bleeding, cholangitis, and perforation in addition to the general risks of therapeutic endoscopy.

Post-ERCP Pancreatitis

Post-ERCP pancreatitis (PEP) is the most frequent complication of ERCP (Dumonceau et al. 2010). It affects approximately 3.5% of patients after ERCP. Usually, its severity is mild to moderate (90% of patients), but PEP can be severe and on rare occasions lethal (Andriulli et al. 2007). The definition of PEP has not been entirely consistent throughout the literature. Most authors use new-onset or intensified abdominal tenderness after ERCP and rise of amylase to 3× upper limit of normal (ULN) (Anderson et al. 2012). The severity of pancreatitis is often graded according to the length of in-hospital stay (mild up to 3 days, moderate 4–10 days, severe >10 days, necroses, pseudocysts). A transient rise in serum amylase is often seen after ERCP, but this does not mandate intervention without clinical signs of pancreatitis.

Patient- and examiner-dependent variables confer risk factors for PEP (◘ Table 4.2). Multiple risk factors are synergistic and must be appreciated when indicating ERCP.

Tip

The following measures help to reduce the PEP rate:

1. Strict patient selection: given the relatively high risks associated with ERCP, ERCP should be restricted to patients with a high probability of need of intervention. Diagnostic ERCP should be replaced by less invasive imaging, wherever possible.
2. PEP prophylaxis: rectal NSAIDS (diclofenac 100 mg or indomethacin 100 mg before, at, or immediately after ERCP has been shown to reduce the PEP risk (Elmunzer et al. 2012). IV ringer lactate during ERCP may be protective (Buxbaum et al. 2014)).
3. Modification of cannulation technique: the PEP risk can be reduced by fewer attempts at the papilla and guide wire-assisted deep cannulation (Tse et al. 2012). If contrast is injected into the pancreatic duct, the volume should be kept at a minimum. Prophylactic pancreatic stenting (e.g., 5 French) is protective especially in high-risk patients and after repeated contrast injection into the duct of Wirsung and helps to straighten the papilla for subsequent deep biliary cannulation (Mazaki et al. 2013). Five to ten days after insertion, spontaneous passage should be ascertained or the stent be removed.

◘ **Table 4.2** Risk factors for post-ERCP pancreatitis

Patient-related risk factors	
Definite	*Probable*
(Suspected) SOD	Young age
Female sex	Normal serum bilirubin
Prior pancreatitis	Non-dilated bile ducts
	Lack of chronic pancreatitis
Examiner-related risk factors	
Definite	*Probable*
Precut sphincterotomy	Difficult biliary cannulation
Pancreatic duct injection	Pancreatic sphincterotomy
Ampullectomy	Biliary sphincter balloon dilatation
	Incomplete clearance of biliary stones

Modified from Dumonceau et al. (2010)

Cholangitis

The risk of ERCP-associated cholangitis is about 1–3% (Rosien et al. 2011). In unselected patients, the rate of infectious complications is not reduced by prophylactic peri-interventional administration of antibiotics. Therefore, routine administration is not recommended. However, prophylactic antimicrobial therapy should be given after potentially incomplete drainage of contrasted bile ducts or in immunocompromised patients. Typical indications are ERC in PSC, Caroli's syndrome, and cholangiocellular carcinoma involving segmental or multiple branches, in patients after liver transplantation (◘ Table 4.3). Antibiotic therapy can be administered before, during, or shortly after ERCP or can be continued according to calculated prior therapy. Such high-risk patients benefit from conservative contrast injection; complete cholangiography of intrahepatic ducts or use of forced contrast with balloon occlusion may not be advisable. Re-aspiration of contrast may also be helpful in this setting. Cholangioscopy, photodynamic therapy, intrabiliary radiofrequency ablation, or PTCD also carries an increased risk of septic complication and should trigger antibiotic prophylaxis.

Bleeding

ERCP-associated hemorrhage occurs in about 1% of patients and depends on the type of intervention and potential coagulation disorders. Mild bleeding after sphincterotomy is not uncommon and usually self-limiting and otherwise can be compressed by biliary stent insertion. Careful coagulation of the bleeding site can be performed during EST; sometimes spraying of (ice cold) adrenalin suspension is used. Diminutive bleedings can be treated after finishing the biliary intervention. If visualization is severely impaired by more severe bleeding, immediate therapy is advocated. Balloon compression can be helpful to localize the exact bleeding site. When injecting higher volumes of NaCl or placing clips for hemostasis, subtle care must be taken to not compromise drainage of the biliary and pancreatic system. Here, stenting is advised in most cases. Delayed bleeding can be seen up to 14 days after EST and often requires re-intervention.

Perforation

Perforation is a rare complication (0.1–0.5%) and may occur in three different settings: most frequently, the perforation is a consequence of an overly wide sphincterotomy. The perforation site is often visible, and/or contrast or air leakage can be identified fluoroscopically. Usually this requires termination of ERCP after insertion of a biliary drainage. In delayed perforation, the perforation site is smaller and toward the retroperitoneum. Therefore, usually there is no free air found on

◘ **Table 4.3** Indications for peri-interventional antibiotic prophylaxis in correlation to patient- and intervention-associated risk

Patient: indication for ERCP	Aim of prophylaxis	Prophylaxis recommended?
Biliary obstruction/intervention, no concurrent cholangitis	Prevent cholangitis	
Complete drainage		Not recommended
Incomplete drainige		Recommended (single shot)
Cholangitis	Prevent bacteremia/sepsis	Calculated/targeted therapy
Biliary complications after liver transplantation	Prevent cholangitis	Recommended (single shot)
Biliary intervention with increased risk for infection	Prevent cholangitis	Recommended (single shot)
Communicating/sterile pancreatic cysts or necrosis (aspiration, drainage)	Prevent (pseudo-)cyst infection	Recommended (single shot)
Immunocompromised patients	Prevent bacteremia	Recommended (single shot)

Modified from Rosien et al. (2011)

plain abdominal X-ray, and CT is required for diagnosis. Symptoms include postinterventional abdominal pain, often without a rise in amylase levels. Conservative therapy with broad spectrum antimicrobial therapy and nil per os is sufficient in over 90% of patients. Less frequently, perforation is a consequence of the intervention within the bile duct or forced wire manipulation. If recognized during the intervention, it should be treated by stenting. Perforation by the endoscope often occurs distant from the papilla. Risk factors include ERC in a postoperative situs such as Billroth II or Roux-en-Y anatomy. Some endoscopy units therefore perform (forward-viewing) EGD prior to the first in-house ERCP for identification of altered anatomy or for differential diagnosis (e.g., ulcers in abdominal pain).

Other Complications

Cardiopulmonary complications are rare. However, longer intervention times, deeper sedation, and (prone) position should be taken into account for patients at risk. Ambient air should not be insufflated into the bile ducts, since lethal pulmonary air embolism has been reported.

4.1.3 General Setting

Minimal requirements as to blood coagulation parameters correspond to those for other endoscopic interventions (cf. Appendix). In addition, bilirubin and other serum liver tests are indicative of the functional relevance of potential findings during ERC, and CRP and leucocytes help to determine the urgency to intervene.

Fluoroscopy is a central requirement for ERCP. The authors prefer side-inverted imaging, i.e., the patient's right side is left on the screen, such as in conventional abdominal X-ray. Radiation protection is key, especially in repeated interventions and in younger patients/children. This includes optimal collimation and magnification of the region of interest (rule of thumb: aperture covers should be seen on all four sides of the image), pulsed rather than continuous fluoroscopy, and storage of fluoroscopy images with last-image hold function rather than full X-ray images, as well as age- and weight-adapted fluoroscopy and filter settings.

Staff requirements have to cover the enhanced need for instrumentation assistance and longer and deeper sedation. Therefore, in addition to the endoscopist, at least one more assistant is needed for instrumentation and one dedicated person for sedation. Well-trained cooperation with the assistant is essential for rapid and successful intervention. The patient can be in prone or supine position. The authors prefer prone position, as it facilitates access toward the papilla and stable position of the duodenoscope. Supine position may be advisable in cardiorespiratory or septic patients (potentially demanding rapid cardiopulmonary support), during general anesthesia, in spinal diseases, and early after abdominal surgery. The use of CO2 for insufflation (if not standard for all endoscopies) is recommended for longer interventions as it helps to reduce postinterventional bloating and abdominal pain, thereby facilitating differentiation from initial PEP.

A history of allergy to contrast agents usually does not mandate specific precautions, as the small intraluminal amounts of contrast agents usually do not trigger systemic allergic reactions. In a history of allergy even after intraductal contrast application, the use of low contrast volumes or 1:1 mixture with sterile NaCl, i.v. prednisolone (e.g., 100 mg), or dimetindene (e.g., 4 mg) may be considered.

If ERCP is performed in an emergency setting and/or outside regular office hours, the personnel may be less familiar with the specific requirements for ERCP. This increases the risk of failure and complications associated with ERCP. Usually, emergency ERCP cannot be performed in intensive care unit, since the use of mobile fluoroscopy devices limits performance outside the endoscopy suite (other than in emergency gastroscopy or colonoscopy). Therefore, postponing ERCP until the next morning or regular endoscopy hours is encouraged, whenever possible. In addition, intervention times should be limited in severely ill patients, such as in septic cholangitis. Here, a rapid first intervention to secure biliary drainage is recommended, and completion of diagnosis and therapy ensues as soon as the patient's clinical situation is sufficiently stable.

4.1.4 ERCP in Selected Patients

Postoperative modification of the anatomy such as after Billroth II resection or Roux-en-Y anastomosis can pose a significant challenge to accessing the biliary system (Fig. 4.1).

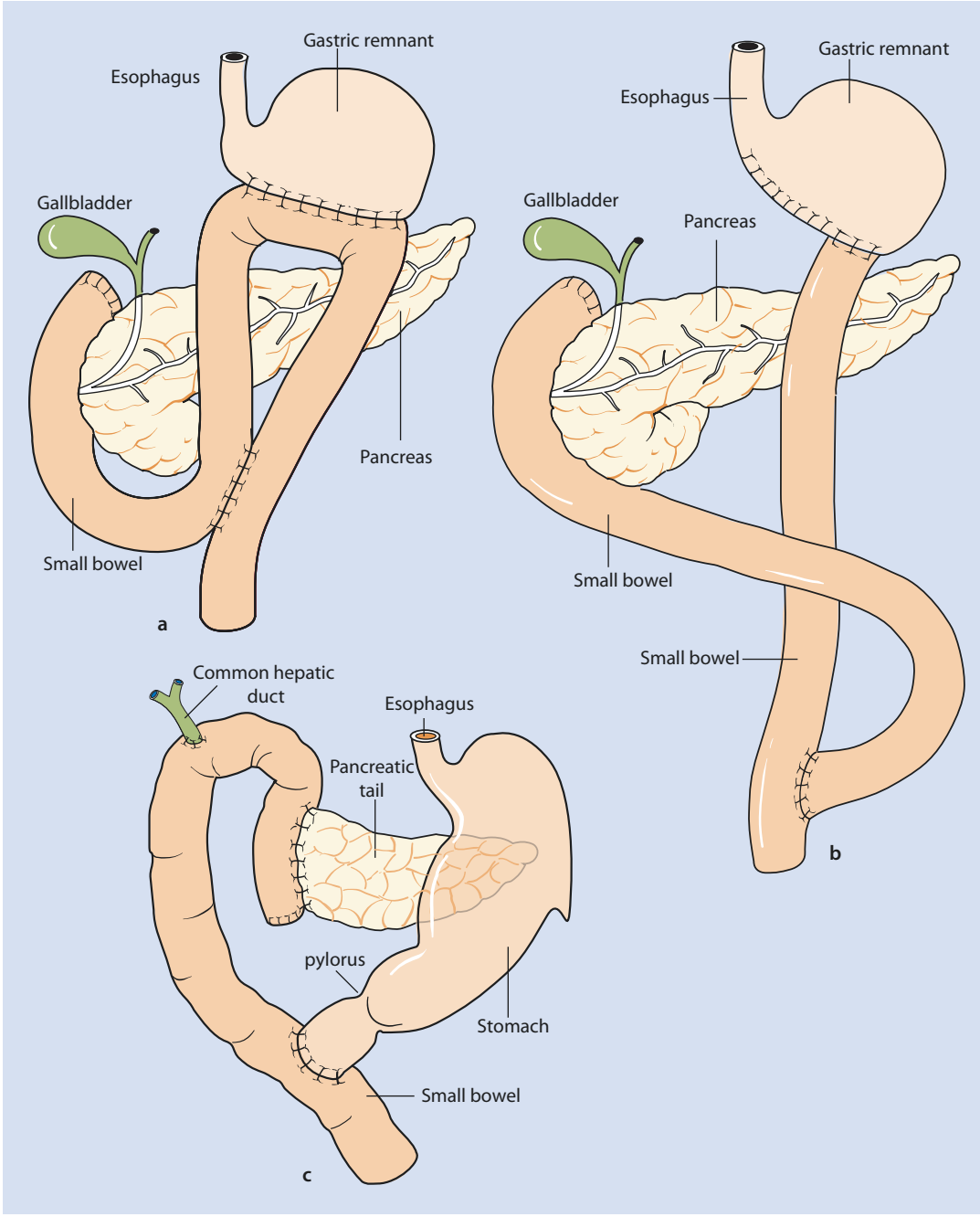


Fig. 4.1 Postoperative anatomy after Billroth II resection **a**, Roux-en-Y anastomosis **b**, and pylorus-preserving Whipple's resection **c**

Tip

In such patients, initial endoscopy with a forward-viewing colonoscope with a large working channel (minimum 3.2 mm, preferably 3.8 mm) is recommended. This facilitates navigation toward the papilla/biliodigestive anastomosis, and the forward orientation of the working channel often corresponds to the intubation angle into the biliary system. In cases where a duodenoscope with an Albarran lever is preferred, endoscopes can be exchanged over a stiff guide wire.

Alternatively, balloon-guided enteroscopy can be used to access the biliodigestive anastomosis, although the postoperative situs can be challenging.

The use of a colonoscope allows utilization of most conventional ERCP accessories. For balloon-enteroscopy-guided ERCP, a specific instrumentarium is available that fits through the longer and smaller working channel. This may limit the ad hoc options for intervention, depending on local availability. In addition, stabilization and navigation in front of the papilla are limited. In patients with altered anatomy after Billroth II resection or Roux-en-Y anastomosis, the papilla is accessed from retrograde, i.e., in 180° rotation. For sphincterotomy in BII patients, if no dedicated Billroth sphincterotomes (with 180°-rotated cutting wire position) are available, needle-knife sphincterotomy over a pancreatic stent is recommended. After biliodigestive anastomosis, dilatation of the orifice is advisable (Fig. 4.2). After bariatric surgery, enteroenterostomy can be quite distally hampering access toward the papilla.

ERCP in infants and children poses specific challenges and is usually limited to selected tertiary care centers. Choice of endoscopes must be tailored according to age and body weight. Specific pediatric duodenoscopes are available (Fig. 4.3) but require specific accessories

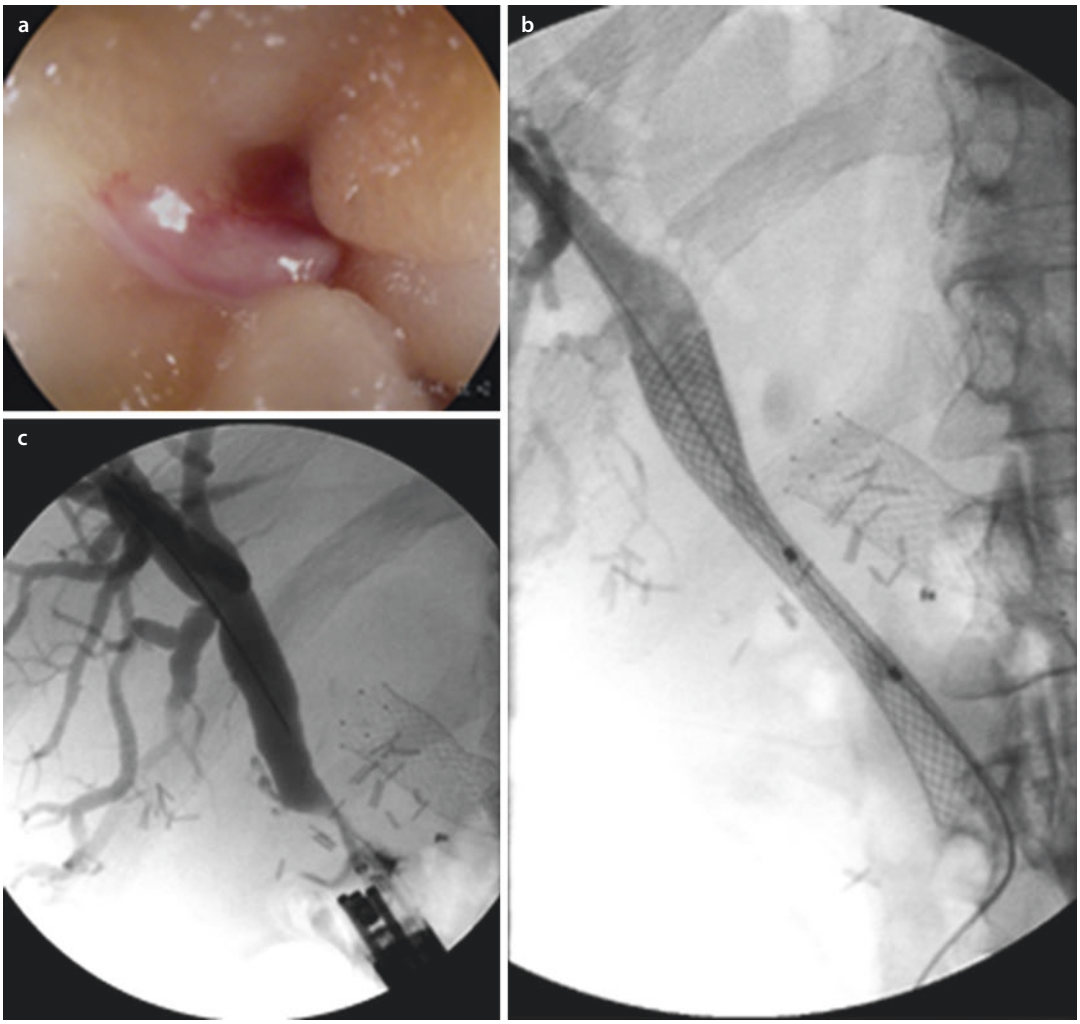


Fig. 4.2 Biliodigestive anastomosis after hemihepatectomy for cholangiocellular carcinoma (cf. surgical clips and portal vein stent) with recurrent tumor manifestation and stenosis of the BDA **a** and distal bile duct **b**. In panel **b**, the tip of the colonoscope and the orientation for intubation (in the longitudinal colonoscope axis, using a balloon catheter) can be seen. A self-expanding metal stent is placed via the 3.8-mm colonoscope working channel, bridging the bile duct and BDA stenosis

Fig. 4.3 Duodenoscopes with outer diameters ranging from 13.7 to 7.5 mm (from *left* to *right*, pediatric duodenoscope with 2-mm working channel)

adapted to the limited working channel size. Usually, general anesthesia is used for pediatric ERCP.

ERCP is not frequently requested during pregnancy in terms of absolute numbers, but hormonal changes predispose to biliary stones. Larger trials are not available, but case series report ERCP during pregnancy (Chan and Enns 2012). Exposure of the fetus to radiation is the major concern. Although no adverse events have been reported, exposure especially in the first trimester should be avoided whenever possible. Apart from minimization of fluoroscopy times and maximized collimation, lead shields under/on the mother's lower abdomen help to minimize direct (but not indirect, scattered) radiation exposure of the fetus. The indication for ERCP can be consolidated by preinterventional EUS or MRCP. Radiation-free ERCP with visualization of deep cannulation and guide wire position by transabdominal ultrasound or with cholangioscopy has been reported in small case series.

4.2 Endoscopic Sphincterotomy: Primary Cannulation of the Papilla

Indications

As explained before, post-ERCP pancreatitis (PEP) is the most common complication from ERCP (Dumonceau et al. 2010). Cannulation of the native papilla is a strong risk factor for PEP. Both papillary edema after recurrent contacts with the papilla and unintended contrast injection into the pancreatic duct may result in an increased pressure gradient across the papilla, associated with the risk for parenchymal injury to the pancreas. PEP can pose a severe and potentially lethal complication and mandates a thorough benefit–risk assessment in ERCP indication.

Tip

Given the PEP risk, purely diagnostic ERCP is generally discouraged. Alternative imaging modalities such as EUS or MRCP are associated with significantly lower adverse event rates.

For this reason, a first ERCP in a patient with native papilla is usually planned as a therapeutic intervention (such as biliary stone removal, recanalization of stenoses, etc.) which usually requires prior sphincterotomy. ERCP in a patient with native papilla therefore usually includes indication for sphincterotomy. Sphincterotomy facilitates access into the respective ducts and enables stent insertion or stone extraction. Biliary stenting without sphincterotomy is only rarely indicated, such as in septic cholangitis (to shorten intervention times) or in patients with impaired coagulation. Some endoscopists refrain from biliary sphincterotomy in favor of insertion of a self-expanding metal stent.

Cannulation of the Native Papilla

Initial ERCP in a patient with native papilla usually requires sphincterotomy, as specified above. For deep cannulation we therefore start with a sphincterotome. Such a proceeding saves time and facilitates cannulation by making use of the bending properties of the sphincterotome. Guide wire-assisted deep cannulation of the bile duct is superior to contrast-guided cannulation with regard to both higher cannulation success and lower PEP rate and is especially recommended early in ERCP training. The ease of cannulation cannot be reliably predicted beforehand. Predictors of «easier cannulation» may be separated biliary and pancreatic orifices or macerated papillas after stone passage. Predictors of «difficult cannulation» may be papillas in diverticula or small or hard-to-identify papillas (in tumor in growth or in chronic pancreatitis) (Fig. 4.4).

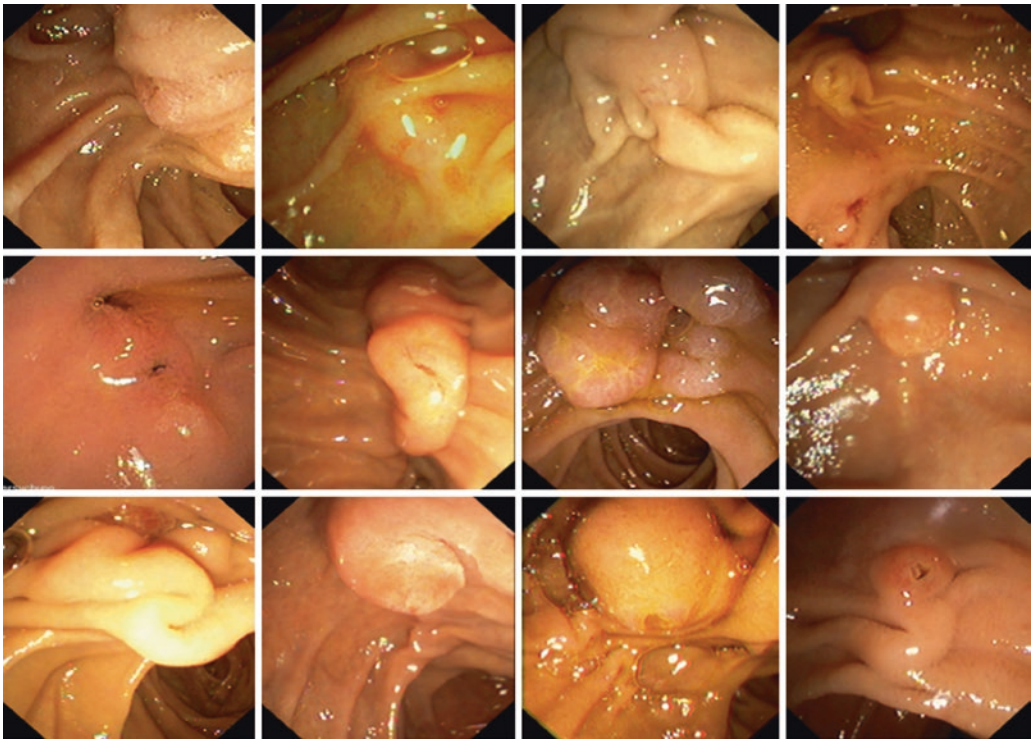


Fig. 4.4 Not all papillas are equal!

Guide wire-assisted cannulation of different types of native papillas can be facilitated in several ways:

Tip

- Cannulation with a standard sphincterotome loaded with a soft hydrophilic guide wire (tip).
- Insertion of the sphincterotome tip into the orifice for 2 mm and careful wire advancement (normal papilla).
- Insertion of the sphincterotome into the orifice over 3–5 mm and careful wire advancement (large/mobile papilla).
- The tip of the guide wire protrudes for about 1–2 mm from the cannula tip and is used for intubation of the orifice. The sphincterotome is used only to direct the wire (small papilla).

For biliary cannulation, the wire/sphincterotome should be inserted at the upper margin of the orifice. By flexing the sphincterotome, the angle of intended intubation (vs axis of the endoscope) should be adjusted to about 45–60°. Cannulation should be oriented toward 11 o'clock (this will also be the orientation of ensuing sphincterotomy). Fine-tuning can be achieved by subtle torquation of the duodenoscope or change in the access orientation with the small wheel. Since the intramural part of the CBD can be siphon-shaped, careful traction on the sphincterotome or slight withdrawal of the duodenoscope can be used to straighten the distal aspect of the CBD. Intubation of the duct of Wirsung has to follow a different (larger) angle and orientation of the cannulation of the orifice toward the 3 o'clock position (Fig. 4.5).

Cannulation of the minor papilla is more challenging in most patients, given the less stable duodenoscope position after slight withdrawal (Fig. 4.6a). Intubation of the tiny papilla is often facilitated by using a small-caliber wire (e.g., 0.018″) and/or dedicated minor cannulation catheters.

Biliary cannulation in surgically altered anatomy may be challenging. After Roux-en-Y or BII resection, only retrograde access toward the papilla can be achieved. The direction for which biliary cannulation follows is rather plane angle

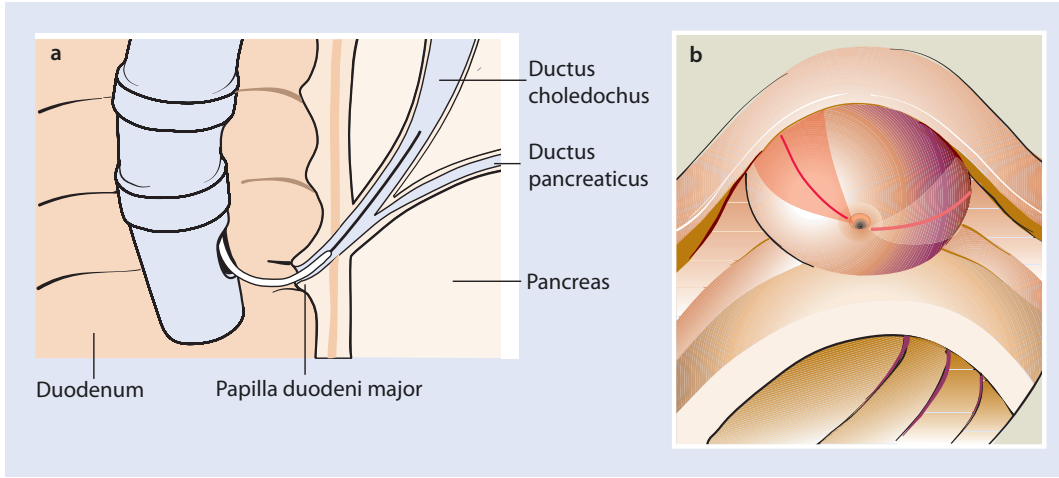


Fig. 4.5 **a** Anatomy of the biliary and pancreatic duct seen (ventro-dorsal view). **b** Papillary anatomy as seen from the duodenoscope, with orientation of biliary sphincterotomy (11 o'clock) and pancreatic sphincterotomy (2–3 o'clock)

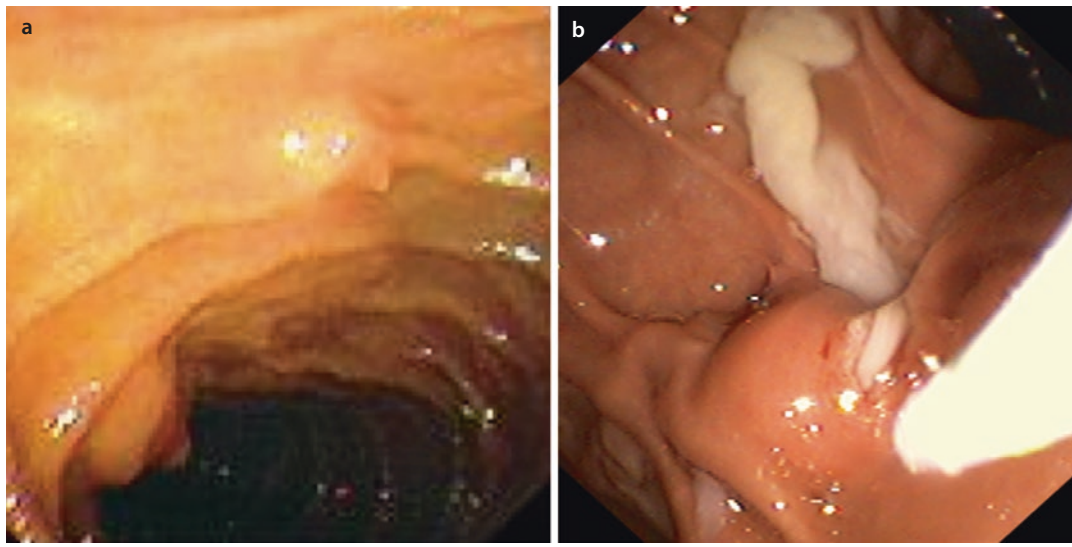


Fig. 4.6 **a** Minor papilla identified as a small elevation 2–3 cm above the major papilla (*left*) closer to the duodenal bulb. **b** Retrograde access to the major papilla in BII anatomy using a pediatric colonoscope (emergency ERC with cholangitis and pus draining from the papilla)

(instead of 45–60° in unaltered anatomy). Therefore, a standard sphincterotome will not be oriented correctly, and «inverted» Billroth II sphincterotomes may be used. Correct orientation for cannulation is sometimes achieved more easily with forward-viewing endoscopes (such as single-/double-balloon enteroscopes, pediatric colonoscopes) than with duodenoscopes.

Cannulation of a native papilla is sometimes hard to achieve. In such cases, precut sphincterotomy is sometimes required. Precut sphincterotomy implies a small cut (initially about 2–5 mm) close to the papillary orifice for unroofing the biliary sphincter. Precut is performed in the 11 o'clock direction. Precut sphincterotomy can be performed with a needle knife or a precut sphincterotome. Fistulotomy (direct cut cranially of the orifice in a typical biliary orientation) is rarely required (impacted stone). If the guide wire repeatedly intubates the pancreatic duct, transpancreatic biliary sphincterotomy can be performed from the pancreatic orifice in the

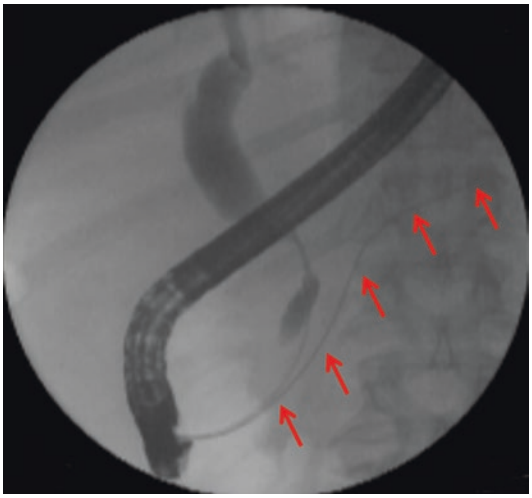


Fig. 4.7 ERCP in obstructive jaundice in pancreatic head cancer. Biliary cannulation and contrast were only achieved in double-wire technique alongside the pancreatic wire (*arrows*) after precut (pancreatic guide wire-assisted biliary cannulation)

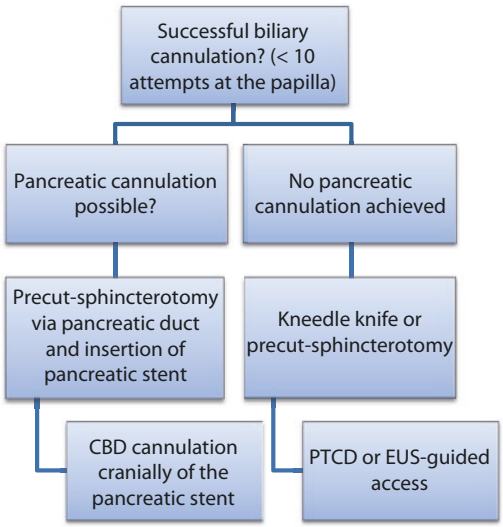


Fig. 4.8 Algorithm for biliary cannulation

direction of the biliary duct. The wire can then be left in place to insert a pancreatic stent (serves also as PEP prophylaxis), and the pancreatic stent can be used to guide biliary cannulation (Figs. 4.7 and 4.8).

If cannulation cannot be achieved with these techniques, PTCD- or EUS-guided drainage can be performed. However, in some cases repeated ERCP after 2–3 days can be successful if papillary edema after multiple attempts at the papilla precluded cannulation. An exchange of the endoscopist may also lead to success. Overeagerness and enforced attempts at the papilla can potentially put the patient at higher risk than abrogation of the ERCP, if immediate biliary access is not mandatory.

Sphincterotomy Technique and Complications

Different sphincterotomes are available. The choice of the specific sphincterotome depends on personal preference and familiarity of the endoscopist and the assistant with the accessories.

The same holds most probably true for the current and coagulation settings for sphincterotomy. Some endoscopists propagate a stronger current for cutting to avoid thermal injury to the papilla and pancreatic orifice from coagulation with potential reduction of PEP risk. However, there is no strong evidence in support of this approach. In our own experience, mixed current (endo-cut mode) does not result in higher PEP rates than pure cutting current, whereas in the latter, a higher risk for bleeding must be taken into account.

In case of mild but persistent bleeding after sphincterotomy, injection of a few milliliters of adrenalin/saline (1:10,000) is usually sufficient. In strong and/or arterial bleeding or in cases of overt perforation, rapid insertion of a plastic or fully covered metal stent is recommended to compress the bleeding site (impaired visualization by clot formation) and/or seal the perforation site while maintaining biliary drainage. Clipping for hemostasis can be performed. However, navigation options and release of the clip through the bending of duodenoscope and lever are limited. In the «naked clip technique,» the plastic sheath of the clip is removed to reduce the resistance in the working channel in order to facilitate navigation and clip release.

Balloon dilatation of the papilla is an alternative to sphincterotomy in selected patients. Balloon sphincteroplasty has been proposed predominantly in Korean trials for extraction of large biliary stones (>15 mm) with fewer complications. The rationale for this approach is the potentially lower bleeding (and perforation) rate for extraction of larger stones as compared to wide sphincterotomy. A high level of expertise is needed for this technique, and a higher PEP risk has been reported, and subsequent pancreatic stenting has been recommended.

4.3 Stone Extraction and Lithotripsy

Indication and Urgency of the Intervention

Up to 20% of patients with cholecystolithiasis demonstrate episodes of intraductal stones. Clinical manifestation of choledocholithiasis comprises biliary colic, jaundice, cholangitis, or pancreatitis. Asymptomatic choledocholithiasis is rare, but smaller stones (<10 mm) may pass spontaneously. The main function of ERC is restoration of biliary drainage. This is usually obtained by complete stone clearance. Macroscopically, black and hard pigment stones can be differentiated from softer, yellowish cholesterol stones (Figs. 4.9 and 4.10). Pancreatic stones are usually whitish (calcium carbonate); biliary casts are dark with a rubber-like texture (Fig. 4.19). Differentiation of stone types does impact on immediate technical management.

ERC is the gold standard for diagnosis of choledocholithiasis. Air bubbles injected with the contrast can be mistaken for biliary stones. Vice versa, smaller stones can be hardly visible after contrast filling especially in severely dilated ducts or can hide behind the endoscope projection onto the CBD. Therefore, we usually use balloon sweeping in cases of high clinical suspicion for choledocholithiasis, even if no stones are visible on fluoroscopy after contrast injection. Intrahepatic stones can be found after retrograde migration or primarily be formed within the intrahepatic ducts. This should prompt investigation for intrahepatic stenoses (e.g., in sclerosing cholangitis), familial syndromes (e.g., progressive familial intrahepatic cholestasis), or recurrent bacterial infection (e.g., recurrent pyogenic cholangitis in Southeast Asia).

Clinical symptoms guide the urgency for endoscopic intervention in choledocholithiasis. In colicky pain, stone removal rapidly results in improvement and can be supported by medical therapy. In cholangitis, rapid restoration of biliary drainage should be intended to avert overt sepsis which is often accompanied by only mild clinical prodromi. If the patient responds to antimicrobial therapy, early elective ERC (<72 h) can be performed, whereas in patients with cholangiogenic sepsis or without response to antimicrobial therapy, emergency ERC is required. In patients with sepsis or impaired coagulation status, rapid biliary drainage can be achieved by placing a plastic stent across the obstruction in order to minimize examination times and to be able to postpone sphincterotomy. However, permanent stent drainage is inferior to complete stone removal and should only be considered in special situations (such as very frail patients,

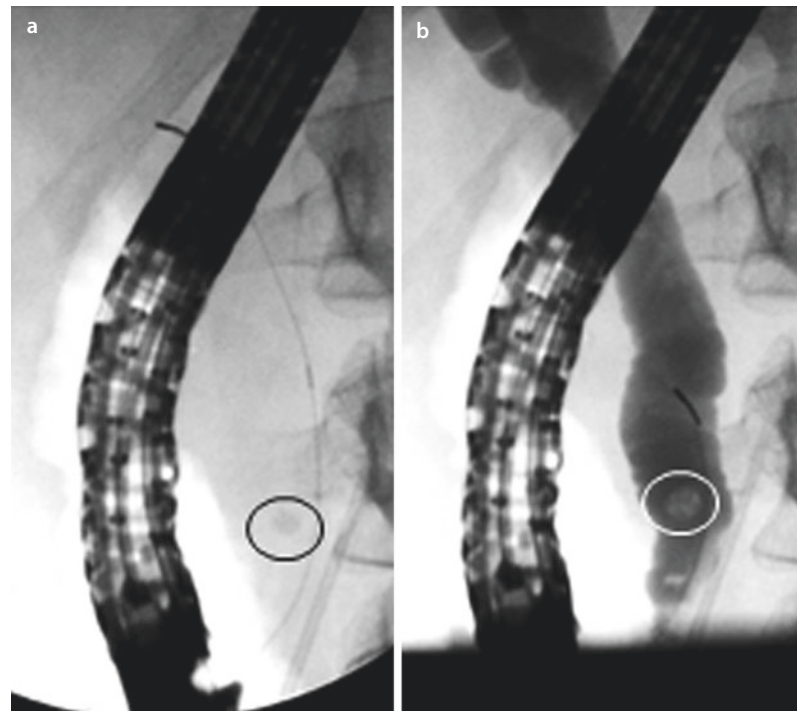


Fig. 4.9 **a** Fluoroscopy shows a calcified biliary stone in projection onto the distal CBD. A 5-Fr pancreatic stent had been inserted previously. **b** After deep cannulation, contrast injection results in a negative silhouette of the stone

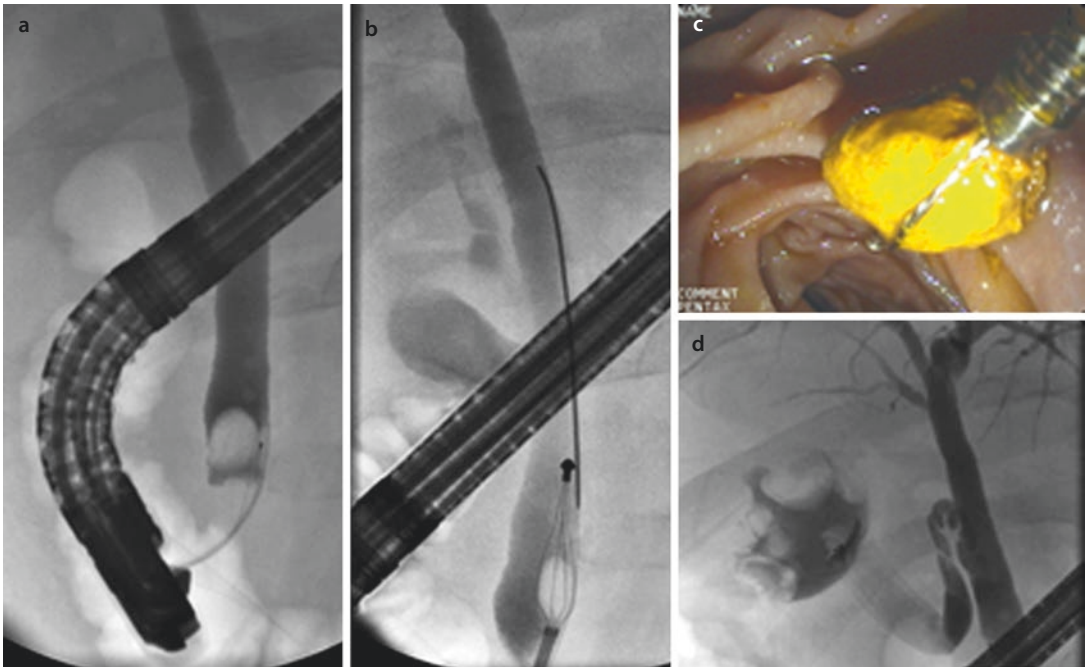


Fig. 4.10 **a** Contrast injection after deep cannulation with the sphincterotome demonstrates two distal CBD stones. **b**, **c** The stones are successively extracted with a basket. **d** Gallbladder contrast shows cholecystolithiasis with multiple stones. The cystic duct entry is well demarcated in the mid-CBD

significant comorbidities) (Chopra et al. 1996). Increased morbidity and mortality rates after permanent stenting in this situation are a consequence of higher infection rates. In asymptomatic choledocholithiasis, ERC is usually recommended, given the high risk of potential complications (which significantly outweighs ERC-associated adverse events). Cholecystectomy is recommended within 2 weeks after stone removal to avoid further stone passages.

Biliary pancreatitis is usually a consequence of (intermittent) obstruction of the pancreatic orifice by the biliary stone. ERC is safe in patients with acute pancreatitis and reduces the rate of subsequent complication. ERCP is recommended within 72 h after admission (Neoptolemos et al. 1988). Contrast injection into the pancreatic duct in acute pancreatitis does not change immediate management in most patients and is discouraged.

The clinical significance of pancreatic duct stones is less clear. Pancreatic concrements are usually found in the context of chronic pancreatitis. They are often associated with fibrous strictures of the main pancreatic duct and require a combination of dilatation and stone extraction. In analogy to choledocholithiasis, restoration of pancreatic duct drainage may follow stone extraction. Such an approach results in amelioration of pancreatic pain in about 50% of patients, especially if a true obstruction is found and treated. However, surgical pancreaticojejunostomy is superior in the long-term prognosis, if significant acute inflammatory changes are absent (Cahen et al. 2007). Therefore, we usually recommend endoscopic intervention as a first step due to its lesser invasiveness but proceed to surgical management in the absence of permanent pain relief.

Technique

Sometimes, calcified stones can be seen on plain fluoroscopy (Fig. 4.9), as can be calcification in chronic pancreatitis. Even if smaller biliary stones can technically be extracted without prior sphincterotomy, enlargement of the biliary access is a standard procedure prior to stone extraction. This is usually achieved by sphincterotomy, less frequently with primary papillary balloon dilatation or balloon dilatation following a (small) initial sphincterotomy.

Stone Extraction

CBD stones can be removed using balloon catheters or baskets of different sizes. Both can be used wire-guided, which facilitates multiple sweeping procedures and repeated cannulation of an edematous papilla.

4

Tip

Push in the duodenoscope in order to align the extraction force with the course of the CBD (Fig. 4.11). This may seem counterintuitive in the early training phase of ERC.

In multiple stones, extraction is started with the most distal stone. Complete contrast of the gallbladder is not required.

Visualization of the cystic duct entry site is helpful for subsequent cholecystectomy.

Balloon Catheters

Balloon catheters are useful for extraction of multiple small stones, of biliary sludge, or of soft stones (Fig. 4.12). Most experts prefer triple-lumen balloon catheters, which allow contrast injection alongside wire insertion and inflation, to double-lumen balloons. If wire guidance is needed, a third lumen facilitates repeated contrast injection after sphincterotomy and stone localization. The balloon tip is advanced beyond the stone taking care not to push the stone across the hilus. Balloon size and insufflation grade are tailored to the bile duct diameter. Overinflation can result in bile duct perforation and in bleeding from the sphincterotomy site after forced sweeping across the papilla, mandating partial desufflation in some patients. On the other hand, too little insufflation may result in insufficient stone clearance. In dilated or siphon-shaped distal CBDs, traction on the balloon may force the stone sideways against the bile duct wall rather than across the papilla. Exchange for a basket is helpful in such cases. In contrast to a stone extraction basket (see below), a balloon catheter cannot be impacted within the bile duct.

Stone Extraction Baskets

Baskets are recommended for larger, harder, or piston-shaped stones or in potential mechanical lithotripsy. Baskets are available in different shapes and sizes (Fig. 4.13) and usually consist of four wires opening in a diamond shape. Rotatable and hexagonally shaped baskets are supposed to facilitate trapping the stone. The wire guidance can exit from the tip of the basket or sideways from the tip of the plastic sheath. Basket tip guidance facilitates papillary intubation and targeted intubation of smaller bile ducts but may interfere with trapping of the stone in the wire meshes (the wire runs centrally inside the «diamond»).

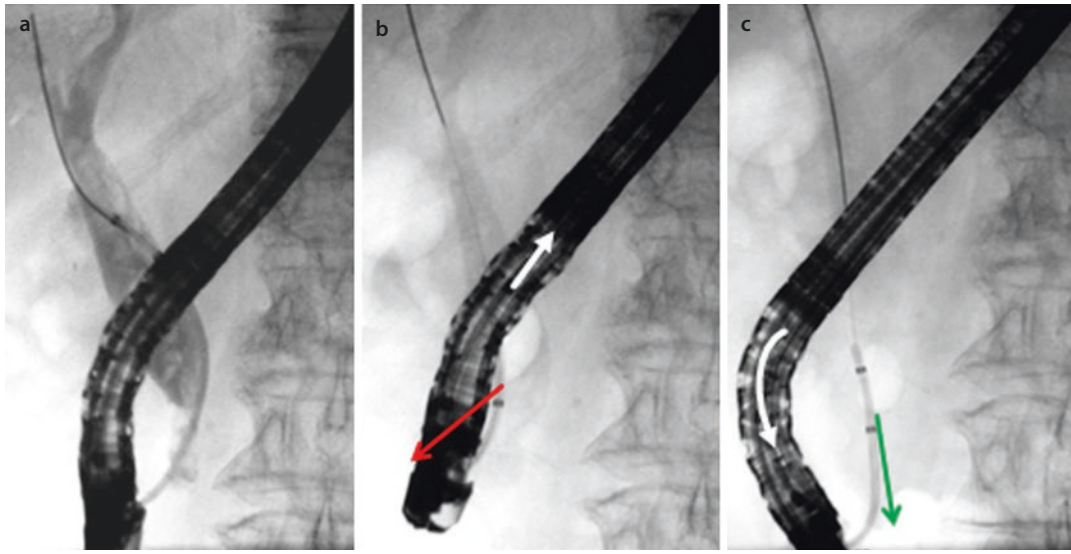


Fig. 4.11 **a** Multiple stones are seen in the CBD. **b** Duodenoscope withdrawal and straightening (*white arrow*) result in an unfavorable angle of the scope toward the CBD axis (*red arrow*), whereas **c** pushing in of the endoscope (*white arrow*) aligns the extraction force with the CBD axis, facilitating stone extraction

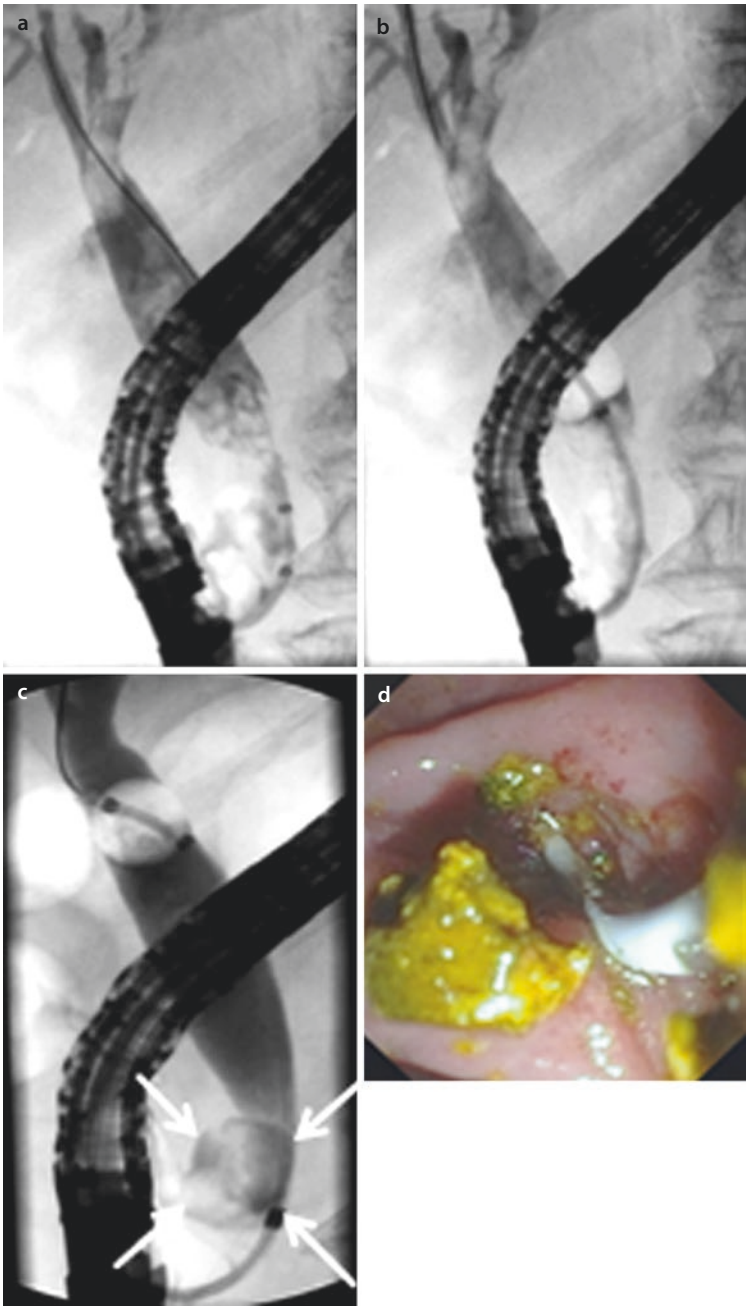


Fig. 4.12 **a** Recurrent biliary stones in CBD compression by a large duodenal diverticulum (*arrows* in **c**). The CBD is filled with stones of different sizes. **b** The balloon catheter is used to gradually clear the bile duct, starting from the distal parts, extracting large amounts of yellowish, soft material **d** until no more stones are visible on fluoroscopy **c**

For stone extraction, the basket is carefully opened beyond the stone passing the stone. Similar to balloon extraction, pushing the stone into the intrahepatic ducts must be avoided. Complete closure of the basket around the stone is not necessary for stone extraction. CBD clearance is easier achieved by trawling the duct with the basket (partially) opened. Jiggling the wires around a larger stone is sometimes necessary. For smaller pancreatic stones and ducts, dedicated smaller and softer pancreatic baskets are available. Similarly to biliary stones, a small pancreatic sphincterotomy is usually recommended prior to stone extraction (Fig. 4.14).

Lithotripsy

Lithotripsy (i.e., mechanical fragmentation of stones) can be achieved by special baskets, if the stone is potentially trapped within the bile duct or the papilla due to its size (>10–15 mm, the stone

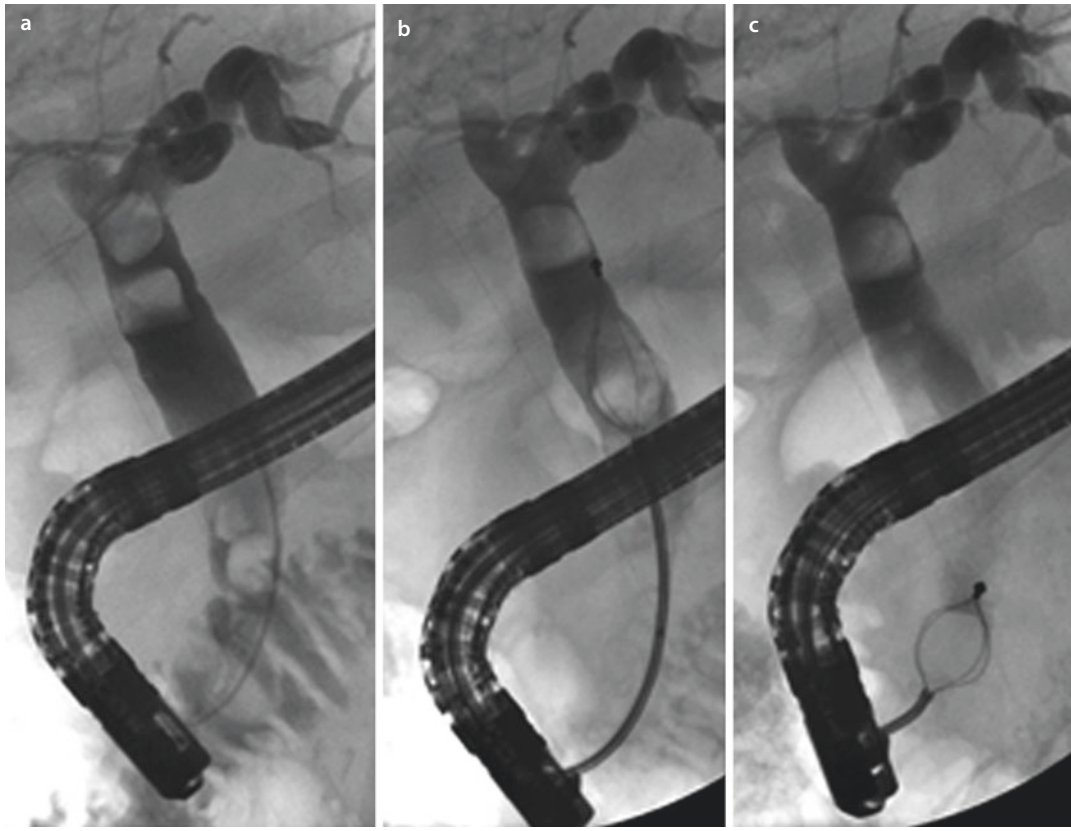


Fig. 4.13 **a** Multiple stones are seen after contrast injection throughout the CBD. **b** Starting from the distal CBD, the stones are successively caught with the basket and extracted **c**

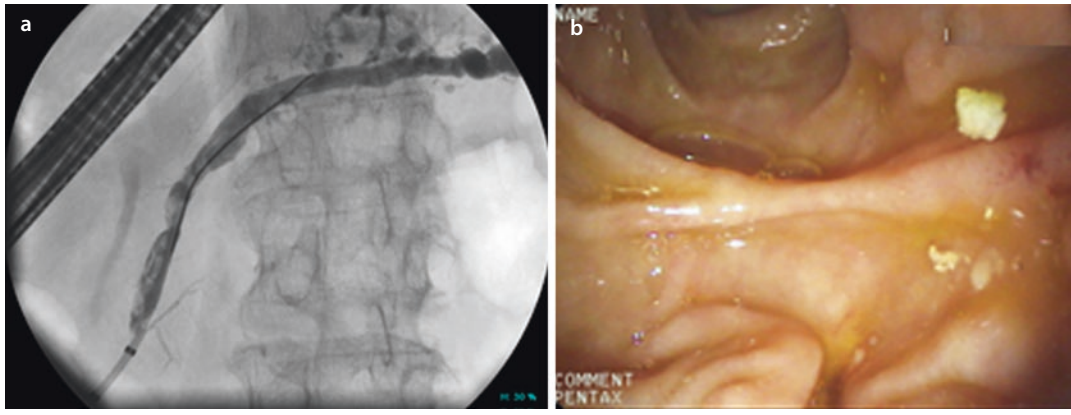


Fig. 4.14 **a** Chronic pancreatitis with dilation of the main duct and side branches. Irregularities that occur without strictures are a typical finding. **b** Whitish stones are extracted

size can be roughly estimated by comparison with the scope diameter on fluoroscopy) or shape. Lithotripsy is achieved by continuous pressure of the basket wires on the stone. Such pressure is exerted manually (similar to closure of a biopsy forceps) or—if stronger force is required—by using a pumping system (similar to dilatation balloons). To avoid traumatizing the papilla, the stone should not be impacted in the papilla for mechanical lithotripsy but be pushed upward into the CBD.

If the stone is caught with a non-lithotripsy basket, but cannot be extracted, the stone should be released from the basket. If this is not possible, increasing pressure on the wires may result in breaking the wires (many baskets have a predetermined breaking point). The stone is then fragmented with a different type of basket.

If this does not result in crushing of the stone but stone and basket are stuck in the bile duct, the handle of the basket catheter is cut off (site usually labeled close to the handle), the plastic sleeve is removed with the wires in place around the stone, and a metal spiral (Soehendra lithotripter) is mounted onto the wires which is then fixed to a reel. The wires are continuously tightened with the metal spiral as an increasing counterpressure against the stone. Only in very rare cases will this not result in fragmentation of the stone or ejection by breaking the wires. In such cases, if available, emergency cholangioscopy-guided lithotripsy can be performed after withdrawal of the duodenoscope (leaving the cut-off basket in place) and reintubation parallel to the wires.

In shock wave lithotripsy, energy from an external generator is focused onto the intraductal stone. Energy can be propelled via a fiber after high-power current discharge and aqueous solution (e.g., saline infused into the bile duct) onto the stone (electrohydraulic lithotripsy, EHL) or by pulsed laser lithotripsy. EHL requires direct contact of the fiber with the stone and is therefore usually performed under cholangioscopic (or rarely fluoroscopic) control to avoid injury to the bile duct. Newer-generation laser lithotripters usually incorporate stone recognition by light reflectance for short-term interruption of power delivery if the impulse does not hit the stone. This basically precludes collateral tissue injury; therefore cholangioscopy for direct fiber–stone contact is not mandatory.

Extracorporeal shock wave lithotripsy (ESWL) has originally been developed for fragmentation of kidney stones. ESWL uses an externally applied, high-intensity acoustic pulse focused onto the stone. ESWL is a complex procedure that is mainly used for pancreatic stones (Fig. 4.15). Preference for either lithotripsy techniques is mainly guided by local expertise and availability.

Difficult Stones

Conventional stone extraction can be hampered by anomalies of the papilla or distal bile duct or by size or location of the stone. Papillary factors include diverticula, an «inverted» papilla in Billroth II anatomy. Siphon-shaped distal bile ducts or location of the stone directly upstream

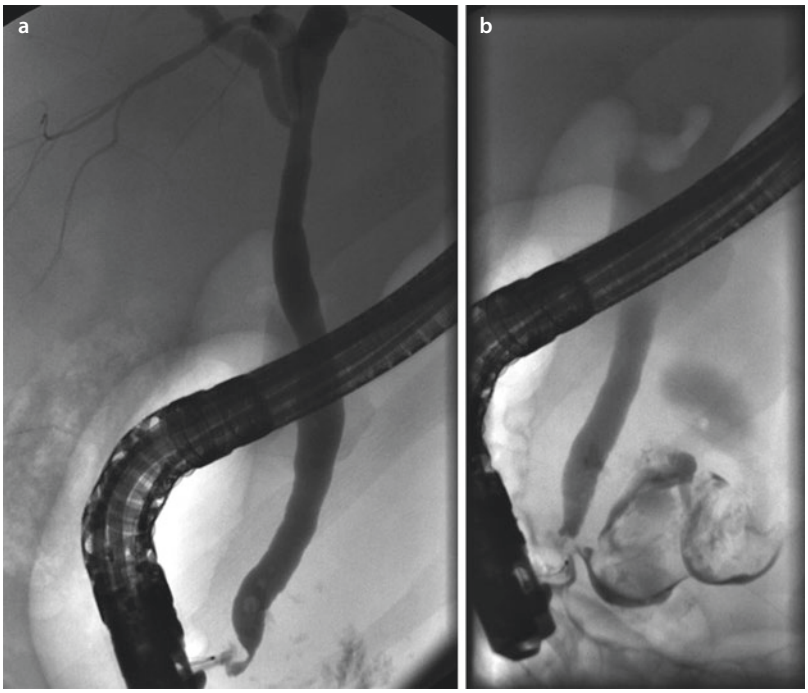


Fig. 4.15 **a** Normal CBD (with small air bubbles from contrast injection). Pancreatic head calcification is seen on fluoroscopy. **b** Two large pancreatic stones and stenosis of the pancreatic duct toward the papilla. Due to the lack of endoscopic options for stone clearance, ESWL or pancreaticojejunostomy may be discussed

from a stenosis may complicate stone retrieval because of limited navigation options of the biliary accessories in this situation. For stones cranial of a biliary stricture, dilatation is usually required before stone extraction. Piston-shaped biliary stones can be surprisingly big and hard to capture with conventional baskets. Impaction of the stone within the bile duct may render opening of the basket around a stone impossible.

If stone clearance is incomplete, stent insertion is recommended to guarantee biliary drainage. Friction between stent and stone sometimes helps to downsize or even fragment a stone. A double pigtail stent can be inserted in very dilated upstream CBS to maximize friction. In Mirizzi's syndrome (mechanical cholestasis by CBD compression of a cystic duct stone), the cystic duct stone may project onto the CBD fluoroscopically and be falsely mistaken for a CBD stone. Selective intubation of the cystic duct can result in decompression by stone extraction (Fig. 4.16).

Stones impacted in the papilla can significantly hamper deep cannulation. Large impacted stones may require needle-knife precut sphincterotomy for extraction (Fig. 4.17). Long-term impaction of stones in the papilla and associated inflammation and pressure can induce fistulas of the papillary roof. Such fistulas may allow passage of the stone and often are the main orifice for biliary drainage, bypassing the sphincter

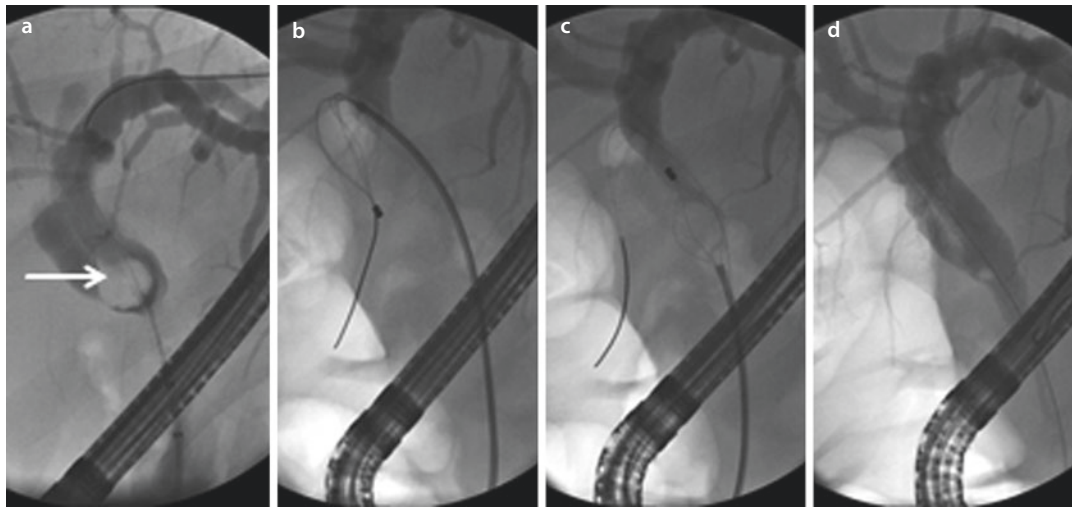


Fig. 4.16 Mirizzi's syndrome. **a** Large stone (*arrow*) in projection onto the mid-CBD and cystic duct entry site. Cholestasis of the common hepatic duct and intrahepatic ducts. Sweeping of the CBD starting from the left hepatic duct (guide wire) is not able to mobilize the stone. **b** Wire-guided, selective intubation of the cystic duct and capture of the stone by distorting the basket around the impacted stone. **c** Extraction through the CBD. **d** Fluoroscopic image of the decompressed CBD

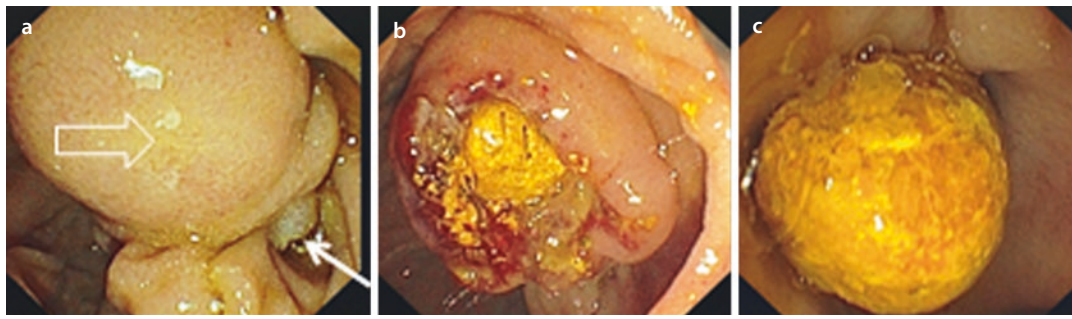


Fig. 4.17 **a** Significant swelling along the intramural distal bile duct (*open arrow*), the biliary orifice is just visible in the distal aspect (*arrow*). **b** After prior contrast injection and fluoroscopic definition of a large impacted stone, needle-knife sphincterotomy is performed and **c** the stone extracted

(Fig. 4.18). Deep cannulation can be performed via the fistula.

Secondary sclerosing cholangitis (SSC) mostly occurs in the setting of prolonged intensive care or posttraumatic situations. SSC shows ductal irregularities resembling PSC but commonly accompanied by multiple intraductal concrements and casts (Fig. 4.19). Extraction starting from the distal parts of the bile duct often results in mobilization of more proximally located casts that require multiple ERC sessions for complete removal. Ischemic-type biliary lesions (ITBL) after orthotopic liver transplantation can show a similar fluoroscopic aspect and rubber-like biliary casts. Both SSC and ITBL are often complicated by chronic bacterial and/or fungal infestation within the bile ducts, so that a biliary specimen should be sent for microbiological testing (ideally aspirate bile before injecting contrast).

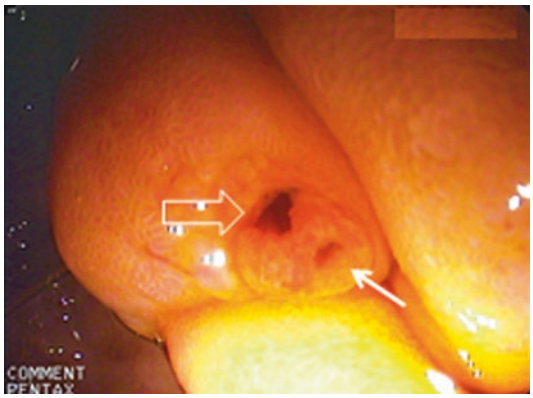


Fig. 4.18 Small caliber orifice (*arrow*) in a swollen papilla. The upper margin of the papilla shows a small fistula (*open arrow*) that had allowed spontaneous passage of the biliary stone

4.4 Recanalization and Drainage: Bougienage, Dilatation, Drainage, and Stenting

Indication

Recanalization techniques are indicated in cholestasis and (imminent) cholangitis due to benign or malignant stenosis of the bile ducts. Differential diagnosis in correlation to their location is given in Table 4.4. Localization and etiology of the stenosis directly impact on technical management to reestablish sufficient drainage (cf. ▶ Chap. 2).

If cholestasis is only moderate, further imaging studies should be undertaken to clarify the nature of the stenosis prior to intervention. If CT suggests findings such as resectable cancer of the distal bile duct or the head of the pancreas, primary stenting is not recommended since it may complicate subsequent surgery. In this situation, stenting is only required when there is high risk of cholangitis (e.g., bilirubin >14 mg/dl) or impaired liver function (van der Gaag *NEJM* 2010).

In addition to recanalization, stenting is required in postoperative or traumatic biliary leakages. Stenting of the bile duct and drainage of the biliary flow result in slow closure of the leakage site (potentially requiring several weeks, depending on the leakage size).

Technique: Bougienage and Dilatation

Prior to long-term drainage by stenting, dilatation or bougienage is often required to allow stent passage. For short and postoperative stenoses (e.g., anastomotic stenosis after liver transplantation), sole-balloon dilatation without subsequent stenting is often sufficient. Additional stent placement (as a foreign body) may in turn induce secondary

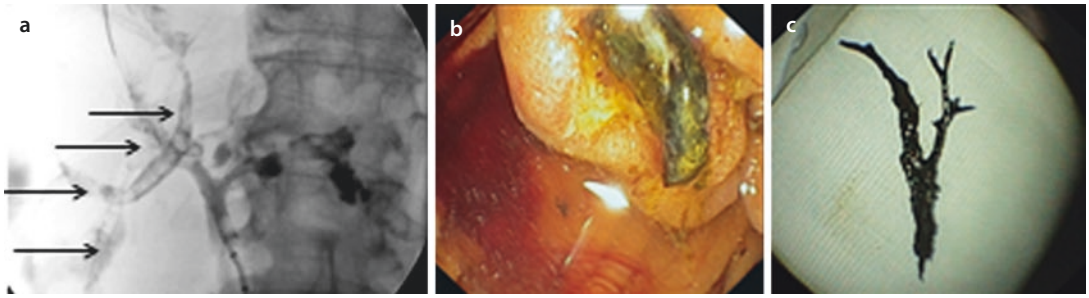
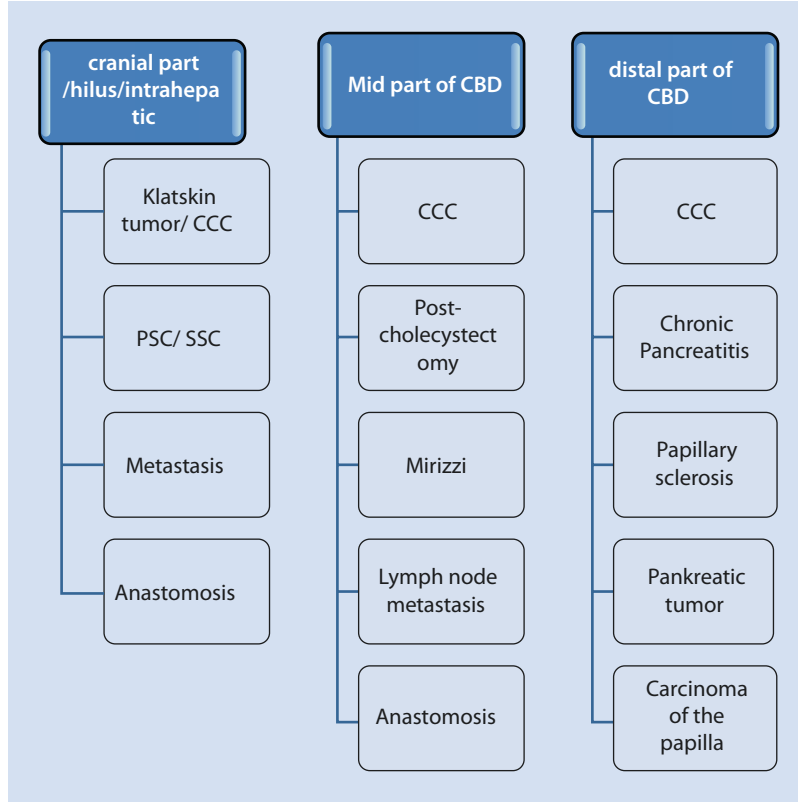


Fig. 4.19 **a** In a patient developing cholestasis 12 weeks after multiple trauma, confluent biliary casts (*arrows*) are found in the intrahepatic ducts. **b** Large biliary casts are mobilized via the papilla. **c** The cast's shape imitates the branching of the intrahepatic ducts

Table 4.4 Etiology of CBD stenosis according to localisation



fibrosis or hyperplasia. On the other hand, some fibrotic strictures (such as after cholecystectomy) reocclude rapidly after balloon dilatation and may require long-term stenting over as long as 1 year (cf. Technique: Stents).

In long and filiform stenoses, bougienage is an option besides balloon dilatation. Bougies are cheaper and allow more haptic feedback of the texture of the stenosis. Bougies come with a soft tapered tip and are also helpful for intubation of complex stenoses.

Technique: Stents

Stents are usually made of plastic or metal mesh (self-expanding metal stents, SEMS). For plastic stents, a multitude of different designs, lengths, diameters, and introducer sets are available from different manufacturers. Rather than defining specific rules as to which indication requires which type of stent, endoscopist and assistant must be familiar with the choice of stents available at their center. The law of Hagen–Poiseuille defines the physical flow through tubes: the drained volume depends on the tube's length and radius, with the radius as the main determinant (r^4). Therefore, a higher diameter stent usually results in a better drainage function and lower frequency of stent exchange. Other determinants include biliary viscosity and lithogeneity. Usually, plastic stents are electively exchanged every 3 months. In hilar stenosis, left and right intrahepatic drainage with 10-Fr stents is optimal. Drainage should be sought for all parts of the biliary system that have been contrasted. In distal stenoses, multiple plastic stents can be placed in parallel (Fig. 4.20) or a covered SEMS inserted (see below). When choosing the adequate stent length, slower drainage and risk of parenchymal injury and impaction in the opposite duodenal wall with longer stents must be considered (cf. ▶ Sect. 4.3). For pancreatic stenting, a stent without proximal flange is recommended to reduce internal migration and pancreatic duct injury during removal.

SEMS are supplied uncovered, partially or fully covered, and in different lengths (4–12 cm) and diameter options (6–10 mm). Initially, SEMS were only inserted in malignant stenoses, but more recently, fully covered SEMS can also be inserted for treatment of benign strictures.

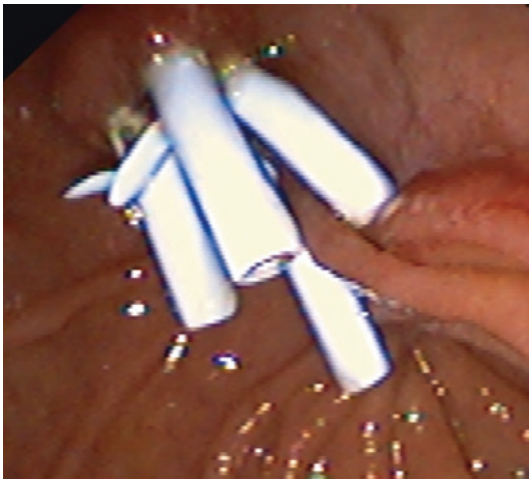


Fig. 4.20 Multistenting (4 × 10Fr) of a bile duct stenosis after cholecystectomy

Hilar stenoses cannot be adequately treated with a bridging SEMS, and for distal stenoses, the cystic duct junction should not be covered if the gallbladder is still in situ, in order to avoid cholecystitis. In treatment of benign stenosis with fully covered SEMS, the manufacturer's initial recommendation for stent exchange after 3 months was associated with significant cost, whereas in clinical routine, exchange every 9–12 months was sufficient (Fig. 4.21). Metal stents in benign stricture after cholecystectomy or in chronic pancreatitis should remain in place for at least 1 year before permanent removal is considered. If removal of a partially or fully covered SEMS is planned, stent-in-stent placement of a fully covered SEMS of the same dimensions can be used to compress tissue in growth through the uncovered meshes, and both stents can be extracted 8 weeks later.

Technique: Optimization of Drainage by PDT and RFA

For treatment of malignant stenoses (preferentially inoperable Klatskin tumors), photodynamic therapy (PDT) or radiofrequency ablation (RFA) can be combined with bougienage, dilatation, and stenting. Laser-induced formation of radicals after application of a photosensitizer (PDT) or thermal ablation (RFA) results in superficial tissue destruction over a predefined length. After therapy, bridging with at least 10-Fr stents should be ensured and peri-interventional antimicrobial prophylaxis administered for reduction of cholangitis and infected biloma rates.

Complications

Recanalization may be associated with early or late complications. Acute, early complications include bile duct perforation in balloon dilatation and hemobilia after bougienage or dilatation, rarely after stenting. Manipulation of the biliary system can induce bacteremia with acute severe systemic symptoms of sepsis (chills, drop in blood pressure, etc.). A guide wire should be left in place to rapidly place at least a thin stent (7Fr) for drainage or bridging of perforation.

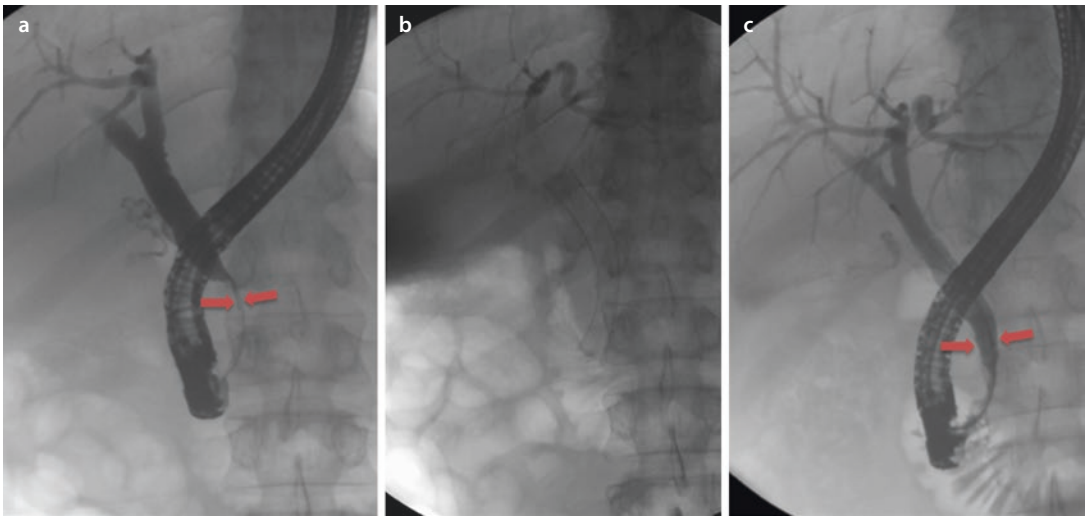


Fig. 4.21 Stenosis of the distal CBD in chronic pancreatitis. Initial stenosis (*arrows*, **a**) is bridged with a SEMS **b** and is significantly dilated after 12 months, with reduction of prestenotic CBD dilatation **c**

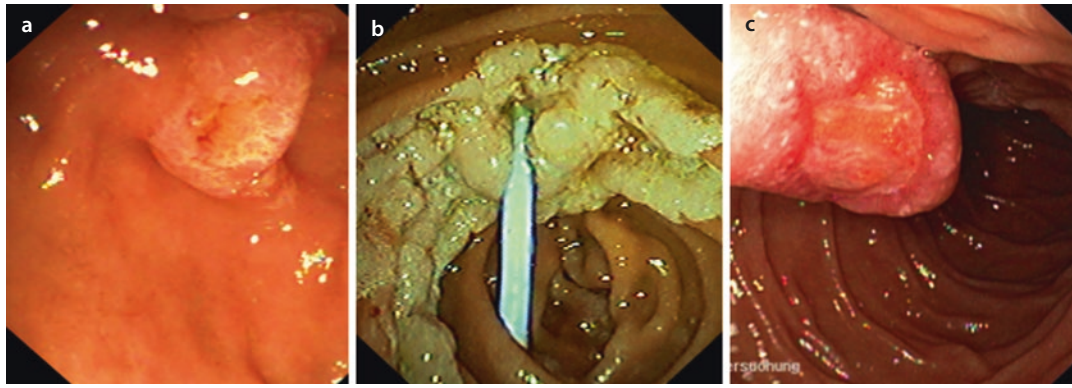


Fig. 4.22 Tumors of the papilla. **a** Small adenoma restricted to the papilla. **b** Low-grade adenoma with semicircumferential spread to the duodenal mucosa after placement of a biliary plastic stent. **c** Carcinoma of the papilla with central erosion

Late complications include stent obstruction in (too) long-term drainage with plastic stents or stent-induced obstruction of the cystic duct inducing cholecystitis. Suboptimally placed or too long stents, or distal stent migration, may induce ulceration of the opposite duodenal wall. Proximal stent migration into the bile or pancreatic duct sometimes mandates challenging retrieval maneuvers with snares, balloons, stent retriever, etc.

4.5 Papillectomy

Indications

Tumors of the papilla (Fig. 4.22) are relatively rare entities but are more frequent in patients with FAP. Detailed inspection of the papilla with the side-viewing duodenoscope therefore is mandatory in surveillance of FAP patients. However, most tumors of the papilla are sporadic adenomas that are detected incidentally, found (and confirmed by biopsy) during EGD with prograde viewing gastroscopes.

Papillectomy (or endoscopic ampullectomy) is the treatment of choice in histologically confirmed low-grade adenomas of the papilla. Surgical treatment (open surgical ampullectomy) would constitute an overtreatment that is usually not indicated. Similar to colorectal adenomas, adenomas of the papilla sequentially progress from low-grade to high-grade adenomas and eventually to cancers. The role of endoscopic resection of high-grade adenomas is a matter of discussion, since biopsy may have just touched the tip of an iceberg with underlying malignancy. In smaller lesions (<15 mm), an endoscopic attempt is justified, if only for diagnostic reasons. In histologically confirmed high-grade intraepithelial neoplasia and/or large tumors, endosonography can help to identify the deep tumor margins and intraductal tumor growth. Diffuse growth of the hypoechoic tumor at the deep margins and/or documentation of suspicious lymph nodes should prompt an initial surgical approach. EUS is not mandatory before resection of flat and low-grade adenomas.

Technique

Papillectomy requires a skilled endoscopist due to its high risk for complications (see below) and the difficult access to the papilla. With the side-viewing duodenoscope, visualization of the papilla is optimized. However, passage across the lever and the use of accessories (injection needle, snare, clips) with the elevator are difficult and mandate thorough training of endoscopist and assistant.

In flat and laterally spreading adenomas, elevation by injection and piecemeal resection is recommended (Fig. 4.23). This is not necessary in nodular adenomas and adenomas restricted to the papilla (Table 4.5). Ideally, the tip of the snare is placed at the oral border of the papilla or adenoma and then closed from the aboral, distal part. After resection, the specimen should be immediately retrieved (or intermittently dropped in the stomach). Butylscopolamine injection helps to optimize vision and to reduce propulsion of the resected specimen by duodenal peristalsis. After piecemeal resection, APC ablation of potential tissue bridges and resection margins should be considered.

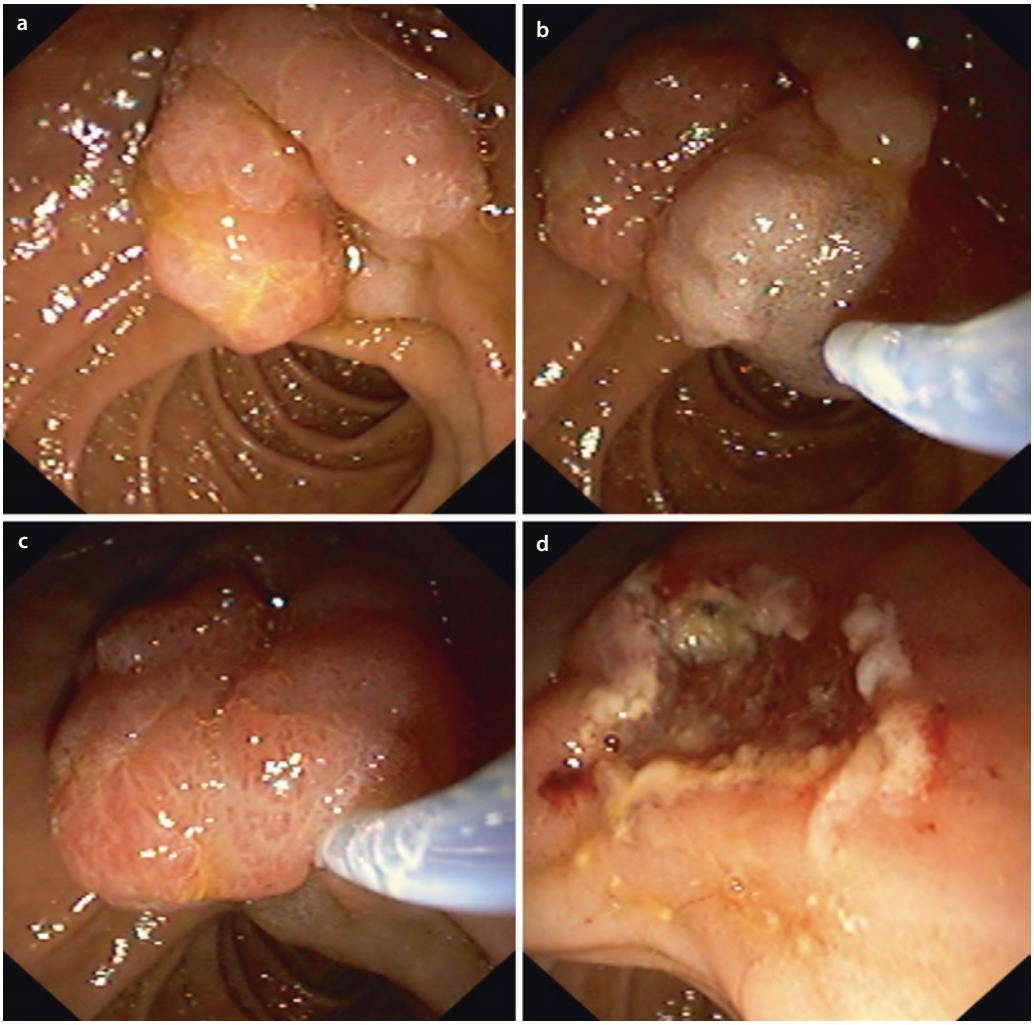


Fig. 4.23 Endoscopic resection of a broad adenoma of the papilla. **a** Because of the spread over the papillary margins, saline injection is performed. **b** The snare is placed at the oral margin, flipped over the adenoma, and closed aborally. **c** Potential residues can be ablated with APC

Table 4.5 PTCD accessories

Puncture	Drainage
Sterile draping for patient, fluoroscopy, abdominal ultrasonography Biopsy guidance Local anesthetic Scalpel Chiba needle (22G) Sterile contrast (5-ml, 20-ml syringes) Sterile saline 0.9% (10-ml syringes) 0.018″ guide wire Clamp	Dilatators/bougies (e.g., 7, 8, 10 Fr) Access port 0.035″ guide wire Drainage catheter Compresses Suture Drainage bag

Complications

Perforations and bleedings are potential risks of any mucosal resection in the gastrointestinal tract. Details of management are found in ▶ Chap. 1; placement of clips and injection therapy are described in detail in ▶ Sect. 4.2 above (cf. sphincterotomy).

Specific risks of papillectomy include the significantly elevated PEP risk (cf. ▶ Sect. 4.1) and incomplete adenoma resection in intraductal growth. PEP risk is explained by the pancreatic duct orifice edema secondary to electrocautery resection. PEP risk is significantly higher in papillectomy (about 12% vs 3–4% in sphincterotomy). The risk can be lowered by placement of a

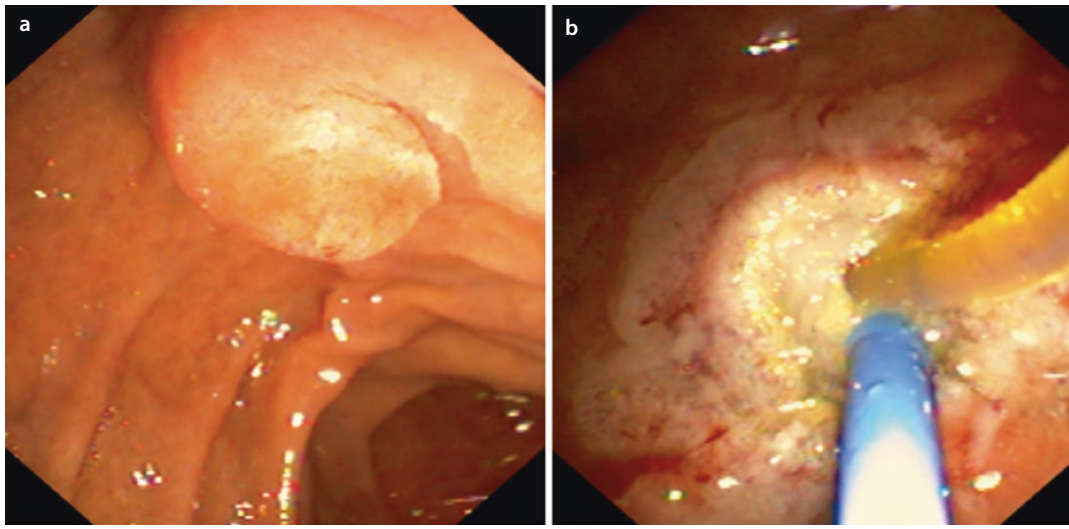


Fig. 4.24 **a** Small adenoma of the papilla. **b** After en bloc resection (without saline injection), a pancreatic stent has been placed (*blue* stent). Subsequently, the distal bile duct is cannulated and contrasted to exclude intraductal remnants

prophylactic pancreatic stent following resection (Fig. 4.24). The pancreatic orifice can be difficult to identify in the resected ulcer. An interesting alternative has been proposed: resection is performed over a previously inserted pancreatic guide wire that is subsequently used for pancreatic stent insertion. For detection of intraductal residues of large adenomas, a wide sphincterotomy may be performed, often resulting in prolapse of adenoma remnants that can be treated by snare resection or APC.

Orientation of the distal ducts becomes clearly visible after papillectomy: aborally duct of Wirsung, toward 3 o'clock at an obtuse angle, and CBD proximally toward 11 o'clock, pointed angle.

4.6 Percutaneous Transhepatic Cholangiography and Drainage

Indication

Percutaneous transhepatic cholangiography (PTC) and biliary drainage that accompanies PTC in most cases (PTCD) are indicated if less invasive measures do not yield sufficient diagnostic accuracy or therapeutic efficacy. Indications greatly overlap with indications for ERC. Given the higher invasiveness and availability of less invasive diagnostic (EUS, MRCP, ERCP) or therapeutic (ERCP) methods, percutaneous biliary access is reserved for specific patient groups, such as with surgically altered anatomy without a transluminal access option to the bile duct system, biliary strictures that cannot be traversed from a transpapillary access, bile duct areas that cannot be sufficiently drained by transpapillary drainage options, or a non-accessible papilla (e.g., in duodenal stenosis in pancreatic cancer or after duodenal stenting). PTC can be performed as a stand-alone diagnostic or therapeutic method or can be combined with ERCP as a rendezvous procedure.

Percutaneous access requires adequate coagulation parameters. In case of concomitant ascites, a cutaneo-biliary fistula tract will not be established. Therefore ascites should be drained prior to PTCD. A small perihepatic lamella can be bridged by short port for biliary access. Perinterventional antimicrobial prophylaxis is recommended for all patients.

Technique

If a PTCD is primarily planned, the patient is in supine position; if rendezvous PTC–ERC is planned, then the patient is positioned as for conventional ERCP (e.g., prone). PTCD is usually tolerated well in conscious sedation. Personnel requirements correspond to those for ERCP. The percutaneous access route is planned according to previous cross-sectional imaging

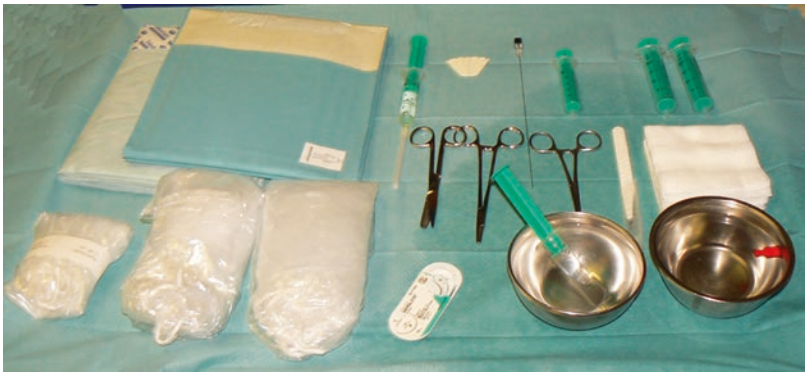


Fig. 4.25 Sterile table for PTCD

studies (ultrasonography, CT, MRCP). Most commonly, access via the right liver lobe from the right lateral flank is preferred, but epigastric access via the left liver lobe is possible. Right lateral access usually confers a better visualization of the access in non-tiltable fluoroscopy facilities, and working is outside the optical path of X-rays.

Materials are (Table 4.5) sterilely prepared on a table such as in Fig. 4.25. We use a Chiba needle (22G, 20 cm) for initial puncture. In non-sonography-guided puncture, a typical puncture site is the tenth intercostal space in the medioclavicular line. After sterile draping, local anesthesia, and a small incision, the needle is advanced under fluoroscopic control in direction of the liver hilus. During slow withdrawal, small boluses of contrast are injected until the bile ducts are contrasted. We usually perform initial puncture of a dilated bile duct under sonographic control. After puncture, biliary access is controlled by contrast injection under fluoroscopy. A 0.018″guide wire is advanced through the needle into the bile ducts and, if possible, into the small intestine. Sharp angles between the needle and the direction of the punctured bile duct can hamper wire manipulation especially in not (severely) dilated bile ducts. Forced retraction of the wire through the needle can result in shearing-off of the wire tip and must be avoided. Depending on the therapeutic intention, a larger contrast catheter can be inserted over the initial wire to secure access and the wire exchanged for a stiffer 0.035″ guide wire for further navigation toward a duodenal/jejunal access. Alternatively, the initial puncture can be used for contrast injection, and the contrasted biliary system is then punctured with a larger needle under fluoroscopic guidance.

Further proceedings depend on the aspects of the altered biliary system. For further interventions, the access site is usually dilated in a stepwise fashion starting with 7-Fr bougies up to 10–12 Fr. Short and less flexible bougies are easier to handle than longer (ERCP) bougies. In general, sterile handling of specialized, shorter PTCD equipment is easier than the use of ERCP accessories; therefore, we sometimes shorten ERCP equipment to fit with use in PTCD. A short port with a large lumen facilitates access with multiple different instruments (e.g., in percutaneous cholangioscopy or lithotripsy). In a very solid, fibrotic stenosis, exchange to a stiffer guide wire helps to transmit and direct the manual force onto the stenosis site. Percutaneous balloon dilatation is performed in analogy to ERC as described in ▶ Sect. 4.4. We are very reluctant to perform sphincterotomy percutaneously, which puts the patient at a higher risk for complications due to the lack of endoscopic visual control, and rather perform percutaneous balloon dilatation of the papilla.

Percutaneous drainage may be purely externally or combined external–internally. Multiple drainage catheters are available that differ as to diameter, flushing options, lateral perforations, and internal catheter end (straight vs pigtail). We mostly use Yamakawa drainage catheters, since the outer plate allows comfortable cutaneous fixation with single-button sutures. Yamakawa catheters can be used as external–internal and external catheters. In the latter use, an external drainage bag must be connected to the drainage. The PTCD catheters should be flushed at least once daily with sterile saline to minimize clogging. If the inner end is advanced across the stenosis into the duodenum/jejunum, external collection bags can be omitted and the outer button plate be

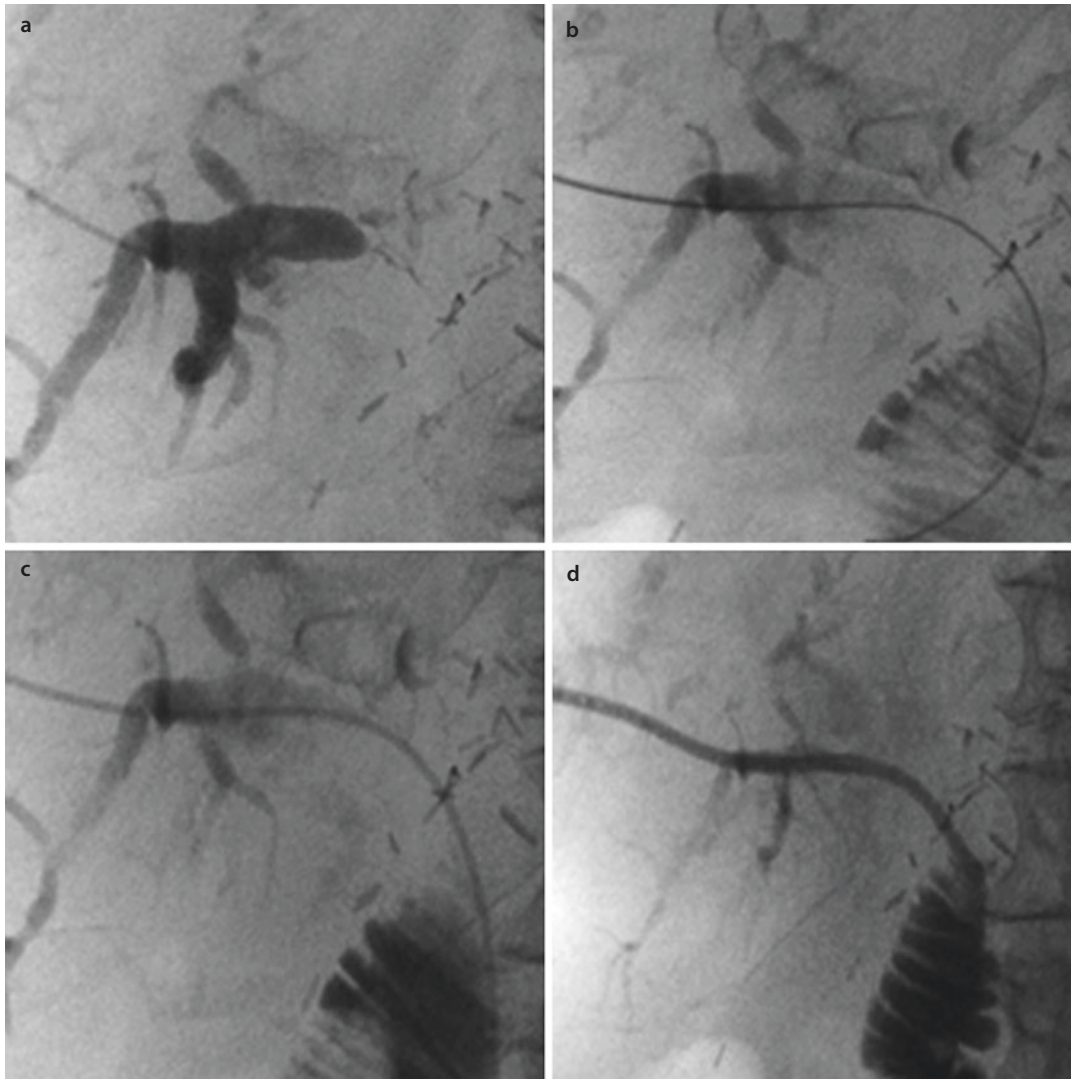


Fig. 4.26 **a** After sonographically guided puncture from the right lateral flank, the dilated right intrahepatic biliary system is contrasted cranially to a stenosis at the choledochojejunostomy. **b** A guide wire and thin contrast catheter are advanced into the jejunum, and jejunal contrast confirms the correct catheter position, before **c** the stenosis is treated by stepwise percutaneous bougienage. **d** A Yamakawa drainage catheter is inserted, and correct position and functional adequacy of the drainage are confirmed by contrast of both the intrahepatic biliary system and the jejunum, as well as rapid clearance of contrast from the bile ducts

closed. This is more comfortable for the patients. Flushing is done without re-aspiration to avoid mobilization of small intestinal contents into the bile ducts.

If advancement into the small intestine cannot be achieved, the drainage has to be individualized (shortened) to avoid kinking at the tip. The distance of the first internal perforation to the button has to be chosen according to the patient's anatomy so that bile ducts proximally to the stenosis and the gut lumen distally to the stenosis are contrasted (Fig. 4.26). More side holes can be added, if needed.

If the PTCD is a permanent drainage solution, the plastic catheter is exchanged every 3 months in analogy to internal plastic stents. Exchange is performed in Seldinger technique over a guide wire. If the external drainage is no longer needed, the biliary fistula closes spontaneously within several days if internal biliary drainage is sufficient. A non-closing fistula may indicate insufficient internal drainage.

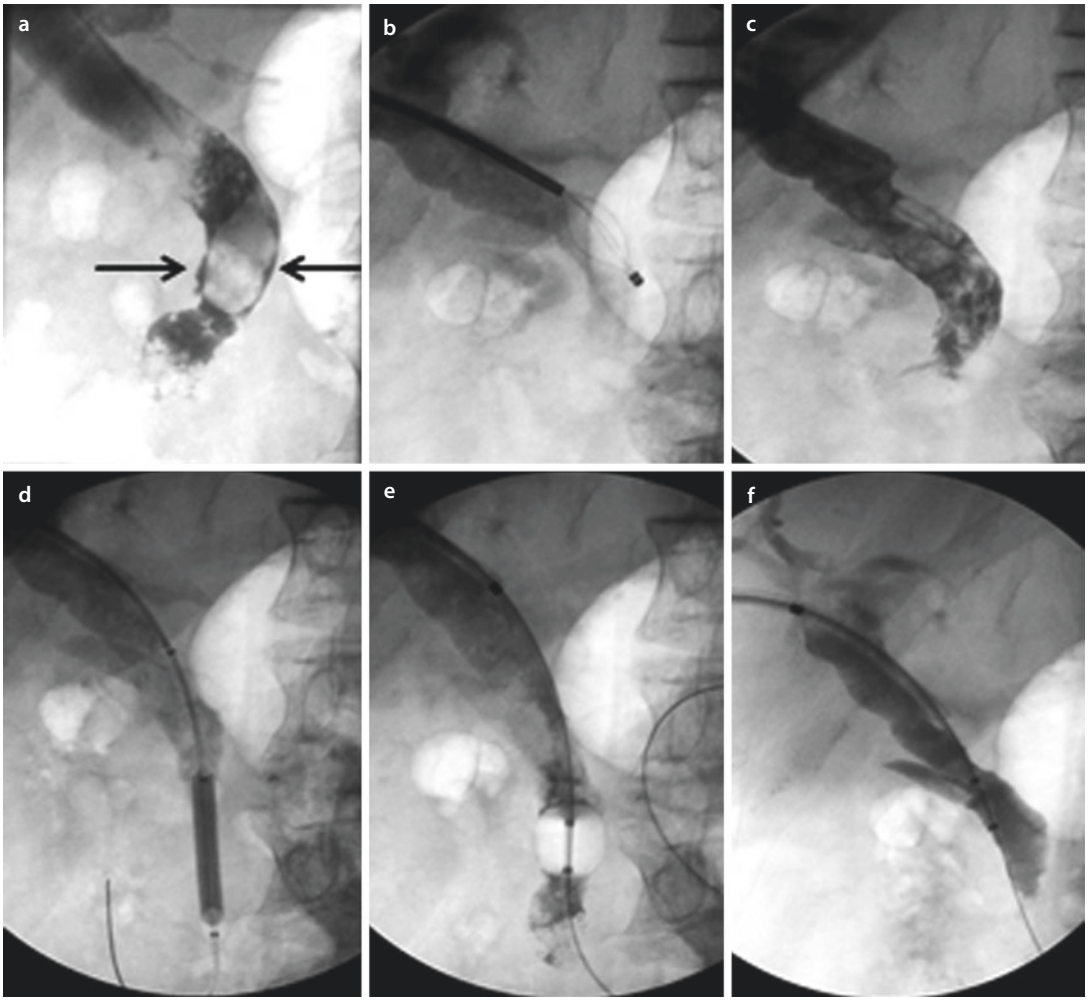


Fig. 4.27 **a** In a patient with Roux-en-Y reconstruction after gastrectomy, a 15-mm biliary stone is visualized in the distal CBD. **b** Via an 11-Fr port, mechanical lithotripsy is performed (fragmented stone, **c**). Percutaneous balloon dilatation of the papilla **d** precedes reverse sweeping of the bile duct with an extraction balloon **e**, until fragments are completely removed **f**

For patients in good general condition, self-expanding metal stents can be placed across malignant strictures to permit palliative drainage in one session. Placement of SEMS is analogous to insertion via ERC—a long (ERCP) guide wire is needed. Corresponding to the access route, setting free the stent is performed from the small intestinal side toward the cranial end, i.e., in reverse direction compared to ERCP-guided placement, and is controlled using the radiopaque markers on the stent. If fluoroscopy control is needed after stent placement, the percutaneous drainage catheter can be left in place for contrast administration and/or reintervention, e.g., 24 h after insertion.

Difficult stones that cannot be successfully cleared by ERC are sometimes more easily accessed percutaneously. All methods for stone extraction from ERC can be transferred to PTCD (Fig. 4.27). For extraction, a large port is usually necessary. Therefore, in most patients sweeping of stones (or fragments) across the papilla (or subsequent clearing by ERC) or biliodigestive anastomosis is easier. Cholangioscopically guided lithotripsy or recanalization can be performed with high success rates in expert hands. Short video cholangioscopes for percutaneous interventions are available; alternatively, single-operator baby cholangioscopes from ERC access can be introduced via a port.

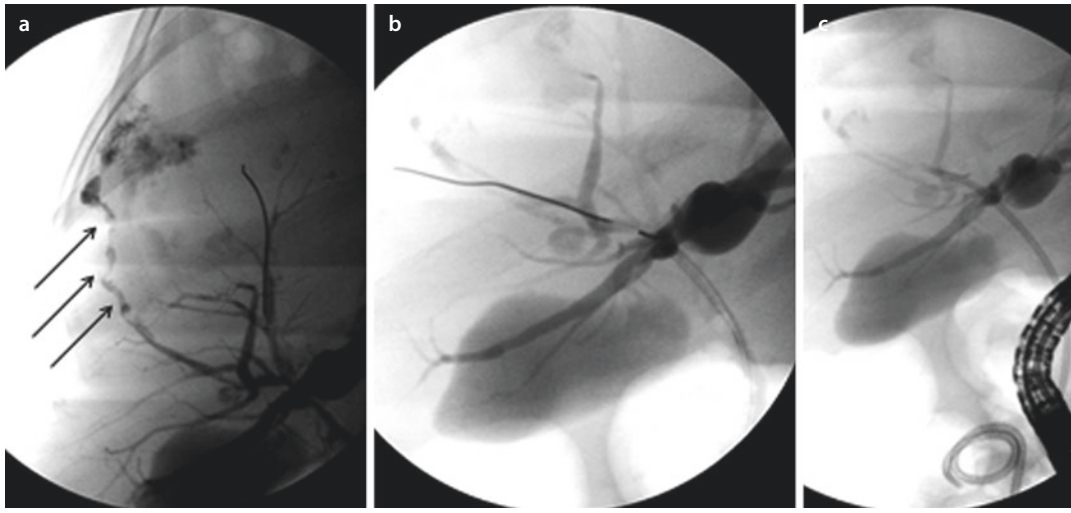


Fig. 4.28 After intermittent PTCD and removal of percutaneous access after ERC rendezvous, the patient developed pleural effusions with elevated bilirubin levels. **a** A bilio-pleural fistula (*arrows*) results in contrast effluence into the pleural space. **b** The fistulating bile duct is selectively cannulated with a guide wire and **c** decompressed with a transpapillary plastic stent

In rendezvous procedures, a percutaneous biliary access is established and a guide wire advanced across the papilla into the duodenum. The wire is taken up into the duodenoscope by a forceps, snare, or dormia basket and externalized over the working channel. Over this transpapillary guide wire, the usual ERC procedures can be performed. For EUS–ERC rendezvous techniques, the reader may refer to ▶ Chap. 5.

Complications

Cholangitis is the most frequent complication of percutaneous biliary access and may occur in 20–50% of patients. Peri-interventional antimicrobial therapy is therefore strongly advised. Bleeding can occur at any site within the puncture canal, and the anatomical proximity of intrahepatic vessels and bile ducts may give rise to portobiliary or even arterio-biliary fistulas. No specific measures are needed for small fistulas and bleedings after initial puncture with a thin 20G needle. However, if larger vessels are dilated with bougies or contrasted with larger lumen catheters, placement of a biliary catheter is recommended to avoid hemorrhage. Catheters with side holes should be placed in a way so that the side holes are not positioned immediately at the fistula site (test by aspiration which should not be hemorrhagic).

Injury of close-by organs by accidental puncture or pneumothorax by puncture through the costodiaphragmatic recess can occur. A bilio-pleural fistula is a rare complication that may become evident only after drainage removal (Fig. 4.28). Interposition of the gut between the lateral abdominal wall and the liver (Chilaiditi's syndrome) can interfere with intercostal access. The patient has to consent to these adverse events in addition to ERCP risks.

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EUS-Guided Interventions: Indications, Contraindications, and Risks

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5.1 Endosonography-Guided Fine-Needle Puncture (EUS-FNP): Indications, Value, and Evidence of Endosonography-Guided Fine–Needle Interventions

General Considerations and Description of the Method

The term endoscopic ultrasound-guided fine-needle puncture (EUS-FNP) includes all endosonographic methods to gain material by the use of biopsy needles such as fine-needle aspiration (needle diameter 19–25G) and Trucut biopsy (=EUS-TCB, diameter 19G). EUS-FNP enables us to gain material out of structures which are otherwise not or only at high risk accessible. The cytohistologic results are of relevance for many patients in terms of diagnosis, prognosis, and further therapeutic treatment. EUS-FNP is the method of choice for the initial tissue-based diagnostic workup of lesions of or around the gastrointestinal tract, for staging of malignant tumors, and for the differential diagnosis of numerous benign diseases.

Despite being judged as minimally invasive, EUS-FNP should be used only if an obvious indication and clinical consequences from the results are given (Dumonceau et al. 2011; Jenssen et al. 2011a; Jenssen and Hollerbach 2013; Hollerbach et al. 2003, 2010). The results should influence the further clinical course of the individual patient, such as neoadjuvant chemotherapy vs initial surgery or directing tumor therapy of malignancies such as lymphoma, GIST, or other diseases.

Personnel, Instrumentation, and Organizational Requirements

A detailed written informed consent obtained by a physician is a legal prerequisite for EUS-FNP (as it is for other endoscopic interventions). Before beginning the procedure, all clinical and anamnestic data of the patient should be present, such as images and reports of previous radiologic and endoscopic examinations or histology reports. Additionally, the examiner should be aware of patient-specific risk factors. This approach enables him to take the whole clinical situation into account.

Personnel Requirements

Interventional endosonography should be performed only by physicians who are experienced with the method. Additionally, it is expensive. Therefore, it is only cost-effective for specialized centers performing more than 100 EUS-FNP interventions per year. The performing physician should be familiar with the use of side-viewing endoscopy and with clinical ultrasound diagnosis. Additionally, he should be able to handle complications such as bleeding or defects of the gastrointestinal wall. Sedation should be performed according to the local national guidelines. According to the German S3 guideline for sedation, one trained nurse cares for the surveillance of the patient (NAPS), while the second assists the physician performing the EUS procedure. In specific situations such as an ASA-III-patient, difficult EUS procedure, a second physician may be needed. These requirements should be taken into consideration when planning the interventions. If the obtained material is processed adequately, there is no need for an onsite pathologist.

Instrumental Requirements

For EUS-guided interventions, linear scanner side-viewing instruments are a prerequisite. They offer the option to perform interventions under ultrasound guidance. Three companies offer suitable instruments (Hitachi–Pentax, Fujinon, Olympus). Digital video endoscopes, when connected with light source and processor, produce endoscopic and ultrasound images, which are transmitted to monitors. The Albarran elevator of interventional instruments offers the option to angulate instruments introduced into the working channel. Most digital echoendoscopes have an oblique side-viewing optic and an ultrasound unit at the tip of the instrument. They differ in size and position of the ultrasound unit, size of the working channel (2–3.8 mm), size and type of adapted ultrasound unit, and electronic image resolution.

The curved-array transducer produces a 120°- or 170°-sector ultrasound image oriented in the longitudinal axis. As a result, every step of the procedure performed via the working channel can be observed under direct endosonographic surveillance. The ultrasound frequency, usually in the range of 5–12 MHz, can be adapted. The coupling of the ultrasound is optimized by a water-filled balloon at the tip with minimization of interfering air bubbles.

All instruments are equipped with a color Doppler and a continuous wave (CW) Doppler to offer the option of differentiated analysis of vessels.

Further detailed descriptions of instruments would lead too far. They are provided by manufacturers of echoendoscopes.

For EUS-FNP, the following instruments are needed:

- Balloons for the ultrasound unit (water coupling, protection)
- Standard EUS-needles for fine-needle puncture (19–25 gauge in diameter with stylet)
- Suction syringe for aspiration (e.g., Hepafix)
- 10–20 ml of sterile saline 0.9% solution (to flush the needle after use)
- Formalin container (for fixation of tissue)
- Microscope slides ± fixation spray for cytology

Organizational Requirements

The technical and personnel needs of interventional endosonography are high. Every intervention should be planned in advance involving the patient and the team. Needs in terms of room, time, and additional instruments should be part of the daily team session. Especially in advance of therapeutic maneuvers such as drainage procedures, interfering influences such as ringing cell phones or uninvolved people passing the room should be eliminated.

The Procedure of EUS-FNP

The EUS-FNP is performed in left lateral position (as in gastroscopy), while the patient is sedated, i.e., by a combination of propofol and midazolam. An analgosedation may be needed for therapeutic procedures. If the procedure takes longer, special attention should be focused on the avoidance of positional damage. Topical pharyngeal anesthetics such as lidocaine spray and sedating drugs (i.e., propofol, pethidine, midazolam) are used as known from standard endoscopic procedures. Oxygen saturation and blood pressure are part of the patient's supervision. Electrocardiogram surveillance is part of the surveillance in risk patients. Additional oxygen via nasal tube should be available. Optimal oxygen supply and minimal resistance of the patient is the goal to allow a safe passage of the endoscope into the stomach. Antibiotic prophylaxis in advance is indicated for patients with personal high risks (such as artificial heart valves) or if extraluminal fluid collections are addressed. Suitable antibiotics are, for instance, amoxicillin, ampicillin, ceftriaxone, ciprofloxacin, or cefuroxime. Special extraction methods such as needle-based brush cytology, special transport media for microbiology, or molecular biology should be prepared in advance.

Indications, Value, and Evidence of EUS- FNP

EUS-FNP has a big impact on visceral medicine in terms of tissue-based diagnostic and tumor staging. By fine-needle puncture, you can achieve more than 1,000 cells for further histologic and cytological examination (for example, paraffin hybrid techniques). EUS-FNP has a high, but examiner-dependent diagnostic accuracy for lesions of the mediastinum, perigastric area, retroperitoneum, and the perirectal space. After initial difficulties, a medium sensitivity of 85–95% can be achieved for suspected lesions of the mediastinum, around the esophagus, stomach, and rectum, as well as for the liver hilum, parts of the liver, the distal bile duct, and the pancreas (Dumonceau et al. 2011; Jenssen et al. 2011a; Jenssen and Hollerbach 2013; Hollerbach et al. 2003, 2010). The reported specificity of 95–100% is high, especially if all additional histopathological methods such as immunohistochemistry, FACS, phenotyping, tumor marker, and surface antigens are part of the spectrum. Details should be discussed with the corresponding local pathologist. Capabilities of fine-needle puncture reach their limit if the method is overextended. This could be the case when puncturing a fibrotic or calcified lymph node or pancreatic tissue. The aspiration of little tissue particles is determined by physical limits. Improvement of cut needles to gain bigger tissue particles for histology is needed.

It is feasible to obtain tissue by EUS-FNP even for lesions smaller than 5 mm. Therefore, the method is particularly suitable for the N-staging of tumors such as lung cancer. Even the diagnostic of malignant lymphomas (HL, NHL) by EUS-FNP is possible, if clinicians and pathologist keep in close contact. EUS-FNP is essential for modern stage-adapted tumor therapy (lung, gastric, and pancreatic cancer, pancreatic NET, and lymphomas). It has impact on the therapeutic approach such as stage-adapted neoadjuvant tumor therapy of stomach and rectum. EUS diagnostic is based on morphology (tumor extent, depth of infiltration, involvement of adjacent structures) and, if clinically indicated, on tissue by cytohistologic biopsy.

Benign and malign mediastinal, retroperitoneal, and perirectal lesions (such as lymphomas, tuberculosis, sarcoidosis, subepithelial lesions) are another indication for rapid histologic diagnosis.

These lesions of the gastrointestinal wall or its surroundings were previously detected by endoscopy (gastroscopy, colonoscopy), by radiology (MRI, CT, X-ray) or by percutaneous ultrasound.

The main indications for EUS-FNP are provided in Table 5.1. The range of indication is mainly dependent on the depth of introduction of the echoendoscope, which usually ends at the

Table 5.1 Indications for EUS-FNA in the posterior mediastinum and/or in the upper and lower GI tract

Mediastinum
Primary diagnosis lung cancer: Cytohistological diagnosis of lung cancer, lymph node metastasis, distant mets
Mediastinal lymph node staging: histologic proof of N2 or N3 situation (NSCLC); proof of any nodal cancer involvement independent of localization (SCLC)
Infradiaphragmatic metastasis in lung cancer: proof of M- situation (i.e., left or right liver lobe, adrenal glands, infradiaphragmatic lymph nodes)
Restaging after neoadjuvant therapy: selected patients with curative therapeutic intention, for instance, patients with NSCLC stage SIII (N2 + /N3 +) following neoadjuvant therapy that may undergo subsequent surgery
Primary diagnosis of other pathologic mediastinal /pulmonary lesions such as tumors, metastasis of unknown origin, indistinct lymphadenopathy, fluid collections/abscesses in the posterior mediastinum (including Hodgkin´s disease, non-Hodgkin's lymphoma, thymoma, germ cell malignancies, esophageal cancer, sarcoidosis, tuberculosis, actinomycosis and others)
Esophagus/cardia/stomach/duodenum
Local *T-, N-, and M- staging* of esophageal, cardiac, gastric, biliary, and pancreatic cancer including their specific surrounding lymph node regions
Primary diagnosis: if failure of simple biopsy methods, in case of contraindications for other diagnostic methods, for instance, in cases with linitis plastica, cancer of bile ducts, or gall bladder cancer
Primary diagnosis and *staging* of subepithelial tumors (SET), i.e., esophageal, gastric, and duodenal tumors including GIST, leiomyoma, leurinoma, lipoma, Abrikosoff tumors, cystic tumors, and others
Primary diagnosis and local *staging*: indistinct abdominal or retroperitoneal lymph node disease/adenopathy
Primary diagnosis and local *staging* of peritoneal tumors, metastasis, lymph nodes, abscess formations and fluid collections including lymphomas, Ormond´s disease, metastasis, inflammatory masses, abscesses, walled-off necrosis, and others
Primary diagnosis and local *staging* of adrenal gland including oncologic and/or endocrinologic cases
Primary diagnosis and local *staging* of lesions at level of Vater´s papilla and/or the extrahepatic portion of the biliary tree including papillary adenomas, adenomyomatosis/«papillitis stenosans,» carcinoma of Vater´s papilla, biliary stones, locoregional, lymph node staging, ductal abnormalities (such as pancreas divisum)
Primary diagnosis and local *staging* of malignancies located in the biliary system and other digestive organs including liver metastasis, malignant ascites, pleural effusions, adrenal gland metastasis, mediastinal lymph node metastasis, indifferent pathologic lesions in accessible parts of the liver and central hilar structures (i.e., metastasis, HCC, CCC)
Primary diagnosis and local *staging* of lesions located in or around the spleen such as abscesses, NHL, Hodgkin´s disease, metastasis, and lesions located in accessible parts of both kidneys
EUS Indication: Lower GI Tract
Staging: locoregional N-staging of lymph nodes of rectal carcinoma
Primary diagnosis: submucosal tumors in/around the rectosigmoid colon
Follow-up: histologic proof of extraluminal recurrences /relapse in CRC and in other GI-malignancies
Primary diagnosis: abscesses and unclear processes located in the lower pelvis
Miscellaneous: prostatic or uterus lesions and/or ovarian/vesicular lesions (selected cases)

Table 5.2 Indications for EUS-FNA in pancreatic malignancies

Non-resectable tumors
Cytologic/histologic diagnosis prior to chemotherapy
Proof of non-resectability (liver metastasis, mediastinal lymph node metastasis, pleura- and peritoneal carcinosis)
Resectable tumors
Suspected solid neoplasia other than ductal adenocarcinoma, i.e., neuroendocrine tumors, malignant lymphoma, pancreatic metastasis
Differentiation and risk assessment of cystic pancreatic lesions
Suspected ductal adenocarcinoma, if patient´s decision for subsequent surgical therapy depends on cytopathologic proof of malignant disease or if neoadjuvant treatment studies are on their way
Unspecific findings
Cytologic/histologic diagnosis proof and differentiation of malignancy in case of low pretest probability for a malignant tumor, for instance, in focal pancreatitis, autoimmune pancreatitis, and others

descending duodenum (upper GIT) or distal sigmoid (lower GIT).

EUS-FNP for Initial Diagnosis

The differential diagnosis of mediastinal or retroperitoneal lymphadenopathy in patients with or without an underlying malignancy could be a challenge. The differential diagnosis can be insufficient or even impossible based on morphologic criteria. It includes unspecific reactive and inflammatory lymph node enlargements, pneumoconiosis, granulomatous diseases (sarcoidosis, tuberculosis, other mycobacterial diseases, mycosis), as well as malignant lymphomas and metastasis of a known or unknown other malignancy (Jenssen and Hollerbach 2013; Hollerbach et al. 2003, 2010).

Having less invasiveness compared to mediastinoscopy and VATS, EUS-FNP has a high power to clarify the nature of unspecified mediastinal lymphadenopathy or other lesions. To tap the full potential, it should include all histologic, immunochemical, molecular-biological, and bacteriological methods (Table 5.1). A close collaboration with the corresponding laboratory and pathology physician and the use of appropriate transport media for specialized examination is crucial.

Likewise, EUS-FNP can be used for difficult accessible lesions of the retroperitoneum (including adrenal gland, kidney, pancreas), of the spleen, and of the left liver lobe including the liver hilum (Table 5.2, Fig. 5.1). Additionally, para-aortic lymph nodes and lesions such as morbus Ormond are accessible up to the level of the aortic bifurcation using a transduodenal approach. EUS-FNP should be taken into account if liver lesions are not clarified by contrast imaging and are not accessible transcutaneously (Dumonceau et al. 2011; Adler et al. 2007).

Solid masses of the adrenal glands most often consist of nonfunctional, benign adenomas or hyperplastic nodules that do not require any histologic assessment (so-called incidentalomas). There are, however, some adrenal masses ranging from 3 to 6 cm in size that may require further workup (according to certain diagnostic algorithms) upon exclusion of hormonal activity from these tumors. EUS-guided fine-needle aspiration (or core-needle) biopsy (EUS-FNA) should only be performed after pheochromocytoma has been ruled out, for instance, by 24-h-sampling of urine to measure catecholamine and metanephrine levels. Most EUS-FNA biopsies with cytohistologic analysis are being carried out to search for metastasis into the adrenal glands in lung cancer, colonic cancer, and others. The left adrenal gland is readily accessible for EUS-FNA in virtually all cases (Fig. 5.2), while the right adrenal gland shows variable accessibility and cannot be seen by EUS in approximately 30–40% of cases.

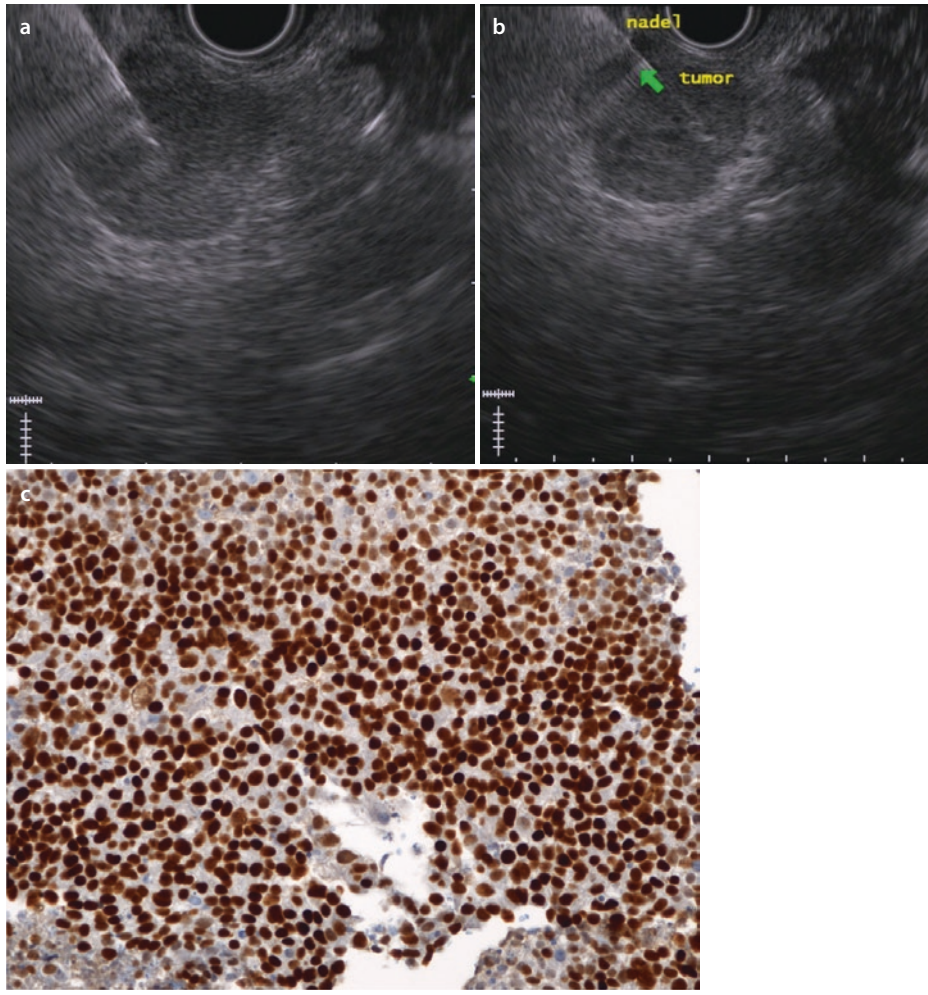

Fig. 5.1 **a** EUS-FNP of a small tumor of the pancreatic head. **b** Additionally, the position of the needle and the ultrasound tip in the duodenum can be seen. **c** The cytohistology confirms the diagnosis of a benign insulinoma

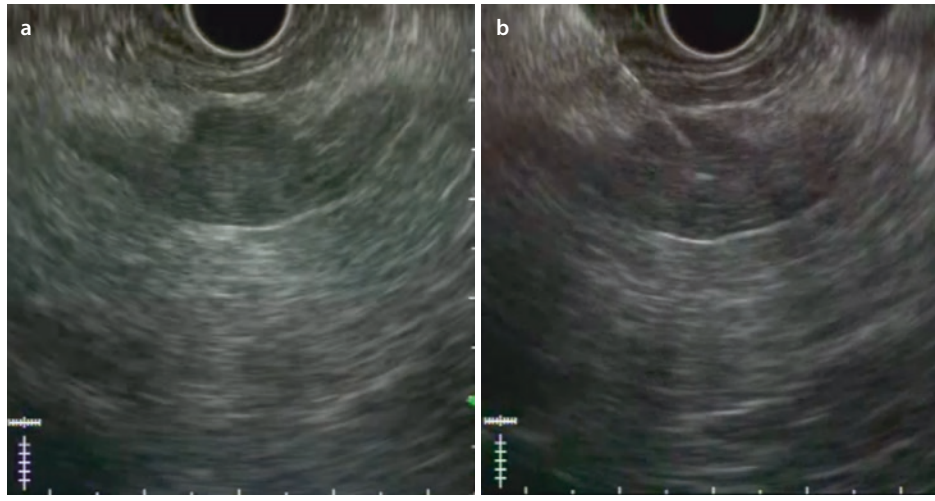

Fig. 5.2 EUS and EUS-FNP of a small metastasis of a colorectal cancer within the left adrenal gland, left adrenal gland with a small protrusion **a**, a metastasis of a colorectal cancer is confirmed by FNP **b**

EUS-FNA for Primary Diagnosis and Assessment of Malignancies

According to evidence-based standards, EUS-FNA is very helpful and indispensable for the primary diagnosis and staging of malignancies such as lung cancer, pancreatic cancer, and other pancreatic neoplasms such as neuroendocrine tumors, lymphoma, GIST, sarcomas, and others (Figs. 5.3 and 5.4). At present, EUS-FNA has replaced many other alternative procedures such as CT-guided or surgical percutaneous biopsies, or ERCP brush cytology specimens (Dumonceau et al. 2011; Jenssen et al. 2011a; Jenssen and Hollerbach 2013; Hollerbach et al. 2003, 2010; Sharples et al. 2012; Adler et al. 2007; Jenssen and Dietrich 2008).

Locoregional staging by EUS-FNA exerts a significant impact on the further clinical decision-making in cancer patients when cytohistologic proof of malignant disease stages a tumor up (or down, if true negative results are revealed). This is frequently the case in patients with lung cancer (NSCLC) – particularly when EUS-FNA reveals metastasis to the adrenal glands or retroperitoneal

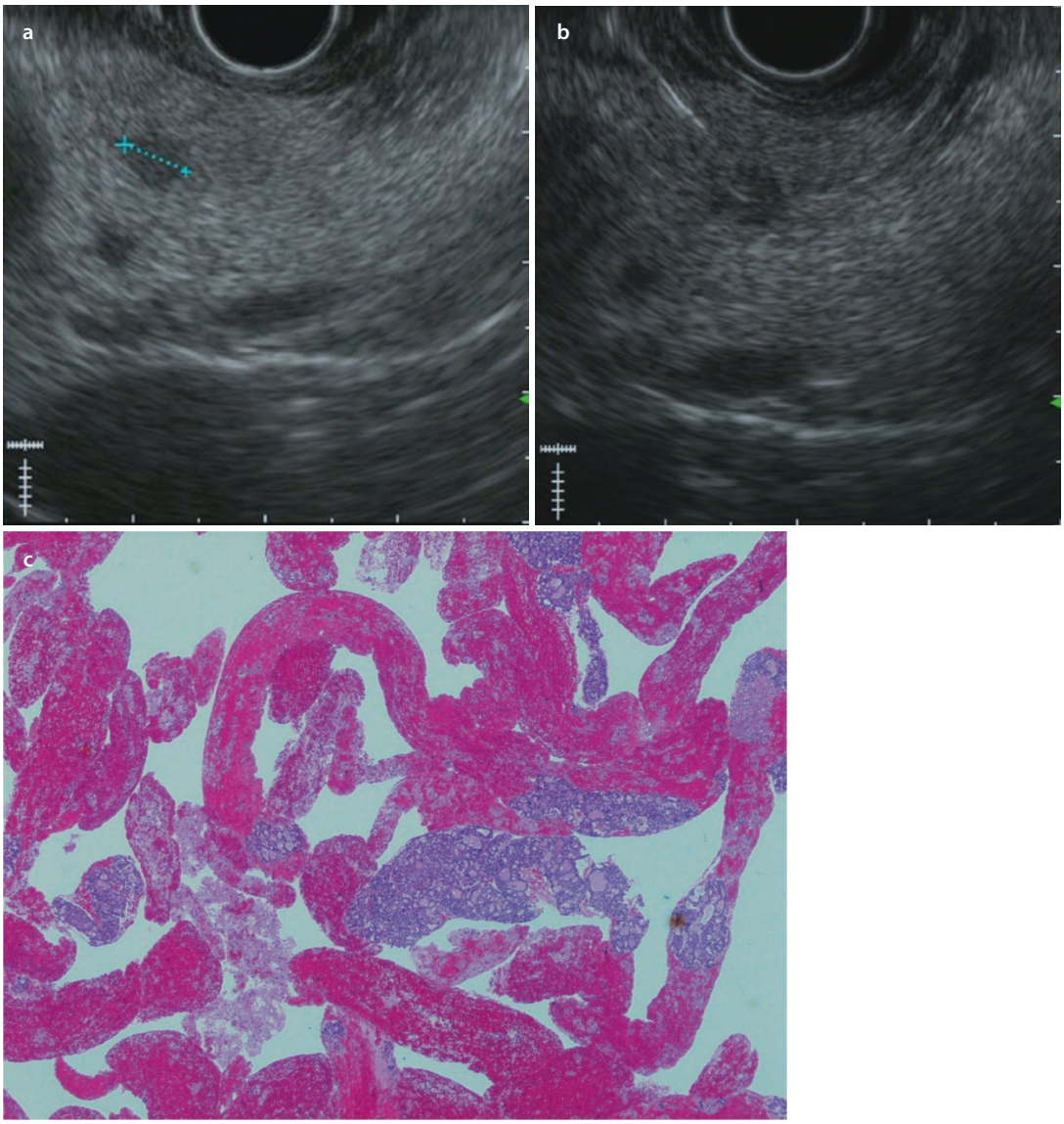

Fig. 5.3 EUS and EUS-FNP of a small pancreatic lesion **a**, which could be diagnosed by EUS-FNP **b** and corresponding cytohistology **c** as a small non-functional neuroendocrine tumor (NET)

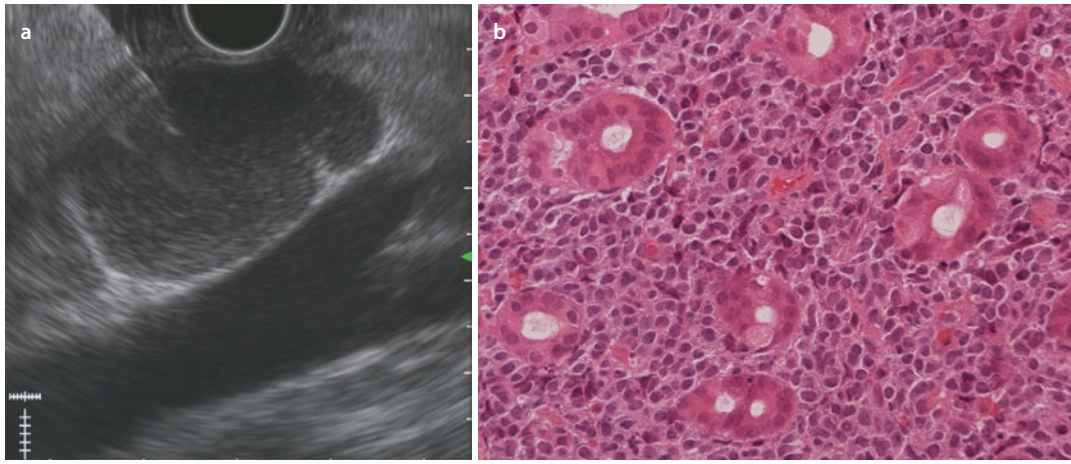

Fig. 5.4 **a** EUS-FNP of a lymphoma of unknown dignity located directly «on» the aorta. **b** The cytohistology confirms the diagnosis of a malign b-cell non-Hodgkin's lymphoma (B-NHL)

lymph nodes or when PET-negative, contralateral lymph nodes have been proved to be infiltrated by cancer (N3 situation). In such circumstances and disease stage, surgical procedures are most often deemed unnecessary and too aggressive since they do not offer any chance of healing to the affected patients but expose the patients to a high risk of postoperative complications (including postoperative mortality ranging from 2% to 4%, pulmonary complications in approximately 15% of cases).

Since both EUS-FNA and EBUS-TBNA exhibit a far superior safety and convenience profile for patients and investigators (when compared with thoracic surgery including mediastinoscopy/thoracotomy), major diagnostic surgery has almost become obsolete. Therefore, most patients do not need any surgical staging procedure. EUS-FNA and EBUS-TBNA are complementary procedures that allow for accurate oncologic tumor staging in almost every patient with lung carcinoma. Up to 25% of patients who are PET-negative do still have carcinomatous infiltrates within their regional lymph node stations, which can be detected by fine-needle biopsy in most instances. Hence, such positive N2- or N3-categories preclude patients from unnecessary operations. EUS-FNA also has the potential to disclose previously undiagnosed distant metastases such as adrenal gland involvement and/or small metastatic nodules in the liver or infradiaphragmatic lymph nodes. In summary, staging of lung carcinoma has been greatly simplified and improved by the use of endoscopic staging procedures including EUS-FNA and EBUS-TBNA (Table 5.2 and Table 5.3) (Jenssen and Hollerbach 2013; Hollerbach et al. 2010; Moehler et al. 2011). Modern contemporary staging concepts reserve surgical mediastinoscopy or VATS for the few remaining clinical cases in which EUS could not be properly performed or which were invariably negative due to technical difficulties or repeated sampling errors (Jenssen and Hollerbach 2013; Sharples et al. 2012). The clinical impact of EUS biopsy results in oncologic treatment algorithms in lung cancer, and other malignancies has been clearly proven by numerous clinical studies and can be considered evidence-based (Sharples et al. 2012).

Table 5.3 Additional clinical indications for EUS-FNA

Masses/suspicious lesions located in the adrenal glands (oncologic and/or endocrinologic queries)
Retroperitoneal masses or lumps (i.e., mesenchymal tumor, paragangliomas, ...)
Liver tumors (particularly HCC) and splenic masses/lesions in patients at increased risk for percutaneous biopsy
Unclear abdominal or retroperitoneal lymph adenopathy
Suspicion of retroperitoneal abscess

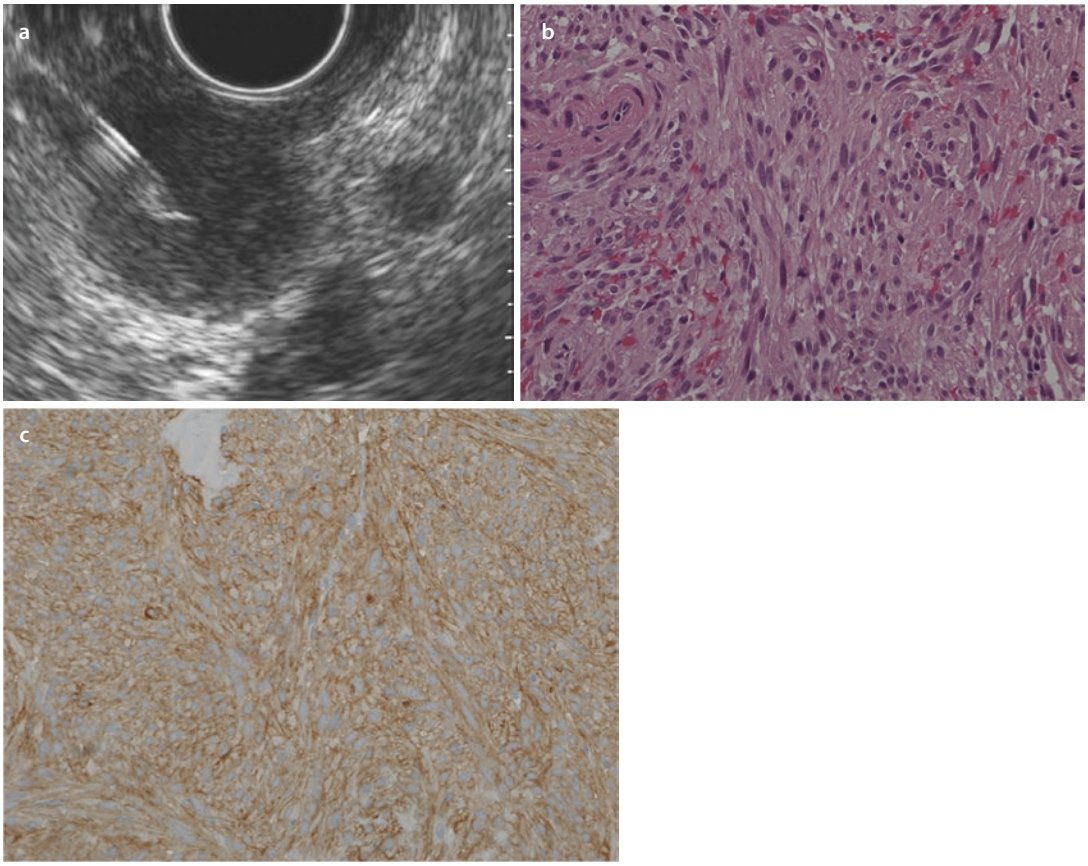

Fig. 5.5 **a** EUS-FNP of a small echoless subepithelial tumor. **b** A benign gastrointestinal stroma tumor (GIST) could be confirmed by cytohistology, as well as being positive for CD 117 **c**

EUS-FNA is also helpful and accurate for cytohistologic assessment of pancreatic tumors that – based on radiologic or endosonographic imaging findings and surgical judgment – appear to be unresectable at time of diagnosis (Dumonceau et al. 2011; Jenssen et al. 2011a; Moehler et al. 2011). Such findings preclude patients from unnecessary surgery and facilitate decision-making for neoadjuvant or palliative treatment decisions.

Approximately 10–15% of pancreatic tumors are not ductal adenocarcinomas but consist of other malignant (or semi-malignant) entities such as neuroendocrine tumors, metastases, lymphomas, or solid-papillary pancreatic tumors (young women). In all cases of doubt, EUS-FNA can be very helpful to establish a definite diagnosis prior to individual therapy, to rule out benign disease such as autoimmune pancreatitis, to assess prognosis of cancer patients, to plan surgical strategy, and – most recently – to allow for novel therapeutic studies that investigate new regimes for neoadjuvant therapy in pancreatic cancer.

EUS-FNA techniques can be helpful for assessment and definite diagnosis of subepithelial tumors (SET) in the upper and lower GI tract (Fig. 5.5). EUS needles, however, have a limited diagnostic accuracy – particularly in small tumors (<1.5 cm) – that is superior to other approaches such as «button-hole» forceps biopsies during EGD (Dumonceau et al. 2011; Jenssen et al. 2011a; Jenssen and Hollerbach 2013; Jenssen and Dietrich 2008) but still doesn't exceed >65–70% in this setting, which is not satisfying as yet. Accuracy can possibly be enhanced by using novel biopsy devices such as the «shark core» needle, but the potential of such techniques remains to be substantiated by ongoing clinical trials.

In patients suffering from ampullary or biliary neoplasias including bile duct and gall bladder carcinomas, EUS-FNA achieves better results than other diagnostic approaches including brush biopsies or

biliary forceps biopsies. Even small neoplasias are clearly visible and detectable by EUS and can be punctured with high diagnostic accuracy.

In some other malignancies including focal liver tumors such as hepatocellular carcinoma (HCC), intrahepatic cholangiocarcinoma (CCC), or scirrhous gastric cancer, EUS-FNA can be used (with high diagnostic accuracy) as an alternative technique to obtain histologic proof of disease and tissue-based diagnosis for targeted oncologic therapies and treatment planning (Dumonceau et al. 2011; Jenssen et al. 2011a; Jenssen and Hollerbach 2013; Hollerbach et al. 2010).

EUS-FNA for Lymph Node (N-)Staging in GI Malignancies

EUS-FNA has been proven to play an evidence-based role for the clinical staging of GI malignancies including N-categories. However, its accuracy for the detection and biopsy of malignant lymph nodes is limited by anatomical factors as well as problems of accessibility for fine-needle puncture. As pointed out earlier, EUS-FNA and EBUS-FNA both play a major role for lung cancer staging including N-staging and have an important impact on clinical decision-making in affected patients.

Detection and locoregional biopsy of suspicious retroperitoneal lymph nodes are also very important in other cancers such as biliary carcinoma, hepatocellular carcinoma, and neuroendocrine tumors, as shown in several clinical studies.

In contrast, locoregional involvement of peripancreatic lymph nodes does not change current treatment protocols including radical surgery as single most important measure, whereas novel neoadjuvant treatment studies are currently on their way that may possibly change the dismal clinical course and prognosis of affected patients.

In patients with esophageal, gastric, duodenal, and rectal cancer, however, the overall survival and prognosis are highly dependent on lymph node (micro-)metastasis, as shown in numerous clinical studies. The presence of lymph node spread (= N+ situation) in such cancers dramatically reduces the 5-year survival rate of affected patients by more than 50%. If stage N+ and/or advanced T stages are found during EUS staging in such cancer patients, neoadjuvant treatment protocols should be the strategy of choice in most instances. Therefore, German clinical S3 guidelines recommend EUS staging for esophageal, gastric, and rectal cancer in combination with imaging studies (CT, MRT, PET), whereas the exact role of FNA has not yet been fully addressed in these guidelines. Accuracy of N-staging can be substantially improved by EUS-FNA (Moehler et al. 2011). If FNA is performed by passing the needle through the tumor into a regional lymph node, this biopsy is often contaminated by tumor cells arising within the GI wall layers but not from the lymph node itself (Jenssen et al. 2011a; Levy et al. 2010). This problem must be avoided during EUS-FNA by choosing different pathways for the biopsy needle that do not go straight or laterally through tumor-infiltrated GI layers, and by removing the stylet of the needle only after the needle tip is clearly visible within the lymph node.

Lymph nodes should only be biopsied, however, during EUS staging if the results have a high likelihood to change the individual treatment strategy in all patients, for instance, decisions in favor of palliative versus surgical treatment.

Distant metastasis is only rarely detectable by EUS techniques in GI cancers because of the locoregional character of this technique and limited access to distant organs and compartments. However, in up to 12–15% of EUS staging cases with esophageal, gastric, pancreatic, and biliary cancers, EUS may detect previously unknown – or unclear – focal lesions that were not clearly visible, or mistaken, during CT or MRT imaging (= «obscure» metastasis). Examples include distant suspicious lymph nodes in pancreatobiliary cancer such as mediastinal lesions, small liver metastasis <5 mm in patients with esophageal or gastric or colorectal cancer, small adrenal noduli, pancreatic lesions, and peritoneal or pleural masses. In such cases of doubt, needle biopsy should be undertaken or attempted since histologic proof of advanced disease may dramatically change treatment decisions, including surgical interventions that are no longer indicated. Knowledge of TNM staging classification for each subtype of GI cancer is absolutely necessary (Sobin et al. 2009) before oncologic treatment plans can be made with accurate certainty.

For therapeutic interventions, advanced expertise arising from advanced experiences with EUS techniques is the principal requirement prior to introduction of such techniques. Table 5.4 demonstrates the current status of therapeutic EUS techniques in the clinical setting, of which several techniques should still be regarded as strictly experimental.

Table 5.4 Existing array/options of EUS-guided endoscopic therapy

Clinically established therapeutic EUS procedures
EUS-guided drainage therapy of pancreatic pseudocysts (including stent and other drainage catheter implementation)
EUS-guided celiac plexus neurolysis (EUS-CPN) for pain therapy in malignant pancreatobiliary tumors or chronic pancreatitis (clinical effectiveness – according to definition – between 50 and 80%).
EUS-guided cholangiodrainage (EUS-TCD)
EUS-guided pancreatic duct drainage (EUS-TPD)
Experimental therapeutic EUS procedures
EUS-guided intratumoral injection therapy (EUS-FNI) of malignant cysts and tumors with cytotoxic agents (such as paclitaxel), chemotherapeutics, immune-modulators (i.e., mixed allogenic lymphocyte populations, TNFerade), and others
EUS-guided implantation of «seeds» for local brachytherapy radiation (tumors, celiac plexus) or medications (tumor therapy)
EUS-guided radio-frequency ablation (RFA) of tumors (pancreatic carcinoma, liver metastasis, retroperitoneal tumors)
EUS-guided local laser-, therapy- or photodynamic therapy
EUS-guided botulinum-toxin therapy (Achalasia)
EUS-guided trans-endoscopic surgery (NOTES), for instance, transmural lymph node extraction, gastrojejunostomy, bariatric endoscopy, and others
EUS-guided endoscopic mucosal resection (EUS-EMR)
EUS-guided variceal injection therapy
EUS-guided intravascular therapy (for instance, endo-coils for PA-embolization)

Contraindications and Clinical Risk Profile of EUS-FNA

Thanks to the small needle size and flexibility of modern echoendoscopes, the number of contraindications for EUS-FNA is very low. EUS-FNA has been proven to be a safe and accurate diagnostic technique in humans, which greatly facilitated its widespread use in the Western world. Naturally, all general rules and limitations and contraindications of other routine endoscopic procedures apply the same way to EUS-FNA. These include therapeutic anticoagulation, novel oral anticoagulation substances[1] (NOAK), or clopidogrel and other ADP-antagonists.[2]

In addition, patients with severe plasmatic coagulopathies (INR >1.75, significantly prolonged activated prothrombine time PT), or those presenting with severe thombopenias (thrombocyte count <50,000), should not be deliberately subjected to EUS-FNA in terms of a pre-diagnostic risk assessment. In contrast, aspirin (ASS) treatment is no longer considered to be a major obstacle to EUS-FNA.

Other absolute contraindications of EUS-FNA include lack of informed consent by patients or lack of visibility during needle biopsy. To minimize risk of bleeding, interpolated vessels located within the needle tract should always be avoided during EUS-FNA.

The general clinical condition of the individual patient needs always to be considered, while EUS-FNA is planned during clinical risk assessment strategies. If EUS-FNA results do not look likely to impact further clinical decision-making, its indication should always be critically reassessed. Tables 5.5 and 5.6 demonstrate absolute and relative contraindications for EUS-FNA.

The *overall rate of complications* of diagnostic endosonography (without FNA) is reported to lie somewhere in the range between 0.03% (retrospective questionnaires) and 0.22% (prospective studies). Complications of EUS-FNA are somewhat more frequent: one systematic analysis of 51 EUS-FNA studies including 10,941 patients reported a cumulative complication rates of 0.98%. Looking at the 31 existing prospective studies only, however, sheds a – probably more realistic – light on the clinical situation: in this analysis the cumulative rate of complications reached 1.71% of cases (Polkowski et al. 2012; Wang et al. 2011; Gottschalk et al. 2012; Jenssen et al. 2011b). Similar data could be obtained from the prospective German Endosonography Register, which reported overall complication rates around 2.05% of diagnostic cases (▶ www.eus-degum.de) (Gottschalk et al. 2012). Mortality

1 Including novel anticoagulants such as dabigatran (Pradaxa®) and rivaroxaban (Xarelto®).
2 Clopidogrel (Plavix ®, Iscover®), prasugrel (Efient ®), ticagrelor (Brilique®).

Table 5.5 Contraindications for EUS-FNA/EUS-FNI

Absolute contraindications
Missing informed consent of patients
Patient uncooperative, lack of sufficient sedation
Severe coagulopathy
Oral anticoagulation, therapeutic heparin treatment or plasmatic clotting disorders (INR > 2; thrombocyte count <50,000)
Thrombocyte-aggregation inhibitors such as clopidogrel and other ADP antagonists (prasugrel, ticagrelor)
Continued intake of novel anticoagulants such as Xa antagonists (e.g., rivaroxaban) or thrombine antagonists (dabigatran)
Combinations of clotting-impairing substances => reduction on ASS only
Cystic mediastinal lesions
Interposition of large blood vessels
Relative contraindications
Patient cases in whom no significant impact of EUS-FNA results can be expected
Limited visibility/control of FNA needle tip at biopsy
EUS-FNA of hepatic lesions in cases of non-sufficient drainage of obstructed bile ducts

Table 5.6 Risk profile and adverse effects of EUS-guided risk profile and adverse neurolysis therapy (EUS-CPN)

Frequent adverse events (in approximately 20–30% of cases)
Post-interventional small–moderate drop of blood pressure RR (hypotonia): usually self-limiting
Transient diarrhea (1–2 days post intervention)
Local hemorrhage (frequently self-limiting, conservative management)
Mild–moderate pyrexia: frequently self-limiting
Local pain syndrome: frequently short-acting, self-limiting
Rare, serious adverse events (in approximately in 1–3% of cases)
Local infections with abscess formation
Sepsis: particularly reported following local corticosteroid injection
Single cases: GI ischemia/infarction including spleen, small bowel, stomach, colon
Single cases: spinal infarct/transient nerve palsy

rates, in contrast, have only been reported in extremely rare circumstances.

The most frequent adverse events (AE) include light (or moderate) pain, transient lipasemia, fever, and light infectious events. Less frequently, intra- and extraluminal bleedings/hemorrhages have been reported that mostly stopped and resolved spontaneously. Severe adverse events (SAE) such as perforation, biliary, and pancreatic leakages, however, have only rarely been reported (Gottschalk et al. 2012; Jenssen et al. 2011b).

The risk of tumor-cell seeding by EUS-FNA may exist in rare cases, but its clinical significance remains obscure despite some reports in the literature. Evidence is poor since only a few case reports exist, and the clinical consequences of such events have not always been reported.

The design and rigidity of some – mostly earlier endoscope series – echoendoscopes exposes the instrument to a somewhat higher risk of perforation, particularly at natural anatomic narrowings such as hypopharynx, the cardia (particularly in the presence of axial hiatal hernia), the distal duodenal bulbs, and the rectosigmoid junction. In addition, rare diverticula such as Zenker's diverticulum, or duodenal diverticula, as well as esophageal, gastric, or intestinal stenosis, puts the patient at increased risk of perforation and should be ruled out by EGD prior to EUS in all patients.

Intestinal stenoses that cannot be passed by echoendoscopes are to be expected in up to 25% of patients presenting with esophageal and rectal carcinomas, while this problem only rarely occurs in gastric and pancreatic carcinoma. The German EUS register (see above) reported only ten cases with GI perforations out of 14,000 diagnostic patient cases (0.07%). Of these, six occurred in the duodenum, two in the esophagus/hypopharynx, one in the stomach, and one in the rectum (Gottschalk et al. 2012). Risk factors for perforations include low level of investigator's experience, unexpected intestinal stenoses, and the presence of diverticula (Polkowski et al. 2012; Wang et al. 2011; Gottschalk et al. 2012).

The number of GI perforations does not appear to be significantly increased by EUS-FNMA techniques, though some cases with free air in the peritoneal cavity after EUS-FNA have been reported. According to these reports, the majority of patients did not exhibit clinical complaints or longer-lasting pain or fever. In contrast, EUS-guided therapy carries a significant risk of GI perforation in most instances and depends on investigator experience as well as on the particular therapeutic maneuver used (see following chapter).

Septicemia and peritonitis are extremely rare incidents after EUS-FNA, if caused by this procedure at all. However, when EUS-FNA of cystic lesions (including pseudocysts, neoplastic cysts, ascites) is considered, peri-interventional antibiotic therapy should be an integral part of the standard operating procedure, since EUS-FNA of cystic and infected lesions exposes the patients to a significantly greater risk of procedure-borne infectious complications.

EUS-FNA of mediastinal cysts can eventually lead to catastrophic events such as mediastinitis and death, without adding any substantial diagnostic or therapeutic yield for such patients. In consequence, its use for bronchogenic cysts and esophageal duplication cysts is not indicated and should be avoided in all cases (Jenssen et al. 2011b). If in doubt, apply intravenous contrast material (SonoVue, Bracco) to rule out neoplastic cysts in cases in whom cellular detritus suggests solid appearances within mediastinal cystic lesions.

If unexpected and/or suspicious cystic lesions are found during in other organs or compartments than the mediastinum during upper GI EUS procedures, we recommend application of i.v. antibiotics prior to FNA of such lesions. Typical antibiotics include broad-spectrum penicillins (such as ampicillin or piperacillin) or gyrase inhibitors such as ciprofloxacin (200 mg). Administration of antibiotic therapy should then be continued until the following day. In immunocompromised patients, antibiotics should be administered generously at the discretion of the treating physician.

For transrectal EUS-FNP, general prophylaxis with antibiotics is not required but should be tailored to individual risk of patients.

Severe hemorrhages after diagnostic EUS-FNA are only rarely encountered. Typical risk factors for major bleedings include severe coagulopathies, anticoagulants (including NOAK), and portal hypertension. Very few fatalities, however, have been reported in the literature. In contrast, continued treatment with aspirin (ASS) appears to be safe and is generally not associated with increased rates of severe hemorrhage after diagnostic EUS-FNA. Continued treatment with combinations of ASS with clopidogrel or similar substances, however, should be avoided prior to EUS-FNA, since this combination increases the risk of severe and prolonged hemorrhage (Polkowski et al. 2012; Jenssen et al. 2011b). Figure 5.6 depicts a typical post-FNA bleeding that was visible during EUS-FNA; in this case, no clinical symptoms occurred, and no consequences had to be considered.

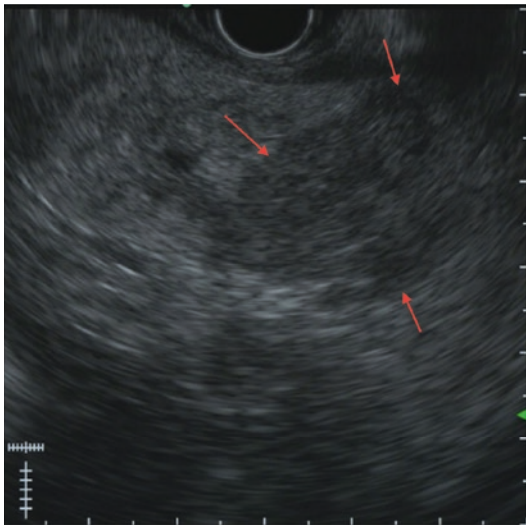

Fig. 5.6 Localized bleeding after EUS-FNP at the pancreatic head. The asymptomatic bleeding stopped without intervention

5.2 EUS-Guided Drainage Techniques

5.2.1 EUS-Guided Cyst Drainage

Initially, bulging of the GI wall was a prerequisite for endoscopic cyst drainage (Bahari and Ismail 1982). By introduction of endoscopic ultrasound as access guidance, intervening vessels within the puncture tract could be avoided (Giovannini et al. 1998). Additionally, fluid collections without bulging became safely accessible (Park et al. 2009;

Varadarajulu et al. 2008). Even without randomized controlled studies, guidance by EUS became the method of choice for access.

Initially, the cyst is punctured by the use of a 19G needle, which makes it possible – after diagnostic aspiration of cyst fluid – to proceed with the introduction of a 0.035″ guide-wire. This guidewire serves as the track for further bougienage and dilatation with instruments such as cystostoms and balloon catheters. The widened access is secured by one or more drainages. Double-pigtail drainages have the advantage of being stable in position. Increasingly, metal stents are used for this purpose.

Alternatively, all-in-one sets are increasingly used, including instruments for access, dilatation, and drainage via a metal stent designed for application via the working channel of the echoendoscope. For further details, see ► Chap. 10.

5.2.2 EUS-Guided Retroperitoneal Necrosectomy

Endoscopic therapy of infected pancreatic necrosis was described in 2000 by Seifert (Seifert et al. 2000). The access to the necrotic cavity is gained analogously to EUS cyst drainage. In contrast, the final diameter should be wider to allow the removal of necrotic material. The location of the access is crucial, since necrosectomy in inversion can be extremely difficult of even impossible.

The indication for endoscopic necrosectomy has to be questioned critically, since it has been shown that even proven infected necrosis can be managed conservatively in many cases (Runzi et al. 2005). In general, only a symptomatic necrosis could be an indication for an intervention. Symptoms could be evoked either by septic complications or by the size of the lesion compressing adjacent structures. Laboratory findings (such as elevation of CRP or leukocytosis) or fever could be indicative for an infection. However, infectious complications have to be taken into account after the beginning of the third week of the pancreatitis, while beforehand, the same findings could be a part of a systemic inflammatory response syndrome (SIRS). The size of a necrosis could lead to an obstruction of the gastrointestinal tract or of the bile duct, while in others, it is asymptomatic or accompanied by pain.

After providing the indication, several therapeutic options have to be weighed. Apart from an endoscopic procedure, surgery and percutaneous drainage are options. These modalities are not exclusive; they could be combined with each other. By percutaneous drainage, a rapid decompression of infected areas is feasible, which often leads to an impressive stabilization of the patient. By guidance of percutaneous ultrasound or computed tomography, it is available in every hospital und even for patients in a dismal condition. The external drainage could serve as flushing access when combined with an internal endoscopic drainage. However, the removal of necrosis by a sole percutaneous access is only feasible with large-bore catheters in combination with long-term flushing. Additionally, this method is associated with a high risk of a persisting pancreatic fistula.

Open surgical removal of infected necrosis, for years the gold standard of therapy, is associated with high mortality. Despite optimization of the surgical technique including minimal invasive retroperitoneal access, the mortality seems to stay higher than endoscopic necrosectomy as described below.

Surgery can be necessary if endoscopic expertise is not available locally and the patient cannot be referred to another hospital. In rare cases, necrosis could be out of range for an endoscopic intervention.

Access to the necrotic cavity is obtained in the same manner as for endoscopic cyst drainage. A suitable drainage site does not show any interfering vessels. An area is preferred as the puncture site where there is an inflammatory connection between the cyst wall and the gastrointestinal wall. In this case, the muscularis propria and the cyst wall may not be delineated. A transgastric route is easier and therefore preferred, since the transduodenal access could be angulated and tight. The less elevation is needed for forward puncturing, the greater is the force. Therefore, a necrotic cavity should be addressed at the end, which is next to the cardia.

When using the sequential technique, the first step is puncturing with a 19 G EUS needle (◘ Fig. 5.7). Aspirated fluid is used for microbiological and laboratory examinations. Instead of the EUS standard fine needle, a specially designed access needle with a sharp stylet at the tip could be used, which becomes blunt after removal of this stylet. The next step is securing the access by introduction of a 0.035″ guide-wire into the necrotic cavity including several loops. (◘ Fig. 5.8). The position of the guide-wire could

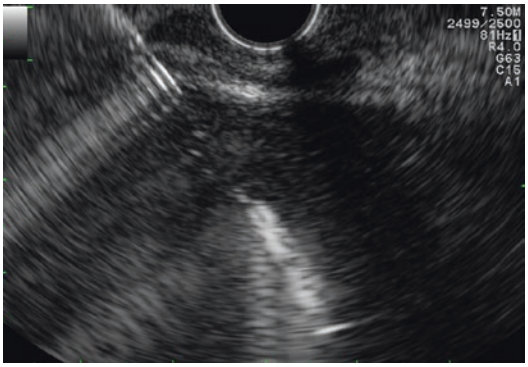

Fig. 5.7 EUS image of the puncture of a pancreatic pseudocyst. The cyst is punctured from *left above*. The reflex of the needle may be easily seen

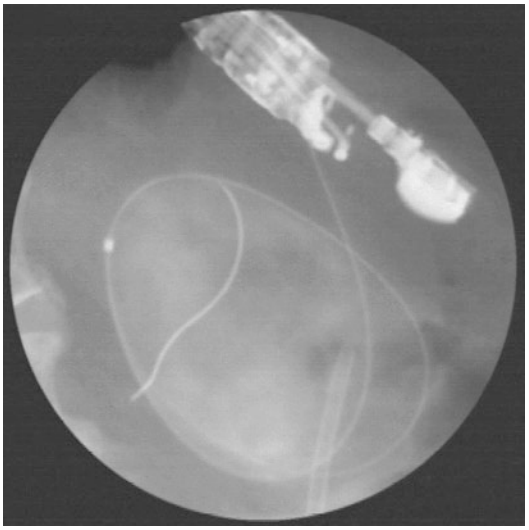

Fig. 5.8 Fluoroscopic image after endosonographic puncture of a pseudocyst, contrast injection, and insertion of the guide-wire with several backup loops

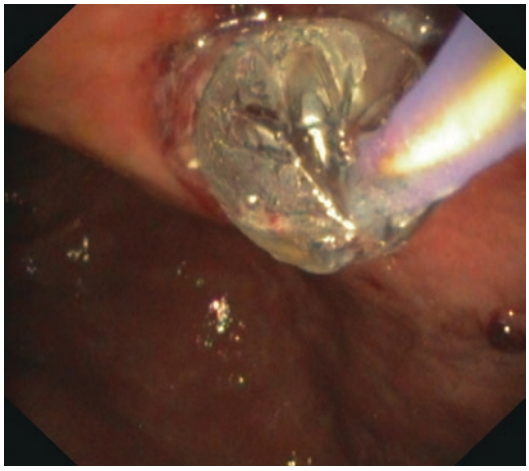

Fig. 5.9 Endoscopic image of an insufflated dilation balloon, which should widen the access to a necrotic cavity

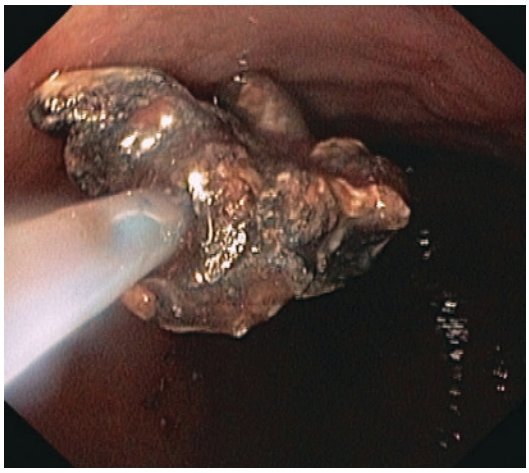

Fig. 5.10 Endoscopic image: necroses are removed by a polyp grasper

be controlled either by endoscopic ultrasound or by fluoroscopy.

The next step is expansion of the access channel electrically by cystostome or mechanically by balloon dilation (Fig. 5.9). The diameter needed for endoscopic necrosectomy is in the range of 16–20 mm. In the case of inflammatory adherence, this diameter could be achieved during the first session, while in other patients a stepwise dilation is recommended. After initial placement of a single 10F drainage, it is feasible to achieve the needed diameter by stepwise adding several drainages. The peri-stent inflammatory reaction leads to the establishment of a stable channel for further removal of necrosis.

Alternatively, the access could be established by lumen-apposing metal stents, which make a faster procedure possible. The costs of this specially designed stent are high but may be justified by the benefits of less and shorter interventions.

At least after the second intervention, the channel is stable and endoscopic necrosectomy can be performed safely (Jurgensen et al. 2012). To begin even during the first session could be associated with an increased risk of perforation, as seen in the American multicenter study (Gardner et al. 2011).

Polyp graspers, snares, and baskets are used to remove necrosis (Fig. 5.10). However, all instruments have their limitations when used to grasp

the necrosis of either smooth or bezoar-like consistence. As a result, the removal of necrosis is enormously time-consuming. In our experience, three endoscopic sessions each lasting 2 h is typical just for removal (Jurgensen et al. 2012). The necrosis is grasped in its cavity and then dropped in the gastrointestinal tract. By this removal, the cavity can become smaller. After each intervention, drainages are repositioned in the channel to prevent a premature closure with the risk of retention of infectious remnants.

Finally, all transluminal drainages are removed 6–8 weeks later, with intermediate demission of the patient. Usually, the cavity has closed in the meantime with the drainages as the last remnant.

Initially successful in single patients, the efficacy of this method has been confirmed in the meantime by three multicenter studies (Gardner et al. 2011; Seifert et al. 2009; Yasuda et al. 2013). Mortality was in the range of 6–8%. One little randomized study was able to show clear advantages for endoscopic necrosectomy in terms of inflammatory parameters compared to a surgical approach (Bakker et al. 2012). However, the difference of mortality (four in the surgical group versus one death in the endoscopic group, with ten patients in each therapeutic arm) was not significant. A randomized comparison from the Dutch pancreatis group is awaited.

In conclusion, endoscopic necrosectomy – if available – has become the method of choice for symptomatic pancreatic necrosis. However, it does not solve all problems, and consensus to its use should be achieved in interdisciplinary consensus.

5.2.3 EUS-Guided Therapy of Common Bile Duct and Pancreatic Duct

EUS-Guided Cholangiodrainage

EUS-guided drainage in cases of cholestasis has been increasingly used over recent years in expert centers. However, it still cannot be judged as an established method. Two different approaches may be distinguished: EUS-guided guide-wire insertion as the basis for a rendezvous maneuver, and EUS-guided direct drainage of bile ducts. A mechanical cholestasis, untreatable by a less invasive method, is an indication for both approaches. This constellation could be given in a patient with inoperable pancreatic carcinoma, when the papilla cannot be accessed or cannulated and the patient refuses to have a percutaneous transhepatic drainage.

The initial step is to puncture the enlarged intrahepatic bile ducts of the dilated common bile duct with a 19G EUS needle under EUS guidance. Injection of contrast and visualization of the bile duct by fluoroscopy is the next. Both are easy steps for an experienced endosonographer. Cholangiography is successful in nearly every patient (97–100%) (Isayama et al. 2013). Then, a 0.035″ guide-wire is advanced through the needle. The attempt is to advance its antegrade through the papilla. If this is successful, the guide-wire can be picked up at the papilla and be used for retrograde intubation, as part of a classical rendezvous maneuver. Further procedure is as known from conventional ERC.

However, even specialists fail in one of four patients to pass the guide-wire antegradely through the papilla (Isayama et al. 2013; Will and Meyer 2012). Now, the concept has to be switched to EUS-guided cholangiodrainage. To stop after puncturing, a congested bile duct with a 19G needle without drainage can become disastrous due to development of a bile fistula into the retroperitoneum. This direct drainage is a more challenging technique and requires a huge amount of technical skill from the endoscopist: after puncturing and advancing a guide-wire, the access has to be enlarged for introduction of a stent. This transduodenal access is characterized by a pushed endoscope position and a contorted route for the further drainage. Additionally, no inflammatory adhesions between common bile duct and the duodenal wall prevent the stiff bile duct from evasion. In case of failure, bile leaks into the retroperitoneum.

If choosing a transhepatic route (◘ Fig. 5.11) the forward power could be limited, resulting in difficulties in widening the access and protruding the drainage. Both access routes include the risk of drainage dislocation, with potentially disastrous consequences.

Fully covert stents (i.e., Axios stent ©) with smaller calibers suitable for the bile duct are developed recently for EUS-guided application.

EUS-Guided Pancreatic Duct Drain age

As for cholestasis, EUS-guided drainage of the pancreatic duct is an attractive option in case of a congested duct. The rare clinical situations of

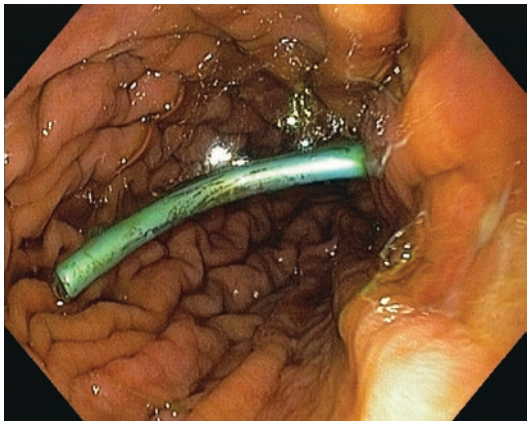

Fig. 5.11 Endoscopic image of a transgastric bile drainage located to drain a dilated left hepatic bile duct

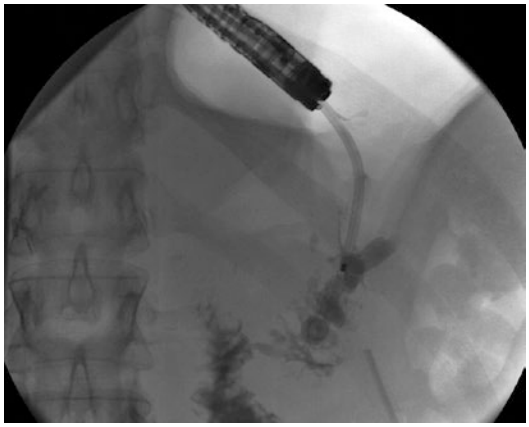

Fig. 5.12 X-ray of a transgastric pancreatic duct drainage after pancreatic head resection. The patient became symptomatic secondary to a stenosis of her filiform pancreatic anastomosis

an intraductal infection or pain caused by inhibited pancreatic outflow are good indications. In most patients, a transpapillary access is feasible. Additionally, surgery is an alternative therapeutic option with better long-term results compared to endoscopy. When considering an EUS-guided pancreatic duct drainage, the technical difficulty and the missing long-term concepts for further management of transmural drainages have to be taken into account.

In most patients, the pancreatic duct is punctured transgastrically. The technique is similar to the above-described procedure of cholangiodrainage. If the transpapillary access fails, the pancreatic parenchyma is often stiff due to chronic pancreatitis. Additionally, the unfavorable further route of the duct is problematic. Finally, if first drainage is successful (Fig. 5.12), these drainages often migrate spontaneously. As a result, only in a small number of interventions it is possible to perform pancreatic duct drainage with an acceptable success rate (Will et al. 2007).

5.2.4 EUS-Guided Local Tumor Therapy

Endoscopic ultrasound is a local method and is therefore only able to be an instrument of local therapy. Therefore, it can be a curative option only for nonmetastatic tumors, which have to be addressed due to their prognosis or due to their symptoms (for instance resulting from hormone secretion). Additionally, it could reduce locally the tumor mass as part of a multimodality treatment (debulking). Finally, endosonography is able to place fiducial markers to guide further radiation therapy.

After the first report of an ablation of an insulinoma by alcohol (Jurgensen et al. 2006), this successful local therapy of hormone-secreting tumors has been confirmed by many case reports and small case series. Additionally, alcohol lavage or injection of paclitaxel has been described for cystic pancreatic tumors. In some of them, it was possible to achieve complete remission by this therapy (DeWitt et al. 2010). However, this therapeutic approach is under discussion, since the exact nature of the cystic lesions and the long-term follow-up were not clarified.

The therapy of a single hepatocellular carcinoma by EUS-guided alcohol injection or by laser ablation has been described.

The feasibility of local therapy by EUS-guided cryoprobe or by injection of modified virus has been evaluated in humans. Long-term follow-up data are not provided. The EUS-guided placement of fiducial markers to direct radiation therapy is feasible in patients with pancreatic or prostate carcinoma. The EUS-guided application of radioactive seeds is feasible. Long-term data is missing as well.

In conclusion, EUS-guided tumor therapy is still experimental. Outside of studies, it could be considered in patients with neuroendocrine tumors or hepatocellular carcinomas, if surgery is not feasible.

5.2.5 EUS-Guided Therapy: Miscellaneous (Fistulae, Vessels)

Endoscopic ultrasound offers the option of further interventions, which are not sufficiently evaluated yet and therefore should not be discussed in detail. Fistulas of the pancreas could develop after pancreatic surgery or as part of severe pancreatitis. These fistulas are often asymptomatic, if they drain into the gastrointestinal tract. In contrast, they could be symptomatic, if they drain into the pleural cavity or cutaneously. Often they are located next to the stomach and could be punctured and filled with contrast by use of the technique described above for pancreatic cysts and necroses. Even if small in diameter, they could be cannulated by a guide-wire and drained transgastrically after dilatation. Additionally, an attempt should be made to improve the transpapillary outflow.

EUS-guided thrombin injection into visceral aneurysms in humans and the obliteration of submucosal arterial vessels in animals have been described. The application of this technique for venous vessels is mainly restricted to varices, mostly of the fundus. Occlusion is achieved by injection of cyanoacrylate or of small coils into the feeding vessels. However, endosonography is often not available in case of acute fundal variceal bleeding, while an obliteration therapy – either endoscopically or via EUS – is not established as part of secondary prophylaxis.

5.3 EUS-Guided Celiac Plexus Neurolysis (EUS-CPN)

■ Introduction, Background, and Indications for EUS-CPN

Pancreatic carcinomas and retroperitoneal metastasis of other tumors frequently produce massive, long-lasting, intractable pain in affected patients. This pain may be difficult to control and manage solely by orally administered drugs or patches (American Cancer Society: Cancer Facts and Figures 2007). Optimizing pain management is therefore the most important goal of palliative care in such patients. In addition, opiates and morphine frequently exhibit various disabling side effects ranging from severe constipation to dizziness/vertigo/nausea and vomiting which may significantly limit or hamper their dosage and use in this patient group.

The celiac plexus is located just below the diaphragm at level of the first lumbar spine (LSP-1). It consists of a dense network of sympathetic nerve fibers that run parallel to the ventral aspect of the abdominal aorta at level of the root of the celiac trunk.

The celiac plexus transmits pain signals of almost all visceral organs cephalad including pancreatic, biliary, hepatic, renal, intestinal, and pelvic pain to higher CBS centers. It is, however, connected with other ganglionic networks. The celiac plexus apparatus is not the sole source of pain in such tumors, since other connected neural structures are also involved in visceral pain generation and transmission, including the hypogastric and mesenteric plexus. Therefore, celiac plexus neurolysis alone may always be limited by this anatomic reality.

Local treatment of chronic pain syndromes by celiac plexus injection has been attempted for decades, particularly in patients with pancreatic carcinoma and chronic pancreatitis. Single centers developed the first percutaneous treatment plans for CPN back in the 1950s, but these techniques never made it far due to great limitations of X-ray techniques until CT scanning was developed in the 1980s of the last century. After CT scanning became common, several centers tried ventral or dorsal access routes under CT guidance to reach the celiac plexus region percutaneously under real-time conditions. The first uncontrolled studies and case series showed some limited clinical success in selected cases that were reported to range up to 60–70% of patients included. However, due to the high degree of specialization and experience, only a few centers offered this form of treatment, and some cases were reported that developed serious adverse events – including paraplegia, severe hemorrhages, infections/abscess formation, ischemia, and even death.

During the 1990s, the novel EUS technique facilitated further refinement and new developments for EUS-guided CPN under real-time conditions. First case reports and case series (Romanelli et al. 1993; Mercadante and Nicosia 1998) and subsequent uncontrolled clinical stud-

ies suggested (Wiersema and Wiersema 1996; Puli et al. 2009; Arcidiacono et al. 2011) some positive and lasting effects of EUS-CPN in selected patients. These effects included reduction of analgesics (dose, number of pills taken) and transient pain relief in up to 80–90% of treated patients for a couple of weeks (Mercadante and Nicosia 1998). The complication rate reported was low, and most adverse events consisted only of mild events including transient diarrhea, transient hypotension, or light pain with spontaneous relief.

One of the most intriguing problems with this EUS-treatment technique is the fact that the simple anterior plexus injection of ablative substances cannot be effectively targeted and visualized during the procedure. Due to the lack of visibility using EUS-FNI, it is not possible to calculate, or assess, the number of plexus fibers/ganglia during intervention, which limits its applicability in clinical practice substantially. Up to now, no sham-controlled, prospective, randomized clinical study exists to serve as an evidence base for EUS-CPN.

Some working groups have, therefore, studied effects of bilateral plexus injections in one single session, or in some patients, EUS-guided «broad-range» injections using small-caliber 25-gauge needles that included areas around the root of the superior mesenteric artery (SMA). These studies reported some improvement, but confirming data are still lacking. Clinical studies are also difficult to achieve since modern analgesics offer subtle and detailed treatment opportunities for most affected patients, and many patients are also subject to oncologic or radio-oncologic treatment.

■ Celiac Plexus Blockade and CP Neurolysis (EUS-CPB, EUS-CPN)

Celiac plexus blockade (CPB) denotes an EUS-guided injection technique for the local therapy of chronic pancreatic pain syndromes. EUS-CPB is performed by topical injection of drugs to block celiac nerve ganglia without permanent destruction of ganglionic neuronal tissues. This approach can readily be compared with anesthesiological nerve block techniques in different clinical scenarios. The goals of EUS-CPB are blockade of neuronal pain transmission signals cephalad to the connected pain networks by using reversible substances such as local anesthetics (i.e., lidocaine or procaine), with or without adding local steroids (triamcinolone) to reduce perineural inflammation in such circumstances.

In contrast, celiac plexus neurolysis (EUS-CPN) causes permanent and irreversible nerve damage and thus toxically destroys most tissues that are hit by the injection jet during CPN. For this purpose, a pure 98% ethanol solution – combined with a common local anesthetic – has been used in most instances.

To avoid toxic hazards during EUS-CPN, both operator and assistant(s) are required to wear fluid-resistant coats and face masks during the operation to protect against toxic splashes, eye contacts, and other harmful collateral effects. For the performance of EUS-CPN, different injection needles have been used ranging from small-caliber 25-G needles over 22-G FNA needles up to 19-G therapeutic FNA needles, while one dedicated injection needle with multiple side holes is still commercially available (companies: MediGlobe, Cook, Boston Scientific, MTW, Olympus, Covidien, and others). Up to now, no clinical study exists that clearly demonstrates distinct differences in terms of the therapeutic yield of the dedicated injection needle that would justify its very high price. Personally, we recommend use of 19- or 20-gauge FNA needles for EUS-CPN, since the wide lumen offers some advantages for the technical performance of injections – even in relatively rigid tissues. This approach should also – at least theoretically – reduce the risk of toxic splashing under such therapeutic conditions.

For EUS-CPN, a dedicated linear sideways-looking or forward-looking echoendoscope is to be used that allows for direct visualization of the root of the celiac plexus and also depicts some of the plexus ganglia in many cases (see paragraph below). The celiac plexus originates ventrally and cephalad of the proximal abdominal aorta, while the celiac plexus and its surrounding ganglion network is largely located in direct anatomical proximity of such visible nerve ganglionic nodules. The smaller nerve fibers and networks, however, cannot be visualized by EUS which limits the technique to some visible – and many suspected but invisible – structures in this clinical setting (see cartoon/image in ◘ Fig. 5.13a). The basic materials and instruments for the performance of EUS-CPN are demonstrated by ◘ Fig. 5.13b.

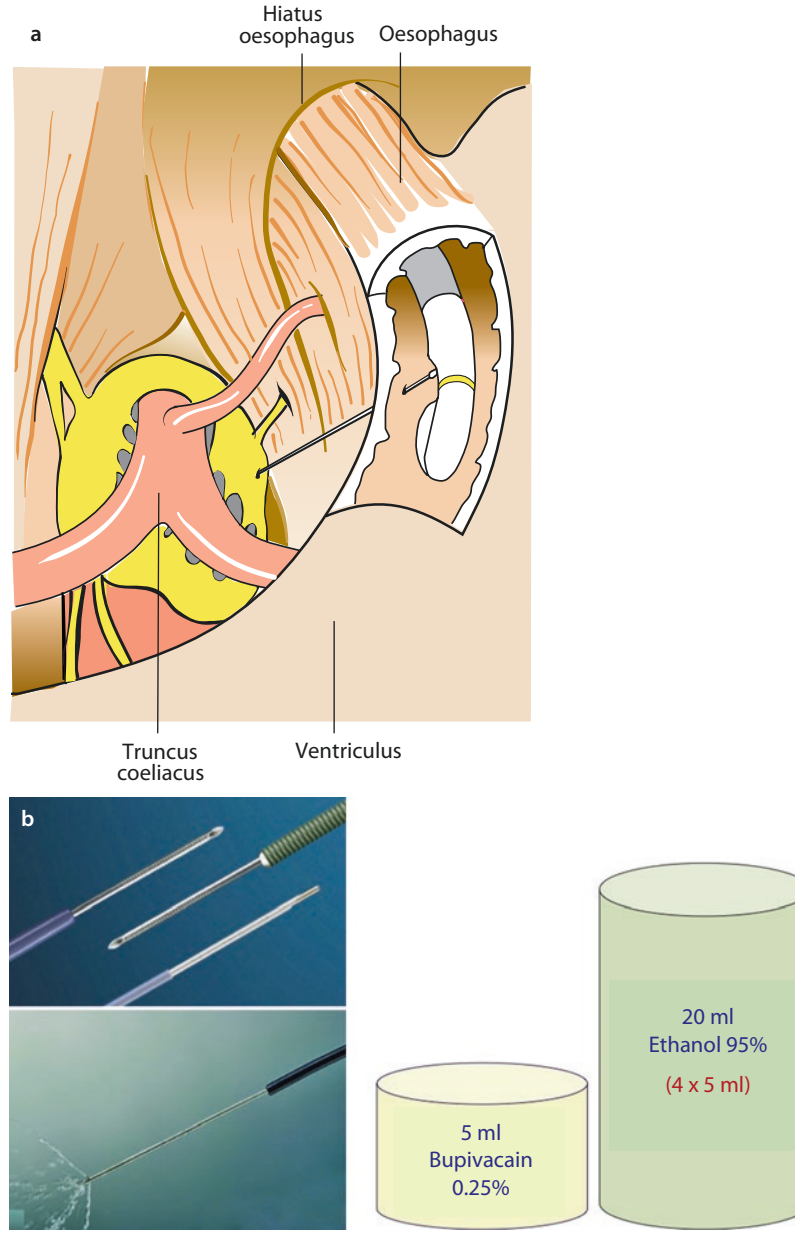

Fig. 5.13 **a** Anatomical position (sketch drawing) of the celiac plexus. **b** Additional materials for the EUS-guided plexus neurolysis of the celiac plexus, also referred to as «EUS-guided celiac injection therapy» (EUS-FNI)

Prior to EUS-CPN, the echoendoscope is forwarded and positioned in the proximal stomach immediately below the gastroesophageal junction. Under direct EUS visualization, the needle is then carefully advanced through the stomach wall and forwarded to the visible celiac plexus ganglia, or the region to where these structures are suspected. The principles of this common EUS-CPN are schematically demonstrated in Figs. 5.14a and b. After advancing the needle toward its target structures, direct injection of a long-lasting local anesthetic agent should be performed at first, for instance, by injecting 5–15 cc of bupivacaine 0.25% (or a similar agent) on both sides of the celiac root – if possible to avoid procedure-induced pain.

Based on our own experience, we believe that a dose of 20 ml is usually sufficient.

Bilateral EUS-CPN and Direct Plexus Neurolysis by Intra-ganglionic Application

According to present studies (Hollerbach 2013; LeBlanc et al. 2011; Ascunce et al. 2011; Wyse et al. 2011), there seems to be no significant difference

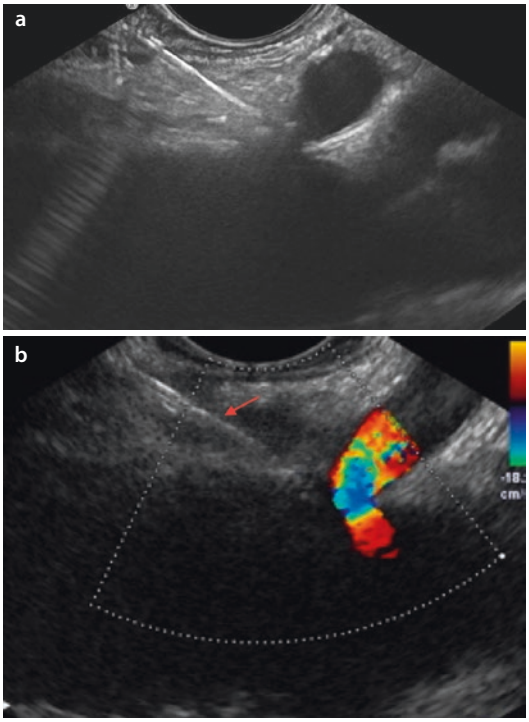

Fig. 5.14 **a** Position of EUS-transducer immediately distal and cephalad of the posterior diaphragm and view on the celiac trunk root; the FNA needle has been pushed out until its tip almost reaches the origin of the celiac trunk. **b** Duplex EUS shows the exact position of the perfused truncus artery that needs to be avoided during FNI; the needle tip reaches an echo-reduced nodular structure in this area that refers to parts of the celiac plexus nerve network in this region

between solitary injections ventrally and cephalad of the celiac trunk and bilateral injection therapy on both sides of the celiac trunk. For reasons of safety we therefore support ventral access to the root of the celiac trunk for topical ethanol injection to facilitate plexus neurolysis in patients, particularly when the visibility of the needle is obscured before, or during injection therapy. One recent randomized controlled study compared the central injection approach with bilateral injection techniques but found no significant differences in terms of clinical outcome. Some other uncontrolled smaller studies, however, have reported some benefit with the bilateral injection approach, but the clinical outcome difference of these findings remains unclear.

Using modern high-resolution EUS equipment, some of the major celiac plexus ganglia can be directly visualized in many patients. Usually, the plexus ganglia can be depicted as a chain of echo-reduced small nodules ventrally

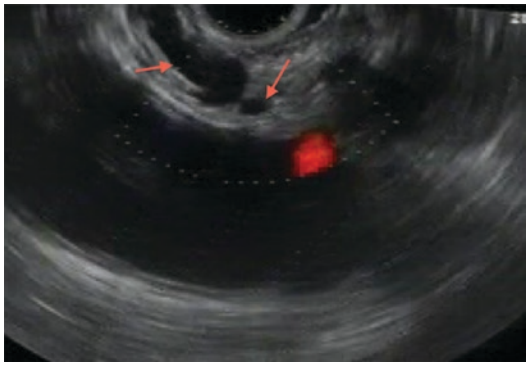

Fig. 5.15 EUS depiction of several nodular nerve structures of the celiac plexus network close to the root of the celiac trunk

and left of the celiac trunk but can easily be misinterpreted as lymph nodes or aspects of the left adrenal gland (Fig. 5.15). Compared with lymph nodes, however, celiac ganglia do not exhibit central echo-enhanced reflexes and are usually multiple and band-like in shape while mimicking a chain of pearls in many cases. Celiac ganglia are supposed to be clearly visible in approximately 70–80% of patients, but this visibility can be greatly obscured by factors such as presence of ascites, retroperitoneal carcinosis, and others. One recent retrospective, uncontrolled study assessed the feasibility and outcome of direct intra-ganglionic administration of ethanol for EUS-CPN and compared this technique with bilateral ethanol injections. Results suggest that direct EUS-CPN into celiac ganglia may result in significantly ameliorated pain scores of patients after CPN, with improvement of VAS scores in 68% of patients versus 33% of patients in the bilateral injection group. This study, however, is mainly limited due to its uncontrolled design, heterogeneity, and possible patient bias. Figure 5.16 demonstrates the CT image of the distribution of ethanol fluid mixed with contrast fluids at the celiac plexus base upon EUS injection (upper panel, unilateral injection; lower panel, bilateral injection). EUS-CPN can be performed both during diagnostic tumor staging and biopsy (endosonographic «one-stop shopping») or as separate local therapy approach.

Other studies have been performed that aimed at pain reduction by topical injection of ethanol and/or steroids (usually triamcinolone) in benign pancreatic diseases such as advanced chronic

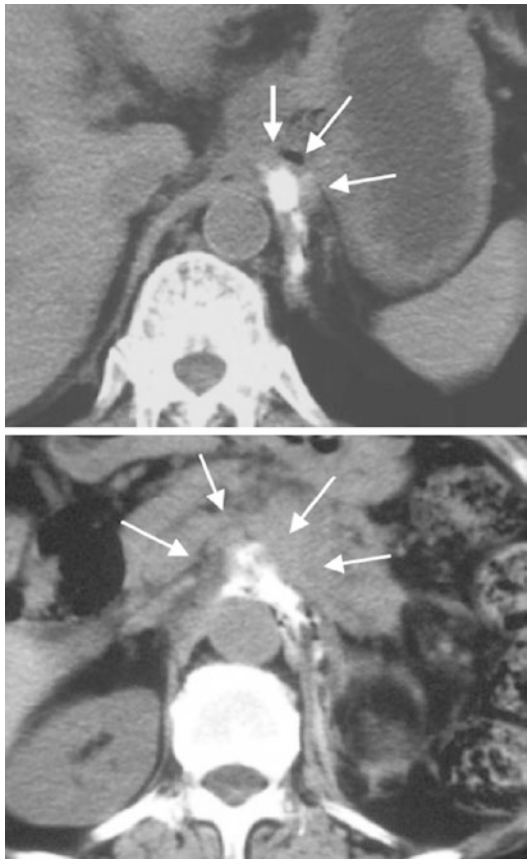

Fig. 5.16 Distribution of fluids upon injection of absolute alcohol mixed with fluoroscopic contrast agents around the base of the celiac trunk and the celiac plexus ganglia after EUS-FNI: the CT scans show the typical distribution of fluids after **a** unilateral injection and, **b** after bilateral injection

pancreatitis, a term called *celiac plexus block* (EUS-CPB). However, results of these uncontrolled and usually retrospective trials (Kaufman et al. 2010; Wilcox 2012) did not point toward clinically meaningful and convincing results since short-term «success rates» reported did usually not exceed 50% of patients, if being successful at all. Up to now, no controlled, randomized studies with regard to this technique exist; there are no long-term experiences, and patient selection seems to be heterogeneous in all previous studies. Hence, there is still no evidence-based justification for EUS-CPB with steroids in this setting, while on the other hand, some reports have been published that reported serious adverse events in some treated patients, including local abscess formation and septicemic episodes and including some lethal patient cases due to ischemic necrosis of stomach and bowel wall (Fujii et al. 2012; Loeve and Mortensen 2013) – the latter only occurring in combination with ethanol application. In summary, whenever EUS-CPB is considered for local pain therapy in chronic pancreatitis, this approach should only be performed in vigorously controlled clinical studies.

Contraindications for Celiac Plexus Neurolysis

On the basis of previous and current studies, EUS-CPN is considered to be a relatively safe therapeutic intervention. However, some peculiar situations exist that should be considered as «red flags» – or absolute and relative contraindications – for any therapeutic intervention around the celiac plexus:

- Lack of signed informed consent of the patient (absolute)
- Intervening vessels within the needle tract that cannot be avoided, e.g., in portal hypertension (relative)
- Lack of visibility of needle tip during the procedure (absolute)
- Severe coagulopathies (INR >3, thrombocytopenia <50,000): absolute
- Need for continued antiplatelet medication or anticoagulants such as NOACs, clopidogrel + aspirin, coumarone, warfarin, and others (relative)

The number and outcome of severe adverse events (SAEs) – or side effects – during EUS-CPN has been shown to be relatively low; however, this procedure may significantly harm some patients at risk, including fatal outcome, thus disclosing a small albeit significant mortality rate. The overall number of AEs with EUS-CPN may lie somewhere in the range between 5% and 10% of procedures, including at least two fatal cases dying from ischemic necrosis of the spleen and/or small intestine. Hence, the indication for EUS-CPN and the conduct of this procedure should always be carried out with the utmost care and thoroughness till the end of the intervention in every patient case to prevent such disastrous outcomes.

Typical expectable complications (Puli et al. 2009; Arcidiacono et al. 2011; Hollerbach 2013; Fujii et al. 2012; Loeve and Mortensen 2013) include:

- Hypotension, usually self-limited
- Transient diarrhea (1–2 days)
- Local hemorrhage (usually self-limited, conservative treatment)

- Fever/hyperthermia, self-limited
- Local infection/abscess formation/septicemia: reported only after steroid injections
- *Rarely*: ischemic infarction (stomach, spleen, small intestine, colon – single cases)
- *Rarely*: spinal infarction/transient neurologic deficits (palsy)

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Endoscopic Interventions for Anastomotic Leaks and Fistulas

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Despite continuing evolution of surgical procedures, anastomotic leaks in the gastrointestinal tract still give rise to a significant morbidity and mortality. By now, interventional endoscopic techniques allow a nonsurgical management of these complications in many cases. Stent therapy has become the standard in the management of anastomotic leaks in the upper gastrointestinal tract, and endoscopic vacuum therapy has become the standard for leaks of rectal anastomoses. Recently, two novel techniques have been added to the methods for endoscopic management of leaks and fistulas: endoscopic vacuum therapy in the upper gastrointestinal tract, which has been introduced into routine application, and the placement of over-the-scope clips (OTSC).

6.1 Anastomotic Leaks in the Upper and Lower Gastrointestinal Tract

R. Mennigen

Classification

Although anastomotic leaks in the gastrointestinal tract are a quite heterogeneous field, we will present a rough classification of anastomotic leaks before discussing endoscopic therapeutic options. This is important, as endoscopic therapy depends on localization of the leak, grade (Table 6.1), time point of occurrence, and further factors.

Table 6.1 Clavien–Dindo classification of surgical complications (Clavien et al. 2009)

Grade 1: Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic, and radiological interventions
Grade 2: Requiring pharmacological treatment with drugs other than those allowed for grade I complications. Blood transfusions and total parenteral nutrition are also included
Grade 3: Requiring surgical, endoscopic, or radiological intervention
Grade 4: Life-threatening complication (including CNS complications) requiring IC/ICU management
Grade 5: Death of a patient
Complications are graded depending on their clinical consequences and necessary therapies

Anastomotic leaks can be classified by the following criteria:

- Localization [upper versus lower GI (gastrointestinal) tract]
- Type of previous operation and anastomotic technique (e.g., esophageal resection with gastric conduit, gastrectomy, rectal resection)
- Time point of postoperative diagnosis: acute versus chronic leak
- Size of leak (given in percent of circumference)
- Presence or absence of a leak cavity
- Severity of the complication (Clavien–Dindo classification, Table 6.1)

Therapeutic Algorithms: Operation, Endoscopy, or Conservative Management?

The severity of the complication and the condition of the patient determine if endoscopic therapy is an option for the management of a postoperative leak. With regard to the Clavien–Dindo classification, the domain of endoscopic therapy are grade 3 complications. These are anastomotic leaks which cannot be managed by parenteral nutrition, antibiotic therapy, and placing of a gastric tube alone. The patient is in a septic condition, but does not fulfill criteria for a grade 4 complication (organ dysfunction). A partial dehiscence of an esophagogastric anastomosis following esophagectomy with viable gastric conduit is a typical example. This is a situation in which endoscopic therapy has replaced surgical management in most cases and has become the gold standard. In this example, endoscopic stent placement is a well-defined standard procedure; recently, endoscopic vacuum therapy is increasingly used in such cases. A typical example of a grade 3 complication in the lower gastrointestinal tract is the rectal anastomotic leak with a leak cavity in the small pelvis with the presence of a diverting ileostomy. In this case, endoscopic vacuum therapy is the accepted standard therapy.

The success of endoscopic therapy combined with low morbidity and mortality of these procedures has even shifted the indications toward grade 4 complications. By now, critical patients with organ dysfunction and ICU therapy are managed by endoscopic means in selected cases.

However, in these cases it has to be critically evaluated if endoscopic therapies are sufficient to manage the life-threatening sepsis. If the septic condition cannot be controlled by endoscopic means or if the local condition of the anastomosis is not suitable for endoscopic therapy (e.g., necrosis of the gastric conduit after esophagectomy), surgical management is still mandatory.

In case an endoscopic therapy is indicated, the choice of method depends on the abovementioned criteria, especially localization of the leak (stent or endoscopic vacuum therapy in the upper gastrointestinal tract, endoscopic vacuum therapy in the lower gastrointestinal tract), the local condition of the anastomosis, and the presence of an infected leak cavity. These aspects are discussed in the context of the respective endoscopic techniques.

6.2 Stent Therapy

M. Colombo-Benkmann

Indication, Evidence, and Significance of Endoluminal Stenting

Implantation of self-expanding endoprotheses, i.e., stents, is indicated in the treatment of leakages of esophagogastrostomies as well as esophagojejunostomies, perforations of the esophagus (van Boeckel et al. 2011), and leakages after bariatric operations (Puli et al. 2012). So far, stenting is not established in the therapy of leaks or perforations of the duodenum, jejunum, or ileum.

At present, stents are made of wires of alloys, e.g., nitinol with a memory effect, which are woven as a cylindrical mesh. Stents can be covered either partially or over their total length by a silicone sheet to prevent ingrowth of the mucosa into the mesh. Each end of the stent should contain a circular thread to allow stretching. This will result in simultaneous reduction of the diameter of the stent, enabling adjustments of its intraluminal position or its removal. The advantage of nitinol stents is that they can be implanted easily without the need for any preparation, in contrast to former endoprostheses made exclusively from plastic.

Further advantages comprise their ability to cover multiple leaks of suture lines such as after sleeve gastrectomy, as well as easy endoscopic removal and amendment in case of a misplacement.

The most common indications of stent insertion are anastomotic leaks after esophageal resections (51%), followed by iatrogenic perforations due to diagnostic or interventional endoscopy (25%) occurring during gastroscopic balloon dilatation or bougienage of stenoses after endoscopic mucosal resection or endoscopic retrograde cholangiopancreaticography, Boerhaave syndrome (17%), and benign fistula, e.g., to the trachea and bronchi (4%) (van Boeckel et al. 2011). Even anastomotic dehiscences comprising up to 100% of the luminal circumference can be treated successfully. This holds true also for leaks after bariatric surgery such as gastric bypass, gastric sleeve, and biliopancreatic diversions (Puli et al. 2012).

Covered stents represent a physical barrier between leakage and lumen, preventing contact of endoluminal secretions with the leak. This represents a crucial prerequisite of leak closure. In addition, patients can receive enteral nutrition 24–48 h after implantation, initially by a simultaneously implanted jejunal tube followed by natural ingestion of food. This prevents the necessity of parenteral nutrition and its associated complications (Puli et al. 2012).

Despite low levels of evidence due to the lack of prospective not to mention randomized studies and due to small patient cohorts, endoluminal stents are the gold standard in the treatment of postoperative leaks and fistula.

Requirements of Manpower, Instrumentation, and Organization

Implantation of intraluminal stents requires at least two, ideally three, persons with expertise in endoluminal stenting: the implanting physician and two assistants who are knowledgeable in the technique of implantation.

Instruments include a gastroscope and a stiff guide-wire with a flexible spiral tip (e.g., Eder–Puestow) which yields when coming into contact with the tissue. Due to the soft spiral tip, the risk of incidental perforation of the hollow organ reduces. The guide-wire should have a length of 200 cm.

Sterile warm water should be injected into the core of the delivery system, to ensure fast expansion of the stent once it is released. In our practice, stents are delivered under fluoroscopic guidance. Thus epicutaneous radiopaque pins, e.g., made from lead, are needed to mark the position of the leak, the eophageal introitus in case of leaks in the

vicinity of the upper esophageal sphincter, the esophagogastric junction, or the pylorus depending on the location of the leak. If adjustment of the stent's position after delivery is required, an alligator forceps should be used.

Ideally, stents should be implanted using a fluoroscopy system. This allows monitoring and documentation of the respective phases of stent implantation from the positioning of the leak until expansion of the stent in its final position.

Implantation is carried out in a supine position of the patient in analgosedation. Intubation should be used to avoid aspiration if there is significant reflux, in case of respiratory failure or fistulas. Constant monitoring of oxygen saturation is mandatory; electrocardiography should be used additionally in patients with cardiac failure or significant cardiac risk factors.

In general, patients who breathe spontaneously during stent implantation should be given oxygen continuously during the procedure by a nasal applicator. This can prevent decrease of oxygen saturation during the procedure. Since many patients already suffer from pre-existent cardiopulmonary morbidity, sedation may result in respiratory failure during implantation. As a consequence, the equipment for manual resuscitation such as a respiratory mask, a resuscitation bag with oxygen supply, and an emergency case with the possibility of endotracheal intubation are to be provided at the site of the procedure.

In case of extraction of the stent, disconnection of the grasping forceps from the stent on the level of the pharynx can result in acute respiratory obstruction, resulting in asphyxia. The attempt of immediate endoscopic extraction by an endoscopic forceps is unlikely to be successful. Instead, we recommend instant insertion of a laryngoscope as used for endotracheal intubation, for visualization of the stent, and a strong needle holder to enable immediate stent removal. Thus, we recommend having these instruments ready to hand.

With regard to selection of specific type of stent, it should be taken into account that in case of the treatment of leaks, it is recommended to remove stents 6 weeks after implantation. Fully covered stents have the advantage that they can be extracted generally without damaging the mucosa. In partially covered stents, there is a significant risk of ingrowth of the mucosa into the mesh. This impedes not only stent extraction, but can result in considerable trauma to the mucosa. Thus, single cases of leak caused by extraction of partially covered stents have been described.

On the other hand, fully covered stents have a significant risk of dislocation, due to their smooth surface allowing them to slide on the mucosa. Choosing an adequate diameter of the shaft and the ends of the stent may impede dislocation. In general, we use fully covered stents with diameters of the shaft of 25 mm and of both ends of at least 30 mm.

Procedure

At first a diagnostic endoscopy is carried out in the sedated or intubated patient. This should comprise not only the esophagus, but all parts of the digestive tract which can be reached by the gastroscope. Independent from the endoscopic verification of a leak, water-soluble contrast dye during fluoroscopy should be applied, since this enables reliably the detection of fistulas in the respiratory tract. The contrast dye is applied by a catheter, which is inserted into the gastroscope. After aspiration of the contrast dye, the leak is marked under fluoroscopy by epicutaneous markers (Fig. 6.1). These have to be attached onto the patient's skin by an adhesive tape. Markers should not be attached onto the patient's clothing. If the leak is close to the upper esophageal sphincter, the latter should be marked in the same way as well, to avoid misplacement of the upper end of the stent, e.g., into the pharynx. When using stents in the treatment of a leak after sleeve gastrectomy, the pylorus should be marked as well, to ensure that the aboral end of the stents is positioned reliably beyond the pylorus.

In the meantime, warm sterile water is instilled into the delivery systems through a respective opening. Subsequently, a guide-wire (Eder–Puestow) is introduced through the gastroscope. The end of the wire is placed aborally to the intended position of the aboral end of the stent. The wire is secured by the assisting staff during retraction of the endoscope, to prevent an incidental dislocation of the wire. Very importantly, the risk of facial and eye injury by the extracorporeal end of the wire is to be considered.

The well-lubricated delivery system is introduced over the wire, and the stent is delivered in a

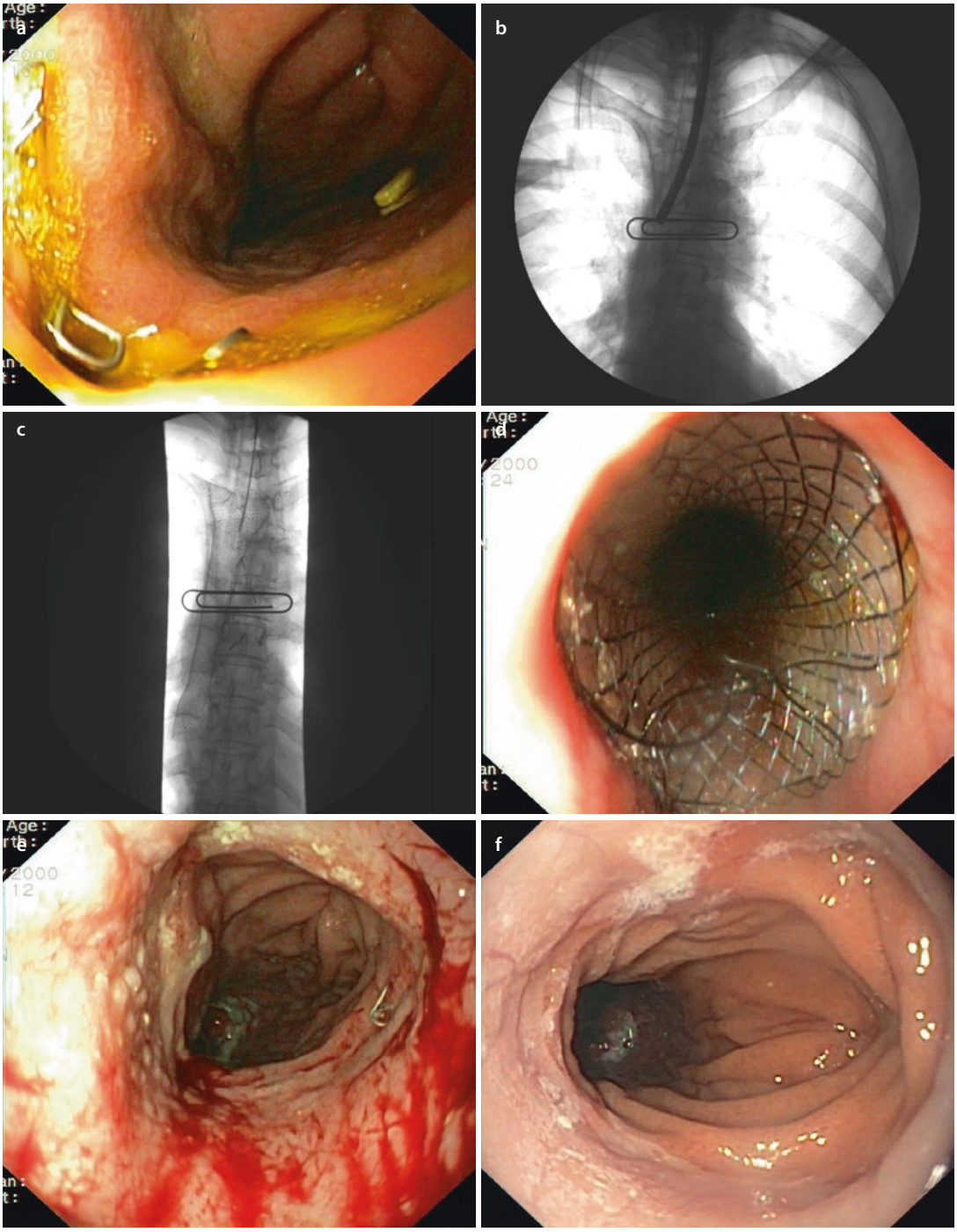


Fig. 6.1 Procedure of stent implantation. **a** Anastomotic leak following esophagectomy with gastric conduit, located at 7 o'clock. **b** The level of anastomosis is indicated by an epicutaneous marker. **c** The stent is placed with the leak being located in the middle portion of the stent. **d** Endoscopic view on the upper opening of the stent. **e** Immediately after stent removal which was performed 6 weeks later: multiple erosions can be seen, and the leak is completely closed. **f** Endoscopic view 3 weeks later: all erosions have resolved, and the anastomosis is healed

way that leak or fistulas are covered with a sealing effect. After the stent has disconnected from the delivery system during its expansion, the latter is pulled out together with the guide-wire. Care has to be taken that the stent is not dislocated by this maneuver. If dislocation occurs or if the position of the stent has to be corrected, an endoscopic grasper should be used.

The final endoscopic exam should be limited to documenting the distance of the upper end of the stent from the front teeth in centimeters, to verify dislocation if it should occur. It is not necessary to intubate a stent not fully expanded, since this carries a high risk of dislocation. Exceptions are the necessary adjustments of the stent's position.

If there is suspicion of a newly occurred stent dislocation, it can be verified by endoscopy or fluoroscopy. Insufficient sealing of the leak can be confirmed by fluoroscopy and water-soluble contrast dye. Occasionally if the diameter of the chosen stent is too small, the failure of sealing can be recognized by a gap between the stent and the hollow organ.

There is no need for a special follow-up if the patient is asymptomatic and receiving his habitual nutrition.

Stent removal is carried out by an endoscopic grasper pulling at the upper thread. If the stent is adherent to the inner layer of the stent due to mucosal overgrowth of the ends of the stent, these adhesions can be eliminated either mechanically by graspers or thermically.

Technical success of stent implantation with complete sealing of leaks and fistulas in non-bariatric patient is between 98% and 100% (van Boeckel et al. 2011).

In non-bariatric patients, the time the stent is left in place is 6 weeks on average, published times are between 3 and 17 weeks on average (van Boeckel et al. 2011) and between 6 and 8 weeks in bariatric patients (Puli et al. 2012).

If the interval chosen to leave the stent in place is too short, this will result in incomplete closure of the leak, while choosing an excessively long interval may result in stent migration or mucosal overgrowth by epithelial cell. This significantly impedes removal of the stent and contains a considerable risk of injury to the hollow organ. In addition to this, if too long intervals are chosen, this can lead to dysphagia.

Removal of fully covered stents in non-bariatric patients is almost completely without any complication. After removal of a partially covered stent, 8% of patients will experience complications (van Boeckel et al. 2011). In bariatric patients, successful stent extraction occurs in 92% of patients (Puli et al. 2012).

The objective of complete closure of leaks and fistulas solely by stents can be achieved in 85% of non-bariatric patients and in 88% of bariatric patients. In this context, successful treatment is defined by complete closure of leaks and fistulas as shown by fluoroscopy with contrast dye, if after stent removal no extraluminal contrast dye can be seen.

If leaks are persistent, re-stenting can be carried out without any problems in general.

Possible Complications and Treatment

Complications associated with implantation of stents such as intraluminal bleeding or perforation are rare and occur in only 3% of patients (van Boeckel et al. 2011).

Dislocation of the stent is one of the most common complications. In fully covered stents, this occurs in 26% and in partially covered stents in 13% of non-bariatric patients. In bariatric patients, the dislocation rate is 16% and 9% (Puli et al. 2012). In bariatric patients, stents can migrate into the jejunum. In such cases, surgery is required to remove the stent; occasionally, stents have been egested by defecation. If repositioning is not successful, a stent with a larger diameter should be chosen or another method is to be applied.

In contrast, partially covered stents are more often overgrown by the epithelium (12%) than fully covered stents (7%) (van Boeckel et al. 2011). As a consequence, the stent cannot be removed (Puli et al. 2012).

Endoscopic reinterventions are necessary in 26% of patients with fully covered stents and in 13% of patients with partially covered stents (van Boeckel et al. 2011). Occasionally, stents are obstructed by food (Puli et al. 2012). If possible, the bolus should be dislocated aborally, to be digested. If this is not possible nor indicated, extraction should be strived.

Surgical therapy is necessary in 13% of non-bariatric patients, since leaks do not close and due to complications associated with the procedure or the stent (van Boeckel et al. 2011). Mortality after stent implantation is due to septicemia associated with the leakage and not due to the endoprostheses. Its incidence in non-bariatric patients is 18% (van Boeckel et al. 2011).

Endoluminal stenting has been the standard treatment of the abovenamed complications for more than 10 years. However, new therapies are becoming available due to the technological progress in medicine. Thus, it can be expected that in the next few years, indications for specific treatment options will be specified, especially if they become more available.

6.3 Endoscopic Vacuum Therapy (EVT)

M.G. Laukoetter

Indication and Evidence

Vacuum therapy (endoscopic vacuum therapy (EVT), VacuSeal, vacuum-assisted closure [VAC] therapy, negative pressure wound therapy [NPWT]) for wound healing simply consists of a sponge-based drainage system connected to negative pressure, leading to decrease of bacterial contamination, secretion, local edema, and promotion of granulation tissue (Holle et al. 2007). Since introduction of this treatment technique in the early 1990s, endoscopic vacuum therapy, as an alternative treatment option for even desolate wounds in almost every localization, has been established in nearly all surgical disciplines (Argenta and Morykwas 1997). After initially being considered and established as a treatment modality for infected superficial skin defects of different sizes and extent (Argenta and Morykwas 1997; Vikatmaa et al. 2008), the first intracorporeal endoscopic vacuum therapy was established successfully for anastomotic leaks after rectal resection (Weidenhagen et al. 2008; Willy et al. 2006). The close proximity of the sphincter and of the anastomotic region in such cases leads to permanent congestion of infected secretion and intestinal gas, leading to potential severe local peritonitis in the pelvic region. In such cases where there is local lower abdominal peritonitis with an endoscopically accessible cavity, the Endo-SPONGE treatment can be applied (Fig. 6.2). An overtube is placed into the cavity,

Fig. 6.2 Endo-SPONGE® system (By courtesy of Braun Melsungen AG)

and, after the endoscope has been withdrawn from the overtube, the sponge is brought down by a pusher. The cavity is drained subsequently by the endoscopically introduced Endo-SPONGE® system. The open pores of the sponge allow the suction to be transferred over all tissues in contact with the sponge surface.

The insertion of a polyurethane sponge into the defect zone, connected transanally to an external vacuum system, does, in contrast to the treatment of superficial skin defects, not require the presence of an airtight sealing, since the pelvic wound cavity seals itself after start-up of the drainage system. Closure rates of >90% avoid reoperations in those patients characterized by a complicated postoperative course (Glitsch et al. 2008; Weidenhagen et al. 2008). Perforations and fistulas of the upper gastrointestinal (GI) tract occur as postoperative complications (anastomotic dehiscence or fistula), during diagnostic or interventional endoscopy, iatrogenic as a consequence of other therapeutic measures (e.g., gastric tube placement, percutaneous endoscopic gastrostomy, transesophageal echocardiography), or spontaneously (ulcers, tumors, Boerhaave syndrome, and others). These perforations often lead to severe septic conditions which are difficult to treat and give rise to a high morbidity and mortality, especially if leading to mediastinitis or peritonitis (Junemann-Ramirez et al. 2005). In particular, reported leak rates after esophagectomy vary widely from 1% to 30% (Ahrens et al. 2010; Whooley et al. 2001). Anastomotic leakage accounts for approximately 40% (Miller et al. 1997; Pross et al. 2000) of all postoperative fatalities and is highly challenging to treat: control of the septic focus is essential; thus, the already critically ill patient often requires intensive additional measures that themselves are associated with high morbidity, adding to the clinical burden (Junemann-Ramirez et al. 2005).

A number of competing treatment modalities ranging from conservative to surgical approaches are available for the management of this situation. The surgical treatment options include revision of the anastomosis, closure of the defect and perifocal drainage, or complete surgical deviation and creation of a cervical stoma. These procedures are usually difficult and carry a high risk for severe complications associated with high morbidity and mortality rates. Therefore reoperation is not always a reasonable option.

In this context, numerous minimally invasive treatment options have more recently become available to treat a variety of secondary surgical complications. Conservative management may be advantageous if reliable endoscopic methods are available. Endoscopic clips (Mennigen et al. 2013; Rodella et al. 1998), fibrin glue injection, absorbable plugs, and endoscopic suturing (EndoCinch) (Adler et al. 2001; Fritscher-Ravens et al. 2010) have been used to close smaller defects. At present, the placement of completely covered metal or plastic stents (Doniec et al. 2003; Hunerbein et al. 2004) is still the favored conservative treatment option for esophageal leakage. The implantation of these stents has been thoroughly studied and has been proven to be effective (Tuebergen et al. 2008; van Boeckel et al. 2011). However, stent implantation does not always lead to a sufficient sealing of the leakage (van Boeckel et al. 2011), and dislocation rates of up to 40% (Kauer et al. 2008) have been reported. Another important complication is failure of stent extraction due to ingrowth of granulation tissue and/or secondary strictures due to scarring (Doniec et al. 2003; Loske and Muller 2009; Schubert et al. 2005). While stents bridge the defect intraluminally and prevent further leakage, continuous local drainage is necessary to prevent inflammatory fluids from remaining in the perianastomotic tissues and maintaining inflammation. The well-established stent therapy is now being challenged increasingly by endoscopic vacuum therapy (EVT). While it can already be considered as standard therapy for leakages of lower colorectal anastomoses, its use in the upper GI tract only evolved several years later. Yet soon after first reports of the technical feasibility of endoscopic vacuum therapy in the upper GI tract, several case series with good success rates in the management of esophageal leaks were published. However, most series include heterogeneous types of leaks and are not focused on anastomotic leaks. All publications report excellent success rates (healing of leaks and perforations in 84–100%) and virtually no procedure-related complications in these patient cohorts. The technique appears to have potential as a first-line therapy for postoperative upper GI leaks (Table 6.2).

Table 6.2 Endoscopic vacuum therapy (EVT) for leaks of different etiology

Literature	Patients (*n*)	Indication for EVT	Success rate (closure of leak by EVT)
Weidenhagen et al.	6	6× a. l.	6/6 (100%)
Wallstabe et al.	1	1× a. l.	1/1 (100%)
Brangewitz et al.	32	30× a. l. 1× perf. 1× b. s.	27/32 (84%)
Schniewind et al.	17	17× a. l.	15/17 (88%)
Bludau et al.	14	8× a. l. 6× perf.	12/14 (87%)
Smallwood et al.	6	1× a. l. 5× perf.	6/6 (100%)
Schorsch et al.	35	21× a. l. 7× perf. 1× b.s. 6× o.o.	32/35 (91%)
Kuehn et al.	21	11× a. l. 8× perf. 2× b.s.	19/21 (91%)
Seyfried et al.	1	1× b. surg.	1/1 (100%)
Total	**133**	**95× a. l.** **27× perf.** **4× b. s.** **1× b. surg.** **6× o. o.**	**119/133** **89.5%**

Synopsis of studies to date which have reported EVT, with number of treated patients and success rates of closure of the defect in total and percentage
a. l. anastomotic leakage, *perf.* perforation, *b. s.* Boerhaave syndrome, *b. surg.* bariatric surgery, and *o. o.* other origin

Since its first description by Wedemeyer et al. and Loske et al. the abovementioned principle is used by all authors, with only small variations in the procedure. Recently, a commercially available and certified drainage system using the overtube principle has been distributed (Eso-SPONGE®, Braun Melsungen AG).

Resources and Organizational Requirements

In case of anastomotic leakage or perforation in the upper gastrointestinal tract, interventional endoscopy has evolved as an effective alternative treatment modality (Maish et al. 2005). Endoscopic vacuum therapy requires a competent, experienced endoscopic team and a well-equipped endoscopic unit permitting additional perinterventional radioscopy as well as an examiner who is well trained in the field of EVT. EVT can be done under conscious sedation or general anesthesia, depending on the general condition of the patient.

The following tools and equipment have to be provided (Fig. 6.3a):

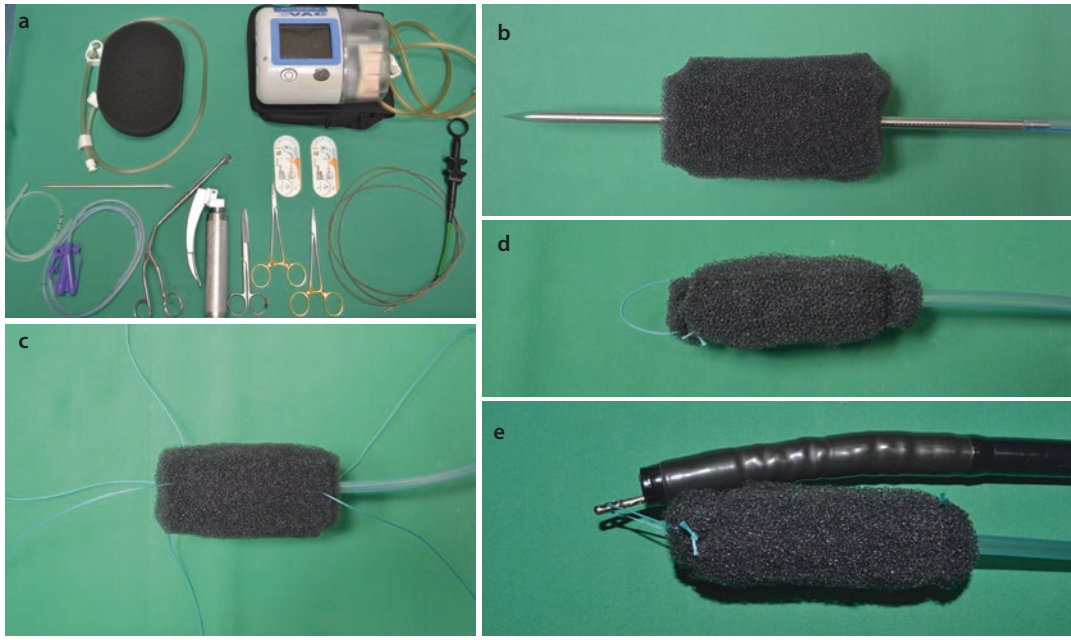


Fig. 6.3 Endoscopic vacuum therapy (EVT) in the upper gastrointestinal tract. **a** Arrangement of the necessary materials. **b** Open-pore polyurethane sponge—sponge preparation. **c** Sponge mounted on a gastric tube for endoscopic vacuum therapy. **d** Mounted sponge—L loop for easy positioning. **e** Principle of sponge drainage insertion into the esophagus using a forceps in a «backpack method»

Materials

- 1× open-pore polyurethane sponge (e.g., VivanoMed® Foam, Paul Hartmann AG, Heidenheim, Germany; V.A.C. GranuFoam, KCI-Kinetic Concepts, Inc., TX, USA)
- 1× electronic vacuum pump system(e.g., VivanoTec®, Paul Hartmann AG, Heidenheim, Germany)
- 1× polyvinyl chloride (PVC) gastroduodenal tube (e.g., Covidien™ Salem Sump™, 14 Fr/Ch (4.7 mm) × 114 cm, Covidien™, MA, USA)
- 2× suture material (e.g., Ethibond Excel, Ethicon, Johnson & Johnson MEDICAL GmbH)
- 1× scissors, 1× clamp, 1× needle holder, 1× Magill forceps, 1× laryngoscope, 1× metal pin for the Redon drainage, 1× tube for nasal diversion, 1× endoscopic forceps, and lubricant

Endoscopic Vacuum Therapy (EVT): Procedure

EVT is performed under conscious sedation or general anesthesia, depending on the general condition of the patient. After endoscopic assessment of the geometry of the leakage and the cavity, a polyurethane foam sponge is cut into the corresponding shape (Fig. 6.3b). The sponge is fixed to the tip of a polyvinyl chloride (PVC) gastroduodenal tube with a suture at the proximal and distal ends of the sponge (Fig. 6.3c) allowing communication between the side ports of the tube with the sponge. An additional suture loop (L loop) is placed at the tip of the sponge (Fig. 6.3d). Thus, the additional loop at the tip of the sponge serves as a purchase for the endoscopic forceps and facilitates manipulation of the sponge into difficult-to-access cavities and hollow spaces. After final shaping of the sponge (Fig. 6.3d), the loop is grasped with a forceps (Fig. 6.3e) and pulled close to the endoscope, and the sponge is placed in the leakage cavity under direct endoscopic vision. If the defect is initially not wide enough to accommodate the endoscope (<10 mm) and an abscess cavity is suspected, the opening can be dilated by endoscopic balloon dilatation (Esophageal Balloon Dilatation Catheter, 10–12 mm, Boston Scientific, Ratingen, Germany) to allow extraluminal inspection by the standard endoscope and examination of the extraluminal septic focus. After sponge placement, the vacuum drainage tube is diverted through the nose. Continuous suction of 100–125 mmHg generated by an electronic vacuum pump system (e.g., VivanoTec®, Paul Hartmann Ag, Heidenheim, Germany) is connected to the drainage tube,

allowing the sponge to stay in position due to continuous suction. Optionally, with the sponge drainage system in place, parenteral feeding, a transnasal enteral feeding tube, a percutaneous endoscopic gastrostomy (PEG,) or a jejunostomy feeding tube ensure enteral nutrition (Fig. 6.4a). A scheduled change of sponges should take place every 3rd to 5th day; and at each session, the size of the defect has to be assessed and be treated with an individually prepared sponge, cut to fit the lesion's dimensions. After each discontinuation of suction, the tube has to be diverted through the mouth and removed simply by pulling. It is advisable to flush the tube with 0.9% saline solution to dissolve the granulation tissue from the pores of the sponge prior to removal. In some cases, remnants of the sponge have to be removed by endoscopic forceps. Over the course of the treatment and with diminishing defect size not allowing an access with the scope, sponge placement can be changed from its initial intracavitary position to intraluminal position onto the defect at any time. Secretion is then drained endoluminally, and the continuous suction force results in temporary complete occlusion of the intestinal passage. Especially in the absence of an extraluminal wound cavity (e.g., with early diagnosis of a transmural defect in case of a Boerhaave syndrome), it is advisable to

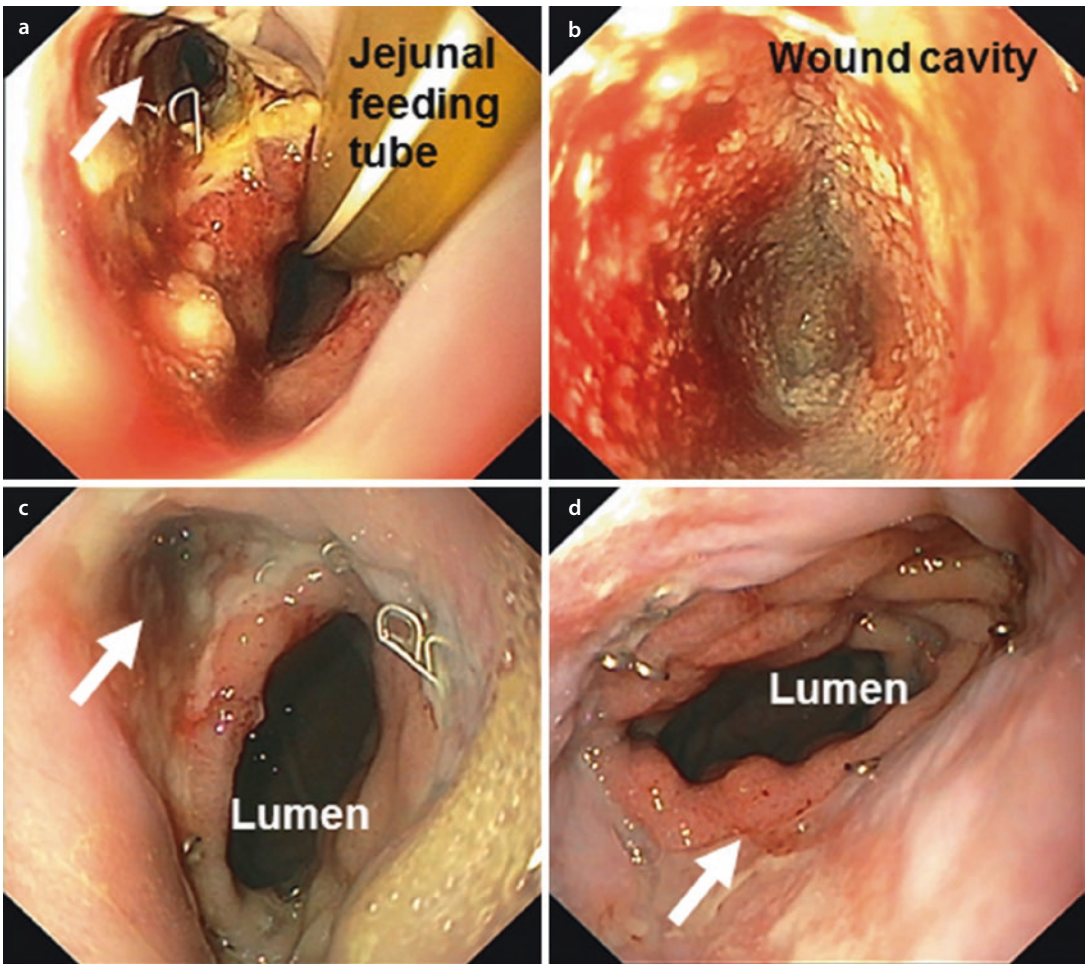


Fig. 6.4 Endoscopic vacuum therapy (EVT) in a case of anastomotic dehiscence after esophagectomy with esophagogastric anastomosis. **a** Mediastinal cavity lateral to the anastomotic ring (*arrow*). Detection on postoperative day 3. **b** Formation of granulation tissue within the cavity after 3 days of endoscopic vacuum therapy. **c** Residual finding and granulation tissue (*arrow*) after four sponge changes. **d** Completely healed anastomosis 3 weeks after initiated endoscopic vacuum therapy and seven sponge changes in total

use an intraluminal sponge drainage covering the whole defect zone within the lumen of the upper GI tract. EVT can be stopped when the defect size becomes too small for further sponge placements and the defect is finally lined with surface epithelium (Fig. 6.4b–d). Complete healing of the anastomosis should be assessed by endoscopy and additional X-ray contrast study showing no clinical signs of persistent leakage. Usually the defect completely closes within 1–2 weeks.

Control of Possible Complications

EVT in the upper GI tract seems to be not only feasible but superior to previous therapeutic procedures such as surgical revision and stent placement for esophageal defects. Although EVT requires multiple endoscopic procedures (every 3–4 days), its advantages with regard to previous treatment options are the regular visualization of the wound cavity and the optimal drainage provided by the vacuum system. This leads to effective sepsis control and final closure of the defect.

Although previous studies reporting heterogeneous types of upper GI tract leakages reported excellent success rates without procedure-related complications (Table 6.2), every sponge change can be associated with minor or major complications. In our prospective single-center study, comprising 52 consecutive patients, we experienced two severe critical events of fatal hemorrhage in patients suffering from a late anastomotic insufficiency after distal esophagectomy. Therefore, we strongly recommend that EVT for esophageal perforations should be performed combined with a CT scan of the thorax done directly before or after every first endoscopic placement of the sponge, to exclude close proximity of the sponge to cardiovascular structures with subsequent risk of erosion bleeding. Patients who show no intermediate tissue layer between the sponge and major thoracic vessels defining a close proximity to cardiovascular structures, and revealing a major complication risk for EVT in the upper GI tract in these patients, should be evaluated critically in terms of potential different therapy regimes and exit strategies such as stent placement.

Minor EVT-associated complications such as sponge dislocation due to swallowing and coughing or minor bleedings after sponge removal usually do not need additional therapy, and EVT can be successfully continued. It is advisable in these cases to fix the sponge properly to the tube and in the case of minor superficial bleedings to interrupt the course of therapy for 1 or 2 days.

In the case of insufficient drainage or large mediastinal cavities, up to two separate sponge drainage systems can be used. Sometimes, even an additional external drainage might be necessary and does not interfere with a successful course of therapy.

6.4 Over-the-Scope Clip

R. Mennigen

Indication, Evidence, and Value of the Technique

Endoscopic clipping of gastrointestinal leaks and fistulas has been tried for many years. Usually, through-the-scope clips (TTSC) have been used which were designed for hemostasis. These procedures were only successful in very small lesions or mucosal defects, and despite several successful case reports, clipping of leaks did not reach widespread use. The small wingspan and especially the low compression force of the TTS clips are the main reasons for this, as they do not allow a full-thickness closure of gastrointestinal leaks with sufficient compression force.

The over-the-scope clip (OTSC; Ovesco Endoscopy AG, Tübingen, Germany) has changed the basic principle of clip placement, thereby overcoming these limitations. The nitinol clip has a «bear-claw» shape and is loaded on a transparent distance cap which is mounted on the endoscope tip.

First, tissue is pulled into the cap. This can be achieved by simple suction, or special instruments introduced via the working channel are used. Then, the clip is deployed by pulling on a string connected to a handwheel mounted on the endoscope—this is basically the same technique used for application of rubber band ligations. The clip application with the cap allows much larger wingspans, and full-thickness closures of defects have become possible with the high compression force of 8–9 Newton that is delivered by the closed clip.

In addition to closure of gastrointestinal leaks, OTSCs are used for hemostasis and for special indications such as marking of endoscopic findings for subsequent operations or for the creation of pseudopolyps for subsequent mucosectomy. These applications are discussed in the respective chapters.

There are no randomized trials on OTSC closure of gastrointestinal leaks, and the evidence is based on retrospective series with heterogeneous indications and applications. Reporting the clinical results to registries, such as the «CLIPPER Study Group,» ensures that the increasing use of OTSCs for leak closure is accompanied by a steady evaluation of the clinical results.

Table 6.3 presents an overview of published case series with overall 301 patients. Reported long-

Table 6.3 Literature review for the closure of gastrointestinal leaks using the OTSC system

Author	Year	*N*	Overall success	Postoperative leaks	Acute endoscopic or interventional perforations	Chronic fistulas and leaks
Albert	2011	12	8/12 (66%)	5/6 (83%)	2/2 (100%)	1/4 (25%)
Arezzo	2012	14	12/14 (86%)	12/14 (86%)		
Baron	2012	36	24/36 (67%)	10/14 (71%)	4/5 (80%)	10/17 (59%)
Jacobsen	2012	10	5/10 (50%)	5/10 (50%)		
Disibeyaz	2012	9	5/9 (56%)	4/7 (57%)	1/1 (100%)	0/1 (0%)
Galizia	2012	3	3/3 (100%)	3/3 (100%)		
Gubler	2012	14	13/14 (93%)		13/14 (93%)	
Hagel	2012	17	11/17 (65%)	2/3 (67%)	7/10 (70%)	2/4 (50%)
Jayaraman	2013	21	12/21 (57%)			
Kirschniak	2007	4	4/4 (100%)		4/4 (100%)	
Kirschniak	2011	19	14/19 (74%)	1/2 (50%)	11/11 (100%)	2/6 (33%)
Manta	2011	12	11/12 (92%)	11/12 (92%)		
Mennigen	2013	14	11/14 (79%)	10/12 (83%)		1/2 (50%)
Mönkemüller	2013	7	3/7 (43%)	1/3 (33%)		2/4 (50%)
Nishiyama	2013	13	11/13 (85%)		7/8 (88%)	4/5 (80%)
Parodi	2010	10	8/10 (80%)	4/6 (67%)	1/1 (100%)	3/3 (100%)
Pohl	2010	2	1/2 (50%)	1/2 (50%)		
Repici	2009	2	2/2 (100%)		2/2 (100%)	
Sandmann	2011	10	9/10 (90%)	2/3 (67%)	3/3 (100%)	4/4 (100%)
Schlag	2013	6	6/6 (100%)		6/6 (100%)	
Seebach	2010	7	5/7 (71%)	2/3 (67%)	3/4 (75%)	
Surace	2011	19	8/19 (42%)	7/18 (39%)		1/1 (100%)
Voermans	2012	36	32/36 (89%)	1/1 (100%)	31/35 (89%)	
Von Renteln	2010	4	2/4 (50%)	0/1 (0%)		2/3 (67%)
Overall		**301**	**220/301 (73%)**	**81/120 (68%)**	**95/106 (90%)**	**32/54 (59%)**

Mennigen et al. (2013), Albert et al. (2011), Arezzo et al. (2012), Baron et al. (2012), Jacobsen et al. (2012), Disibeyaz et al. (2012), Galizia et al. (2012), Gubler and Bauerfeind (2012), Hagel et al. (2012), Jayaraman et al. (2013), Kirschniak et al. (2007), Kirschniak et al. (2011), Manta et al. (2011), Monkemuller et al. (2013), Nishiyama et al. (2013), Parodi et al. (2010), Pohl et al. (2010), Repici et al. (2009), Sandmann et al. (2011), Schlag et al. (2013), Seebach et al. (2010), Surace et al. (2011), Voermans et al. (2012), and von Renteln et al. (2010)

term success rates range from 42% to 100%; the average success rate was 73% (220/301). However, follow-up was quite short in most studies.

There are three different types of indications:

1. Acute endoscopic or interventional perforations being diagnosed immediately during the procedure, like colonic perforation during polypectomy
2. Postoperative leaks and fistulas, especially anastomotic leaks
3. A very heterogeneous field of chronic fistulas and leaks not belonging to the first two groups. This, for example, includes enterocutaneous fistula, perforated ulcers, or persistent gastrocutaneous fistulas after removal of PEG tubes.

Acute Endoscopic or Interventional Perforations

The success rate of OTSC closure in acute endoscopic or interventional perforations is 90% (95/106), meaning that most perforations occurring during endoscopic interventions can be managed by OTSC applications. From the technical point of view, acute perforations are the ideal indication for OTSC closure: the acute lesion is free from infection or scarring and is not contaminated by luminal contents, and the patient usually is already located in a specialized endoscopy unit. The OTSC application can avoid a surgical management in these cases, and some authors already claim «sparing the surgeon.» However, a certain amount of patients still undergo operations for safety reasons, with the finding of a sufficient OTSC closure of the leak in most cases.

OTSC closure of acute endoscopic perforations requires special care and caution.

After OTSC closure of an endoscopic perforation, the sufficient closure must be proven by endoscopic aspect and, if possible, by contrast study (application of contrast dye via the endoscope).

There is one fatality in the literature after dislocation of an OTSC placed on a colonic leakage, leading to a fatal peritonitis.

After OTSC closure of acute perforations, intensive clinical monitoring of the patient is mandatory. If in doubt, safety of the patient is the highest priority, even if this means an exploratory laparotomy.

Tip

Massive pneumoperitoneum is a frequent problem after OTSC closure of endoscopic perforations. Therefore, CO_2 insufflation should be used for interventions with a risk of perforation. After closure of the perforation, pneumoperitoneum can be easily drained by a cannulation of the peritoneum. This usually leads to a rapid improvement of symptoms. With the occurrence of a perforation being treated by OTSC, broad-spectrum antibiotic therapy should be initiated.

Postoperative leaks

Postoperative leaks and fistulas are another important indication for OTSC application. There are reports of successful closure of chronic fistulas following gastric sleeve resection, of fistulas at esophagojejunal and esophagogastric anastomoses, of fistulas at colorectal anastomoses, and in some cases of acute anastomotic leakage. The overall success rate is 68% (81/120), which is substantially lower than for acute endoscopic perforations. Fibrosis and acute inflammation at the site of leak are the most mentioned reasons for OTSC failure in these cases. In cases of early postoperative anastomotic leaks, the OTSC closure can be impaired by progressive necrosis or dehiscence at the anastomosis.

Despite these limitations, the OTSC closure of leaks and fistulas has a low risk and does not impair subsequent therapies in case of OTSC failure. The exact place of the OTSC in therapeutic algorithms for postoperative leaks and fistulas still has to be determined. Possible indications are summarized in the following box:

Suitable Indications for OTSC Closure of Postoperative Leaks

- Leaks which can be closed with one single OTSC (in selected cases, closure can be done with two or even more adjacent clips).
- No acute inflammation of the leak area.
- Little fibrosis and scarring.
- Chronic fistulas, especially residual fistulas after stent or endoscopic vacuum therapy.

- Under favorable circumstances, possibly acute anastomotic leaks. In these cases, alternative endoscopic vacuum therapy should be evaluated, as it provides sufficient drainage and debridement of the leak cavity.

Chronic Leaks and Fistulas

The field of chronic leaks and fistulas naturally is very heterogeneous. Chronic fistulas are often difficult to manage; stent therapy or application of fibrin glue is frequently not successful. The OTSC is a valuable alternative in these cases and should be considered before surgical management. Chronic fistulas usually show a lot of fibrosis, which makes it more difficult to get enough tissue into the clip. In this respect, the success rate of 59% (32/54) is lower than for acute endoscopic perforations. The value of the OTSC, however, is high in this setting, e.g., even esophagobronchial fistulas can be closed by OTSC, which significantly reduces morbidity and mortality compared to redoing thoracotomy for fistula repair.

Requirements of Staff, Instrumentation, and Organization

The endoscopist must be familiar with the application of the OTSC system, as well as with the different assist devices like twin grasper and anchor. The procedure requires, at least one, better two assisting persons who are not occupied with the sedation and monitoring of the patient.

The OTSC system consists of a clip loaded on a transparent cap; this system is placed on the tip of the endoscope (Fig. 6.5). A string is pulled through the working channel and connected to a handwheel. The clip is placed by pulling the target tissue into the cap (by suction or by using the twin grasper or the anchor), and by turning the handwheel, the string pulls the clip off the cap resulting in the closure of the leak (Fig. 6.6).

Ovesco provides OTSCs in different specifications. There are three different cap diameters (11, 12, and 14 mm), so any standard endoscope can be used. There are two different heights of the cap (3 and 6 mm). This cap height determines how much tissue can be pulled into the cap. Finally, there are three different shapes of the teeth of the clip (Fig. 6.7): «a» for atraumatic, blunt teeth, «t» for sharp teeth with improved anchoring, and a special clip geometry «gc» (gastric closure) for the closure of gastric full-thickness defects, e.g., during NOTES surgery.

The cap diameter is selected according to the endoscope used. For most purposes, a cap height of 6 mm is appropriate, as this allows the clip to grasp more tissue. The "t" shape with its sharp teeth possibly provides a more solid anchoring at the application site, and it can be used for most indications (Fig. 6.7).

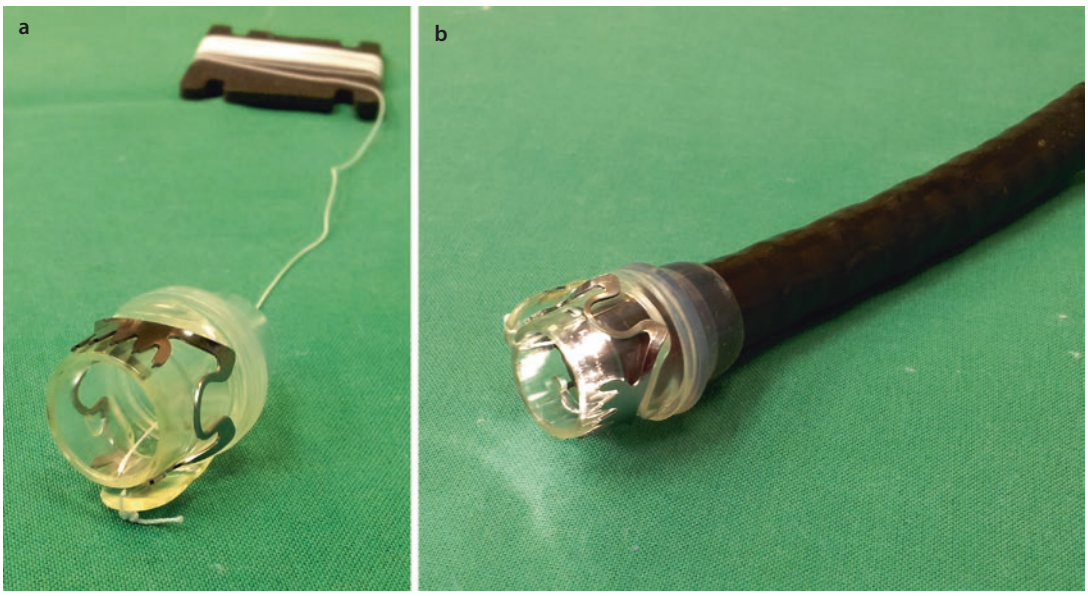


Fig. 6.5 **a** OTSC loaded on cap, the attached string is pulled through the working channel before mounting the cap. **b** OTSC system mounted on the endoscope

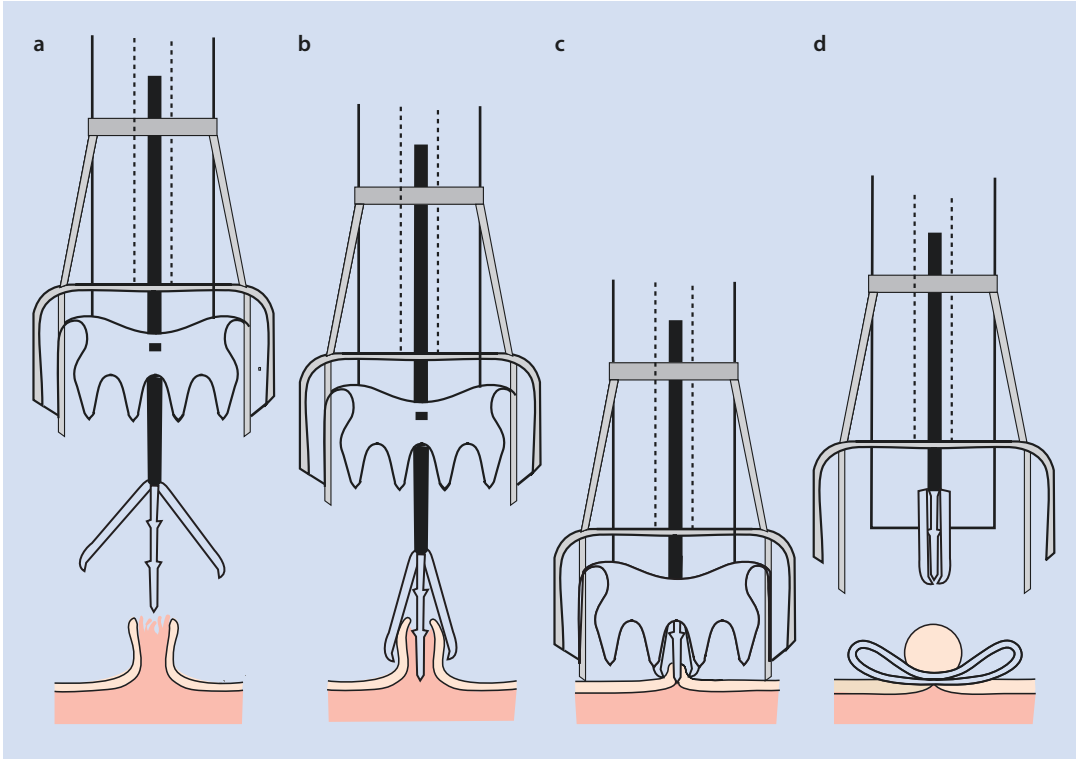


Fig. 6.6 OTSC application (here using a twin grasper). The defect is pulled into the cap by the twin grasper, before firing the clip. **a** Aiming at the lesion. **b** Pulling the tissue into the cap. **c** Firing the clip by turning the handwheel. **d** The clip is placed

Fig. 6.7 OTSC in different specifications («a,» «t,» and «gc») (Ovesco Endoscopy AG, Tübingen, Germany, with kind permission)

Fig. 6.8 Anchor and twin grasper (Ovesco Endoscopy AG, Tübingen, Germany, with kind permission)

The easiest way of clip application is certainly to bring the tissue into the cap by suction with subsequent firing of the clip. Ovesco provides two optional devices which can be introduced via the working channel: the anchor and the twin grasper (Fig. 6.8). The anchor basically is a probe which has three hooks («anchors») which can be moved out by the assisting person. This system is very valuable when dealing with small fibrotic fistulas. After introduction of the anchor into the fistula, the fistula can be pulled into the cap. The twin grasper is a forceps with two independently opening branches on each side, so both edges of a defect can be grasped separately, thus making possible the closure of larger defects.

Procedure

The applications of an OTSC on fistulas and leaks include the following steps:

OTSC Application on Fistulas and Leaks

- Diagnostic endoscopy with assessment of exact localization of the leak, check of endoscopic accessibility, and check of stable endoscope position at the planed application site
- If necessary: lavage of the leak, debridement
- Positioning the mounted cap on the leak or fistula site
- Pulling the leak site into the cap (by suction, by twin grasper, or by anchor)
- Firing the OTSC
- Endoscopic visual control of successful closure
- When indicated, contrast study to ensure a sufficient closure of the leak

Before placing an OTSC, the leak site must be thoroughly inspected. After assessment of leak type, its localization, the grade of fibrosis, and inflammation, the indication for a possible OTSC application should be evaluated using the above-mentioned criteria. Especially chronic leaks or fistulas should undergo a debridement, e.g., with a brush, prior to OTSC application.

Always check if there is a relevant cavity behind the leak. This prohibits OTSC application, as the cavity would then be without drainage, which inevitably would lead to an abscess.

In these situations, an additional drainage of the leak cavity is mandatory, or an alternative therapy, such as endoscopic vacuum therapy, should be used. All fistulas and cavities should be intensively rinsed.

During this preparatory endoscopy, the following aspects are important:

- Can the leak site be reached with the mounted OTSC system? Is there a stenosis preventing the passage of the system?
- Will it be possible to place the cap onto the leak site?

Tip

At some sites it is quite difficult to place the cap onto the leak, especially in the esophagus or duodenum. In such situations, it is good advice to check the accessibility with a standard distance cap mounted on the endoscope. The OTSC system is only opened if this test is successful. This avoids unnecessary costs for mounted OTSC systems which finally cannot be placed at the intended site.

After mounting the OTSC system, the endoscope again has to be introduced to the site of leak. With the cap mounted, this has to be done very carefully.

In particular, the passage of the mounted OTSC system through the upper esophageal sphincter has to be done very carefully; an iatrogenic perforation of the proximal esophagus is one of the most severe complications reported in the literature.

The optimal placement of the cap onto the leak site is not always easy. The assisting person fixing or pushing the endoscope can be of great help in these situations. Optimal communication within the team is important. Once the tissue is pulled into the cap, the assisting person has to ensure that the endoscope remains in exactly the correct position.

The application of the OTSC by suction of the tissue is the easiest and usually most suitable technique. The cap is placed on the leak site; the assisting person holds the endoscope in this exact position, allowing the endoscopist to use both hands for the following clip application. While applying continuous suction with his left hand, he turns the handwheel with his right hand. The OTSC drop-off can usually be visualized.

Small fibrotic fistulas often cannot be sucked into the cap. In these situations, the anchor is a good instrument. Its application is quite easy: the anchor is introduced into the fistula. While the assisting person ensures the position of the endoscope and of the cap on the fistula, the hooks of the anchor are extended, and the endoscopist can pull the fistula into the cap. This procedure can be facilitated by applying suction.

Larger defects can be closed using the twin grasper, which makes it possible to grasp both edges of the defect separately and to pull them together into the cap before firing the clip.

Before firing the OTSC, it has to be checked that the device (anchor or twin grasper) is completely pulled into the cap. Otherwise the instrument is fixed to the surrounding tissue by the fired OTSC.

After placing the OTSC, the former leak site is endoscopically assessed:

- Is the clip exactly positioned on the leak?
- Is the leak completely closed?
- Is the OTSC sufficiently anchored?
- Is the remaining lumen (especially in the esophagus, duodenum, and small bowel) still wide enough?

Documenting the sufficient sealing of the leak by contrast study during endoscopy is advisable; it is mandatory in cases of acute endoscopic perforations which otherwise would make an operation necessary. If this contrast study cannot be done during endoscopy, it can be subsequently be done by CT scan with oral or rectal application of contrast dye.

Two clinical cases demonstrating the OTSC closure of postoperative leaks are shown in Figs. 6.9 and 6.10.

Possible Complications and Their Management

Only a few complications have been described in the available literature; some of these, however, were severe.

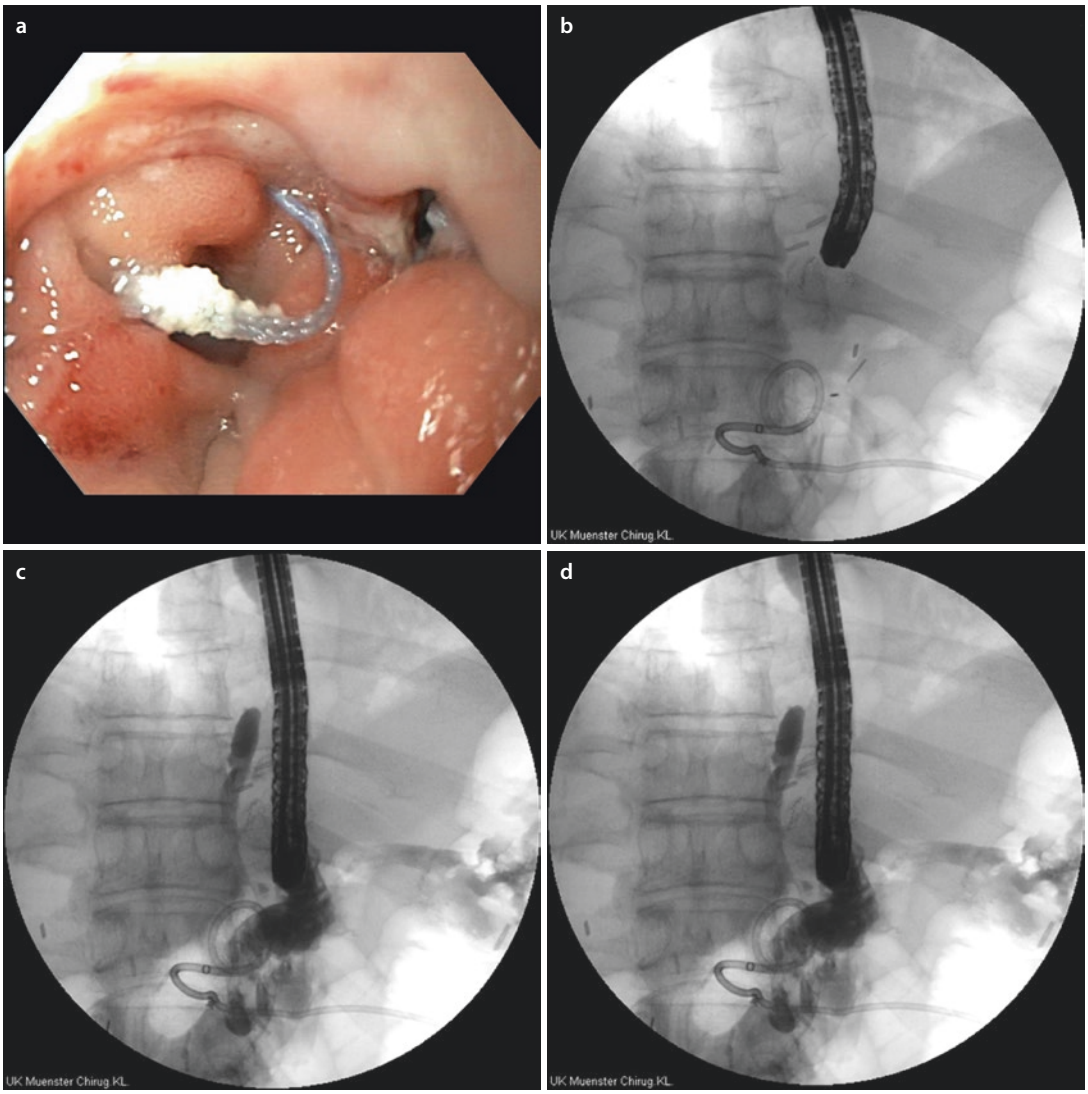
The introduction of the mounted OTSC system can induce injuries, especially at the upper esophageal sphincter or in the anal canal. Frequently, these are superficial mucosal tears; the published case of proximal esophageal perforation has already been mentioned before.

If not retracted completely, the assist devices «twin grasper» or «anchor» can be fixed to the gastrointestinal wall by the fired OTSC. Pulling on the device is the only option in this situation (after retracting the hooks of the anchor), and this usually is quite unproblematic, as the surface of the instruments is smooth and they can slip out of the clip. This procedure of course impairs the safety of the OTSC leak closure; special attention has to be paid to a possible displacement of the clip or to a persistent leak.

Wrong positioning of the OTSC can give rise to complications, too. If the lesion is not centered correctly, a persistent leak can be the result. In some cases, a second OTSC can be placed next to the first one. However, this is technically demanding. After application of OTSCs in duodenum and small bowel, unintended complete or subtotal closure of the lumen has been reported in some cases; these cases were managed by surgery. When using the OTSC in the distal rectum, special attention has to be paid not to place the OTSC in the sensitive anoderm. Placing an OTSC in this sensitive area is only possible under anesthesia. For this

purpose, Ovesco offers a special «OTSC proctology» device allowing the closure of anal fistulas.

The removal of wrongly positioned OTSCs is not trivial; therefore, they should be placed with utmost caution. Before the introduction of a special device, authors reported the successful removal of OTSCs by Nd:YAG lasers. Recently, Ovesco developed a special device for the purpose of OTSC removal (remOVE, Ovesco Endoscopy AG, Tübingen, Germany; ◘ Fig. 6.11.). It is a bipolar forceps with a DC generator connected to it. The instrument is introduced via the working channel. The clip is grasped at its thinnest point. A short electric impulse melts the nitinol between the branches. Due to the bipolar construction, no relevant electric current runs through the patient. The divided clip can then be extracted by a forceps under protection of a soft cap.



◘ **Fig. 6.9** OTSC closure of an anastomotic leak following gastrectomy. **a** After gastrectomy with stapled esophagojejunostomy, the patient developed an anastomotic fistula. **b** Fluoroscopy: a CT-guided pigtail drain is located in the leak cavity. **c** Contrast dye application into the fistula via a cannula, showing a bizarre leak cavity. **d** Contrast dye application into the jejunum. **e** Rinsing the fistula via a cannula. **f** OTSC placed onto the fistula. **g** Endoscopic aspect after 2 months: enduring closure of the fistula. **h** Contrast study after 2 months: no leakage present, clip in situ

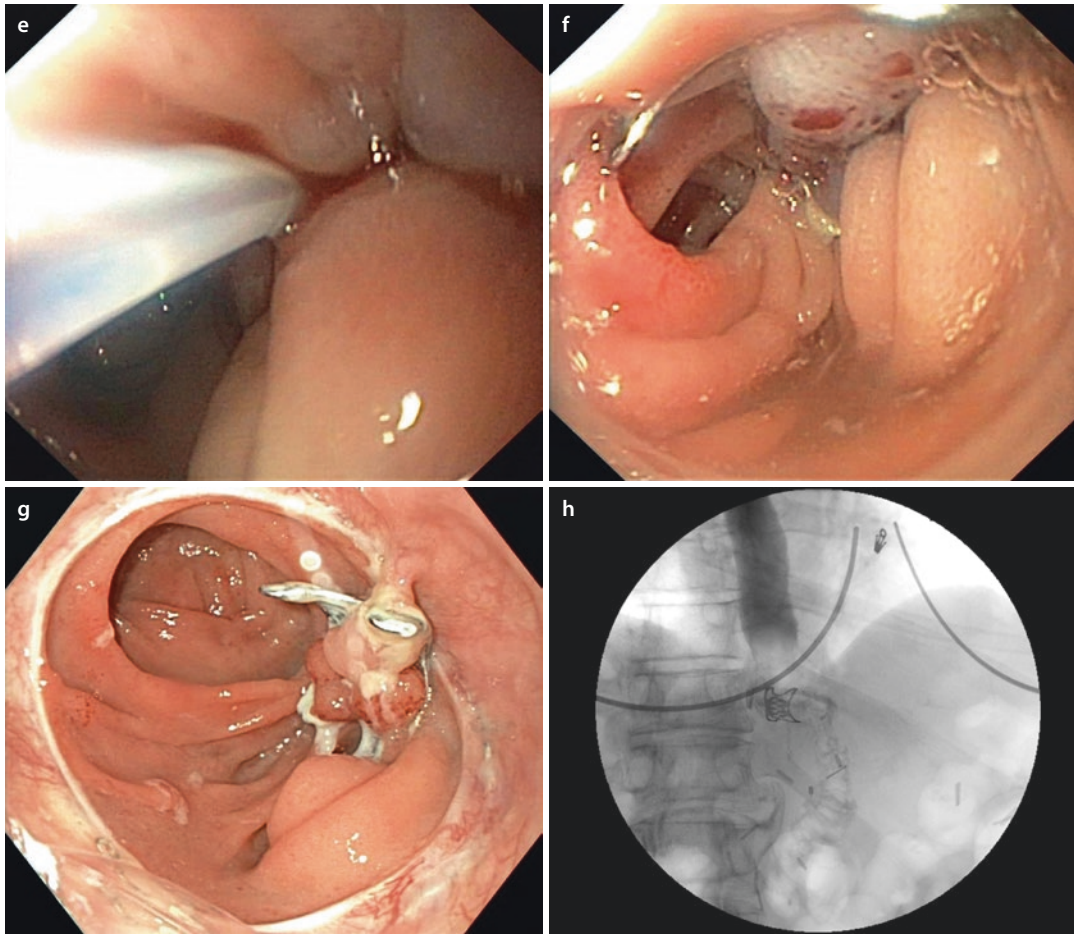


Fig. 6.9 (continued)

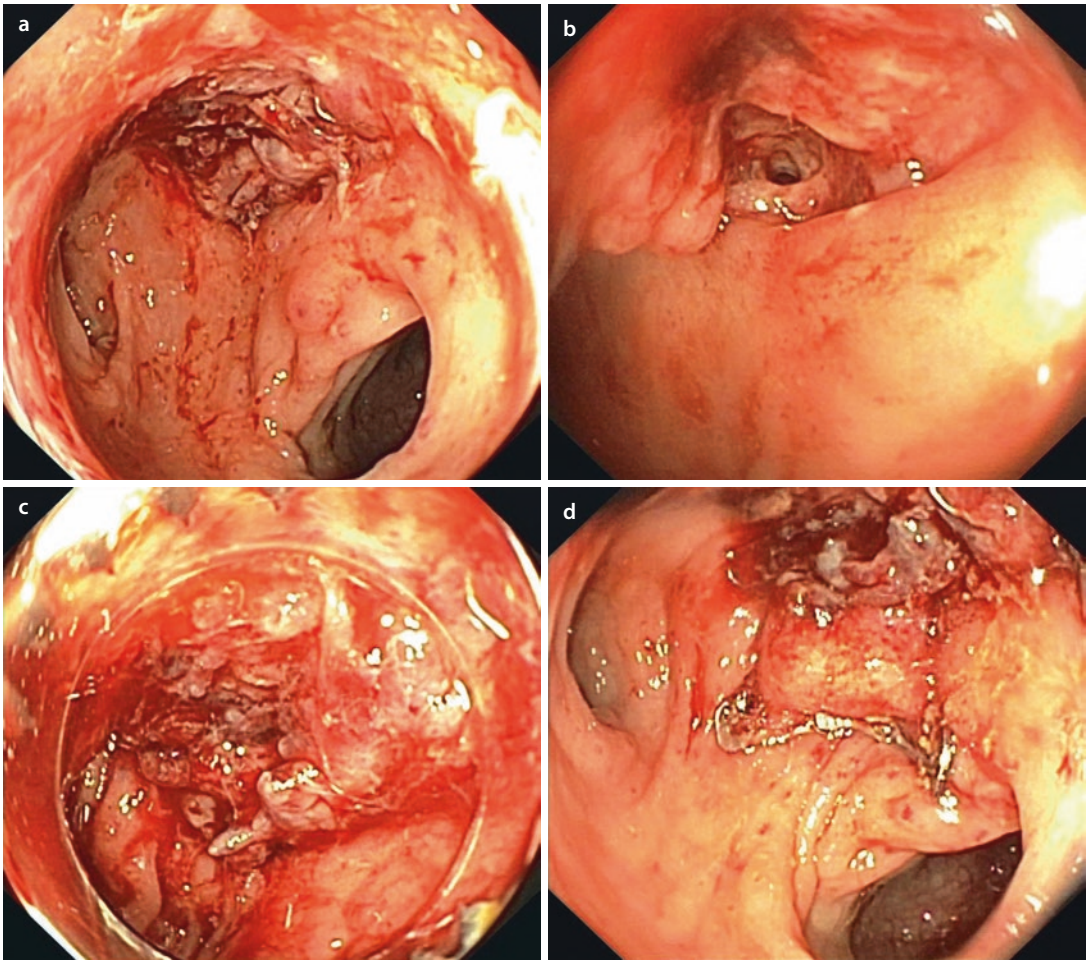


Fig. 6.10 OTSC closure of an anastomotic fistula following rectal resection (residual fistula after endoscopic vacuum therapy). **a** Side-to-end anastomosis of descending colon and rectum. Fistula located at 12 o'clock. **b** Closer view of the fistula. **c** Placing the cap onto the fistula. **d** OTSC placed correctly on the fistula

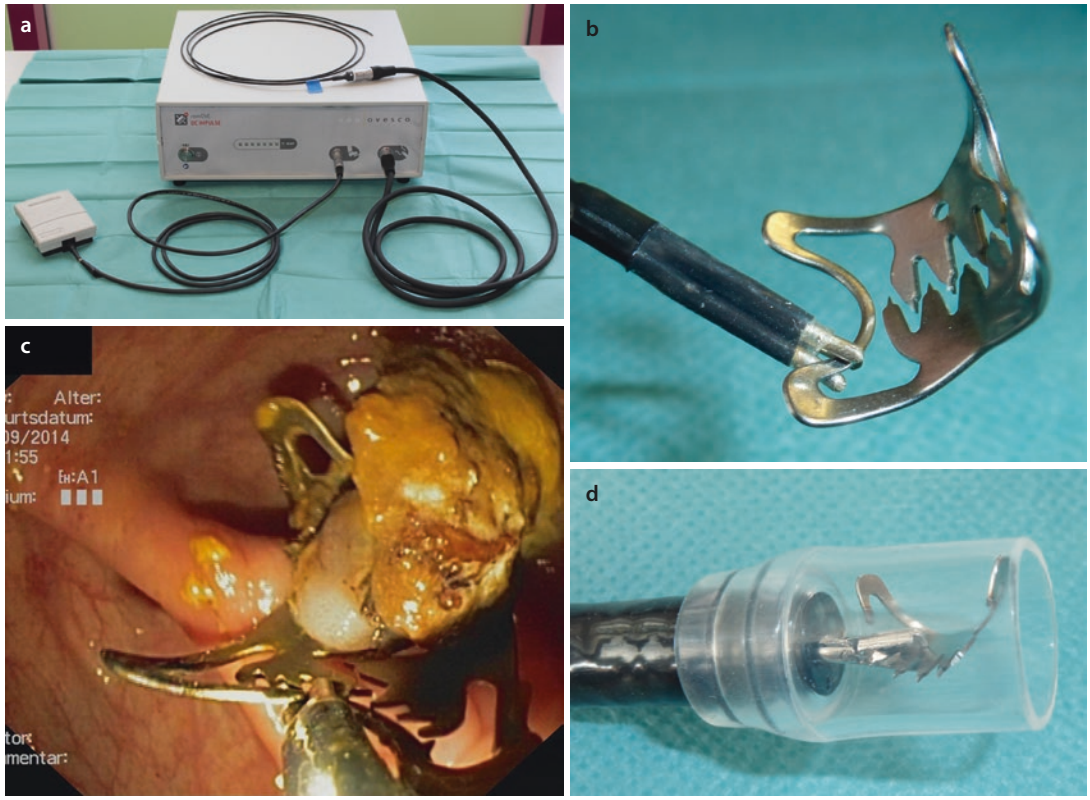


Fig. 6.11 Removal of an OTSC with the remOVE system. **a** DC generator. **b** Bipolar forceps allowing the fragmentation of the OTSC. **c** Clinical case: removal of an OTSC at the appendix base in order to allow a control biopsy after former full-thickness resection with the FTRD System (Ovesco). **d** Extraction of the divided clip within a covering soft cap (**a**, **b**, **d** with kind permission of Ovesco Endoscopy AG, Tübingen, Germany; **c** with kind permission of Dr. Arthur Schmidt, Klinikum Ludwigsburg, Germany)

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Endoscopic Feeding Techniques

Arno J. Dormann

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In the last 50 years, the use of endoscopic placement of feeding tubes has been used increasingly in clinical settings. After the use of traditional surgical gastrostomies and then later on nasogastric tubes, nowadays, predominantly percutaneous systems are used long term. Differentiated indication is imperative here. Even now, the individualized use of these procedures requires a high level of education. As of recently, endoscopic implants have also been used temporarily and also in cases of metabolic illnesses; these developments are also depicted here.

7.1 General Aspects

Oral food intake is the normal way of taking in food. Compared to artificial enteral feeding via tubes, this original way of taking in food offers significant benefits. Oral intake is comfortable, has a high social component and can, in the case of illness, e.g. swallowing disorders, be used therapeutically. Significant disadvantages of oral food intake, especially in patients with swallowing disorders are, at the same time, the reasons leading to the indication of tube feeding. The danger of aspiration, physical fatigue and especially the insufficient intake of substrates, even when using supplements, are significant. Prior to determining that a tube feeding is indicated, a feeding protocol about the intake of food and drink should always be created, so as to allow for ideal planning of therapy.

Introduction and Nomenclature of Tubes

Nowadays, different procedures of tube techniques are available, all of which differ significantly regarding the application of tubes and administration of substrates.

Basically, we must differentiate between tubes introduced through preformed stomas (e.g. nose) and percutaneously introduced tubes. The tubes are primarily named after the site of introduction into the body (nasal, gastric, enteral [jejunal, duodenal] (Fig. 7.1). A particular case is the endoscopically introduced percutaneous endoscopic caecostomy (PEC), which will be explained more in detail later on as well as surgically introduced tubes.

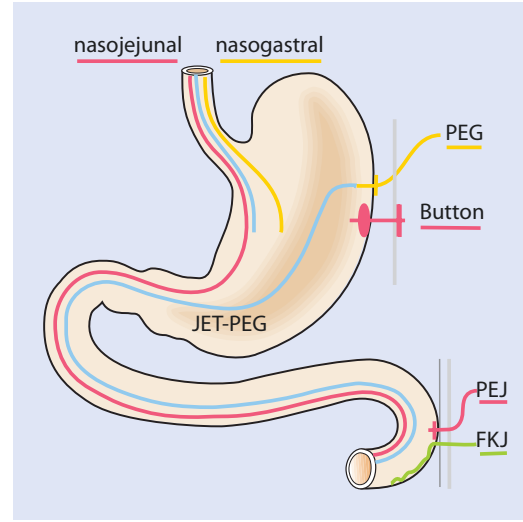

Fig. 7.1 Localization of feeding tubes at the upper GI tract (*Jet-PEG* PEG with jejunal port)

Tubes' nomenclature:
Tubes to be inserted manually:
Nasogastric tubes:
- Nasogastric

Tubes to be inserted endoscopically:
Nasal tubes:
- Jejunal tubes
- Combination tubes (tubes with multiple ports)

Percutaneous tubes – gastric/jejunal:
1. Primary techniques:
   - PEG: percutaneous endoscopic gastrostomy
   - PEG with jejunal port: «jejunal tube through PEG» = PEG + internal catheter
   - PEJ: percutaneous endoscopic jejunostomy (also «EPJ»)
2. Secondary techniques:
   - Button
   - Gastrotube

Percutaneous tubes – colon:
- PEC: percutaneous endoscopic colostomy/caecostomy

Tubes to be inserted surgically:
- FNCJ: fine-needle catheter jejunostomy

Ethical-Legal Aspects Regarding Tube Feeding

The primary objective of nutritional therapy is to maintain the patient's nutritional state or to improve it, thus positively influencing the patient's prognosis regarding his illness. Nutrition used to be an instrument of basic care, but in the meantime, it has developed into a highly efficient instrument for medical therapy and prevention and has become part of a modern and multimodal therapy concept (e.g. intensive therapy, oncological therapy, paediatrics, etc.). In addition to tube-specific indications, which are explained in the individual sections, it is now part of the physician's skills to develop a patient-dependent and targeted strategy under medical and ethical aspects, together with the care personal, the relatives and others involved. The type of patients treated ranges from a child in intensive care to the geriatric patient suffering from dementia at the end of his life.

Generally valid procedures cannot be determined. The legal provisions (living will, guardianship, possibly associated with the involvement of court, if needed) as well as the basics of palliative care and the involvement of an ethics consultation at the hospital (Oehmichen et al. 2013) should be taken into consideration.

7.2 Transnasal Tubes

Transnasal tubes are used when tube feeding is only performed for a short period of time (<4 weeks) or when the duration of feeding remains unclear and the definitive decision about the further procedure is still waited on (e.g. after a stroke with dysphagia and tendency of improving quickly or in intensive care patients) (Bernhardt 2007). The area of use varies significantly, and there are a number of tube sizes available for children and adults (▶ Sect. 2.1). Currently, only tubes made of polyurethane or silicone are used (Bernhardt 2007).

Nasogastric or nasojejunal tubes are used for brief (up to 4 weeks) enteral feeding.

Nowadays, we differentiate between three types of tubes (◘ Fig. 7.1).

Nasogastric Tube Various types of tubes are available; they differ in their outside diameter, length and the number of ports. They can be placed without the assistance of instruments, endoscopically or radiologically and/or a combination of both procedures.

Nasointestinal Tube This tube has one port only and is the simplest type of jejunal tube. Usually, the tube can be inserted under radiological or endoscopic control down into the upper jejunum. For the latter technique, diameters of 8.5 CH are available, through which only nutritional solution containing no fibre can be applied.

Combined Tube (Gastric and Jejunal Port) Usually, two-port tubes are used. The second port ends in the stomach, as is the case in the gastric tube, and serves for decompression of the stomach. Three-port tubes are also available, which are a combination of the two-port tube with an additional possibility for ventilating the stomach and an intestinal port.

Indications and Contraindications

Gastric tubes are usually used for the isolated and temporary deviation of secretion from the upper gastrointestinal tract, especially of the stomach. Here, peri- and postinterventional motility disorders, e.g. after interventions at the upper abdomen, must be named. In the case of a st. p. (partial) removal of the stomach, jejunal feeding via one-port tube is preferred; it is, e.g. necessary, when an early enteral feeding is planned, but the stomach's motility has not yet returned. One-port tubes are used for short-term enteral feeding (up to a max. of 4 weeks) or when a PEG is contraindicated (▶ Sect. 3). One benefit of two-port gastric tubes is that the stomach can be actively decompressed through the port inserted into the stomach, while the other port is available for the administration of nutrition or for removing secretions. This prevents the mucous membranes from adhering.

Tubes with multiple ports, with a gastric port and a jejunal port, can be used for decompression of the stomach as well as of the upper jejunum, as you would be able to with a one-port gastric tube. At the same time, jejunal feeding is possible or liquid medication can be administered. This is particularly indicated after surgery at disrupted increase of feeding or during long-term intensive therapy.

Further indications include the bridging of oesophagogastric, oesophagojejunal or gastrojejunal anastomoses and insufficiencies of anastomoses

or patients with motility disorders of the stomach caused by diabetes mellitus, neurosurgical interventions or peritoneal carcinomatosis. In these cases, tubes with multiple ports can serve to relieve pressure in the area of the anastomosis but predominantly serve early enteral postoperative feeding.

For tube insertion, the same indications and contraindications apply as for gastroscopy. Passing through anastomoses must be discussed with the surgeon prior to the intervention, since it might lead to increased stress on the anastomosis. Usually, tubes are inserted without problems; the risk of an endoscopic passage is often overestimated.

In cases of injuries to the face or skull, the therapeutic options have to be checked from case to case, since particularly in the case of tubes with multiple ports, a nasal access should be used.

Preparation of Patient

The patient's preparation also mostly corresponds to that of a routine gastroscopy. Prior to placing the tube, the patient and/or the relatives should be informed about the measure, which should also include subsequent nutritional therapy. In case of a nasal tube, the upper gastrointestinal tract must be freely passable.

For jejunal tubes, the patient must be prepared as he would be for an endoscopy. Intensive care patients are usually already sedated and ventilated. For a patient who is awake, analgosedation is essential for the endoscopic insertion of a tube.

Personnel-Related Requirements

Nasogastric tubes are usually inserted by trained nursing staff. The tube is often also inserted during surgery, during anaesthesia.

During an endoscopy, at least one endoscopy nurse and one physician must be present. The physicians must be experienced in endoscopy and in the use of the application technique required, since, depending on the site, a modification might be necessary. The measure should be planned in advance by the treating physician.

Instrument-Related Requirements

Usually, little is required of instruments. Tube-grasping forceps are practicable for grabbing the tubes. Ideally, devices with larger working canals (greater than 3 mm) are used. An endoscopy unit (possibly with mobile use in intensive care) must be present; additionally, the possibility of monitoring must also be available, if it is not an intensive care patient.

The preparation of the respective types of tubes will be depicted in the following sections.

7.2.1 Nasogastric Tubes

Instrument-Related Requirements

The following items are required: tube; lubricant for the mandrin, if needed; a stethoscope; irrigation syringe; bandage set; local anaesthetic; and a collection bag.

Practical Course

A number of tube sizes are available for children and adults (diameter 6.5–15 CH, length 40–60 cm for children, 100–130 cm for adults). PVC tubes should not be used anymore. Due to their high biocompatibility, the decreased feeling of foreign body and the good long-term stability, newer tubes made of polyurethane plastics and silicone rubber are also used for long-term nasal and percutaneous use.

The selection of tubes depends on various parameters. The tube's diameter should be as small as possible to allow for the highest possible comfort of the patient. At the same time, however, if the diameter is too small, application of nutrition and/or medication might become more difficult and can lead to an occlusion of the tube. For children, usually tubes with a diameter of 8 CH are used, whereas for adults, tubes with a diameter of 15 CH are usually used. For children, the tube should be 50–60 cm long, and for adults, however, it should be between 100 and 120 cm.

Sometimes, it can be of use to determine the respective length of the tube required ahead of time. For this, the distance from the earlobe to the tip of the nose (usually 10 cm) must be added to the distance of the nose to the epigastrium (usually 40–50 cm). This distance can then be marked on the tube to avoid a curling of the tube once it is placed in the stomach.

After having cleaned the nasal passages and selected the larger nostril, the nasal entry is anaesthetized with a local anaesthetic gel or spray. The patient is positioned in an upright or semi-upright position. Initially, the tube is advanced for about 10 cm at the bottom of the inferior nasal meatus.

Then, the head is tilted forwards and the patient is asked to actively swallow while, at the same time, advancing the tube. If the patient is coughing or if there is resistance, the tube must be retracted, and another attempt must be made. In case of a good passage, advance the tube in gastric direction, and after having determined the position, usually by blowing in air through auscultation (alternative methods include determination of pH or x-rays), the tube is then secured to the nose.

▪ Complications and Management of the Same

Great advantages of the nasogastric tube placement include the bedside placement and simple technique, which is noninvasive and available everywhere. Compared to the percutaneous techniques, no parallel techniques are required (Bernhardt 2007).

Despite all precautions, the placement of a nasogastric tube is also associated with acute and chronic risks. The placement of tubes can lead to nosebleed and injuries to the afferent ways as well as to a refractory bradycardia up to asystole. In the long run, repeated tube dislocations and lesions of the afferent paths (nose, oropharynx, oesophagus, stomach) limit the use of these types of tube systems. In addition, swallowing rehabilitation is also more difficult when a tube is inserted. Clinically relevant factors include the reduced application of enteral nutrition compared to percutaneous tubes, caused by dislocation, as well as the latent danger of aspiration. This can lead to a vital threat to patients.

▪ Standardized Aftercare After the Placement of Tubes

Aftercare generally corresponds to the general care guidelines; food can be introduced immediately.

7.2.2 Nasojejunal Tubes

▪ Instrument-Related Requirements

The following are required: prepared tube, possibly lubricant for the mandrin, a bandage set, a gastroscope (with a large lumen) and grasping forceps. In the case of many manufacturers, preparation of the tube includes filling the lumen with silicone oil or water, which significantly facilitates the later removal of the mandrin.

Figs. 7.2, 7.3 and 7.4 show tubes with one, two and three ports.

Fig. 7.2 One-port tube (Courtesy of company Fresenius)

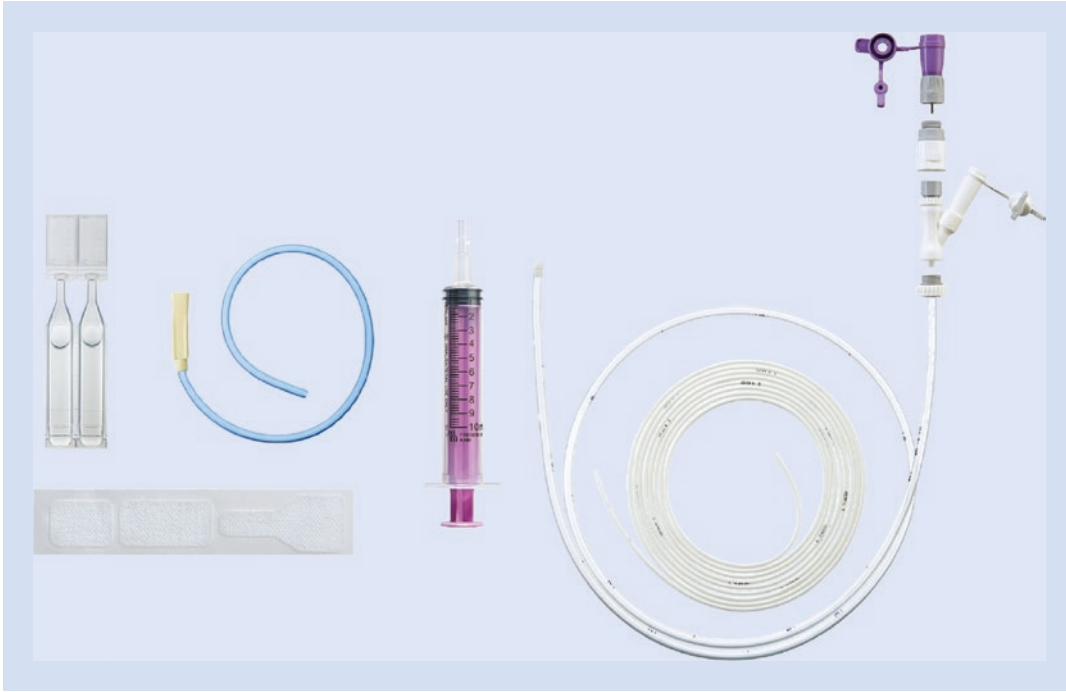

Fig. 7.3 Two-port tube (Easy In) (Courtesy of company Fresenius)

Fig. 7.4 Three-port tube Trelumina (Courtesy of company Fresenius)

A deciding factor for the successful clinical use of nasointestinal tubes is the application technique that must guarantee the secure and permanent position of the tube in the area distal of the duodenojejunal flexure or, in rare cases, in the distal duodenum (Külling et al. 2000).

Techniques of jejunal tube placement:

- TTS («through the scope»)
- OTW («over the wire»)
- BTS («beneath the scope»)

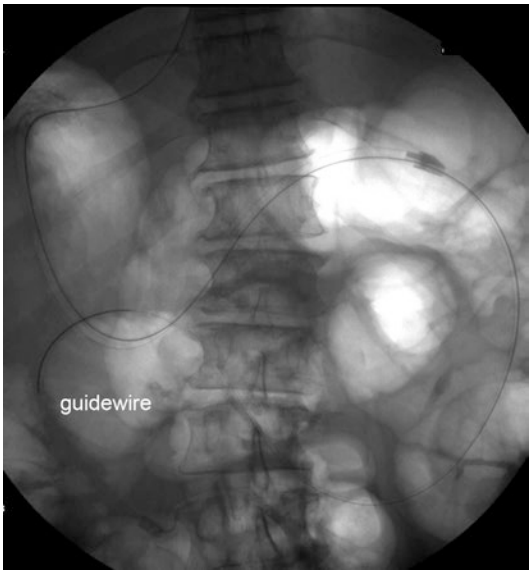

Fig. 7.5 Insertion of a Trelumina tube over a guidewire (OTW technique)

The simplest method is the «through the scope» technique (TTS), which includes the direct insertion of a thin tube directly into the jejunum through a widely guided endoscope, which is then left in place when removing the device. During the final naso-oral deviation, it must be ensured that the tube is placed straight in the hypopharynx. A disadvantage of this method is that even when a device with a maximum-sized working canal is used, only tubes with one port and a small diameter can be used.

In the case of the «over-the-wire» (OTW) technique, a guidewire (e.g. 0.035″ Jagwire Boston Scientific) is endoscopically inserted into the small intestine and remains in place when removing the endoscope. Through this inserted wire, which had been deviated nasally, a tube is placed (Fig. 7.5) (see technique of nasobiliary tube, ▶ Chap. 4).

This technique can be used for one-port (nasojejunal) as well as for tubes with several ports, but usually requires a radiological checking of the position prior to applying nutrition.

Especially in the case of tubes with several ports, a radiological control or having marked the tube with a colour code is helpful.

Very often, the insertion technique «beneath the scope» (BTS) is used. It includes grabbing the distal end of the nasally inserted tube with special forceps endoscopic-gastrically, which is then guided in intestinal direction using the device. If further endoscopy is not possible anymore, the forceps with the affixed tube are advanced as much as possible and then remain in situ while the device is retracted. Once the (diagnostic) endoscope is positioned in the stomach, the forceps are loosened and then slowly moved back into the device. This technique is generally helpful when inserting intestinal tubes, such as a jejunal tube via PEG.

If the tube is dislocated in proximal direction, the tube can then be advanced again using the grasping forceps. When placing tubes with several ports, it must be ensured that the gastric tube opening is not placed transpylorically. Sometimes, this endoscopic procedure is work intense and also requires special skills of the person performing the procedure. An advantage includes the good control of the tube's position through direct visual control.

The BTS procedure is of the same value as the OTW procedure described before; the method being used is up to the person performing the procedure.

Due to the comfortable technique, two procedures of inserting a tube are usually combined. In the case of the two-port tube Easy In, the jejunal tube is initially placed using the TTS technique. The jejunal part of the tube is then deviated with a deviation tube as would be the case when inserting a nasobiliary tube (▶ Chap. 4). Afterwards, the inserted tube is used as a splint for the gastric port, which is inserted through the same into the stomach, nasally. An alternative procedure would include the nasal insertion of the three-port tube into the stomach, as would be the case with a gastric tube, and then placed into the jejunum using the BTS technique.

Complications and Management of the Same

Acute complications during the insertion procedure are rare. An inexperienced endoscopic physician might have difficulties with the placement, which may sometimes be technically even impossible for him. Time requirements vary significantly, but usually it takes an experienced physician 15 min.

The following applies to all intestinal procedures: The small diameter of the tube promotes

occlusion, especially when applying medication. In addition to the problems associated with nasal tubes, which are identified above, intestinal tubes carry the potential risk of dislocation with the consecutive risk of aspiration. This is particularly the case when there is no deep intestinal placement.

Changing from the mouth into the nose also carries the risk of dislocation.

Tubes inserted for a longer period of time carry the risk of erosions and ulcerations at the distal oesophagus and stomach. For these reasons, these should not be inserted for more than 2 weeks; then instead, a PEG is placed. In the end, nasointestinal tubes with one or more ports should only be used for short periods of time, in selected patients. Deciding factors are experience and success of primary placement (Dormann and Deppe 2002).

7.3 Percutaneous Endoscopic Gastroscopy

Since the initial description through Gauderer and Ponsky in 1980, the percutaneous endoscopic gastrostomy (PEG) is now widely spread worldwide due to the technically simple and secure placement options and due to the high acceptance by patients. In the United States, about 216,000 PEG tubes are now newly inserted annually (210,000 adults, 6000 children). The annual growth rate is in the double digits. There are no reliable numbers for Germany, but based on epidemiology, we assume that in Germany, there must be about 130,000 PEGS newly inserted annually.

Indications

Please view Table 7.1 regarding the indications for a percutaneous tube. As is the case in every medicamentous therapy, each case must be assessed carefully to ensure that this type of feeding procedure is a reasonable therapeutic option. This especially applies to patients suffering from dementia.

Table 7.1 Significant indications for the insertion of a PEG

Neurological illnesses	Swallowing disorders, e.g. due to insult, cerebral trauma or surgery, atrophic lateral sclerosis (ALS), brain tumours, multiple sclerosis, dementia (?)
Oncological illnesses	Swallowing disorders, e.g. in cases of stenosing tumours in the oropharynx and oesophagus Tumour cachexia due to inadequate oral food intake Mucositis, diarrhoea
Other indications	Traumas of the facial skull or surgery Chronic obstructive pulmonary illnesses with severe cachexia Severe absorption disorders, also short bowel syndrome Mucoviscidosis Systemic illnesses (collagenoses, etc.) Palliative decompression, retention stomach Longer enteral feeding at intensive care

Contraindications

The absolute contraindications are clinically significant.

Absolute contraindications for insertion of a PEG:

- Endoscopy cannot be performed, e.g. in the case of absolute passage obstruction
- Severe coagulation disorders (Quick <50%, PTT >45 s, platelets <50,000/µl)
- Pylorus stenosis, e.g. endoscopic local findings (large ulcers, severe erosive gastritis, extensive tumour infiltration of the stomach)
- General contraindications for enteral feeding, e.g. peritonitis, ileus
- Acute abdominal illnesses, e.g. intraabdominal infections, pancreatitis, peritonitis
- Anorexia nervosa
- Severe psychosis

The relative contraindications are predominantly dependent on the examiner's experience and should be checked strictly by the beginner.

Relative contraindications for PEG insertion:

- Chemotherapy, acute infections, sepsis
- No diaphanoscopy
- Ascites, peritoneal carcinomatosis
- Ulcer in the area of the puncture
- (Partial) stomach removal (select jejunal tube technique)
- Anatomical particularities (e.g. hernias of the abdominal wall)
- Portal hypertension, abdominal wall varices
- Peritoneal carcinomatosis
- Ventriculoperitoneal shunt
- Peritoneal dialysis
- Ileus/intestinal obstruction
- Gastrointestinal fistulas
- Infaust prognosis (survival time <4 weeks)

If the patient is suffering from an acute infection or sepsis, enteral feeding should be guaranteed by a nasal tube until the infection has consolidated. In the case of an acute infection and prior to and/or after chemotherapy with leucocyte nadir, the elective insertion of a PEG should be postponed and performed at a more beneficial time. If that is not possible, a periinterventional antibiotic prophylaxis should be performed for a few days, and/or ongoing antibiotic therapy should be continued.

Nowadays, a missing diaphanoscopy is not considered a contraindication anymore. If an impression of the abdominal wall leads to a good protrusion of the stomach's wall and if a good passage into the stomach can be achieved with a thin needle during the trial puncture, a PEG can also be inserted into these patients, provided the physician has some experience (Ponsky 1996). Patients proven to be suffering from disorders affecting the emptying of the stomach should primarily receive a jejunal tube. If that is not possible, a PEG can be initially inserted, which can then, over time, be increased in length in jejunal direction (▶ Sect. 4). Larger amounts of ascites or a peritoneal carcinomatosis can prevent the adhering of the stomach to the abdominal wall and pose a contraindication. If, periinterventionally, insertion of a long-term ascites drain is guaranteed, a PEG can also be inserted in these patients using a direct puncture procedure and gastropexy (▶ Sect. 3.2). In this case, however, the tube remains taught for a prolonged period of time, so as to ensure adherence of the anterior wall of the stomach to the anterior abdominal wall.

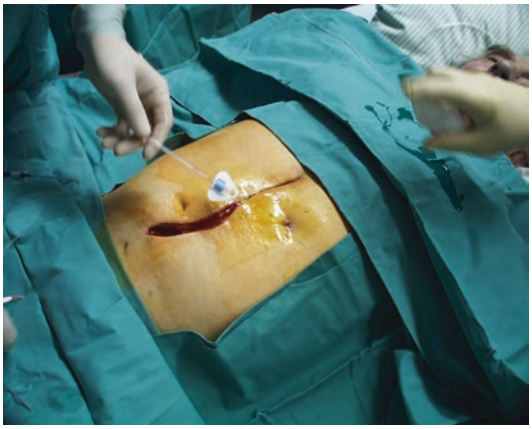

Fig. 7.6 Postoperative insertion of a PEG

An active ulcer is only a problem if the ulcer is located directly in the area of the puncture site at the anterior wall of the stomach or at the pyloric orifice. In these cases, ulcer therapy should take place first, and the tube should be inserted later on. An alternative would be using the jejunal tube technique. Placement of a PEG may also be impossible due to st. p. surgeries, especially when stomach-removing procedures were selected and when the remaining residual stomach is too small or not present (Fig. 7.6).

If placement is not possible, a jejunal tube insertion is usually possible without problems in these cases. Sporadically, larger hernias in the upper abdomen can make placing a tube more difficult. In cases of portal hypertension leading to oesophageal varices and hypertensive gastropathy, placement of a PEG can sometimes be impossible due to large vessel convolutes or severe coagulation disorders. In patients with a ventriculoperitoneal shunt or peritoneal dialysis catheters, making a decision is more difficult. For both cases, there are reports of successful placements of PEGs. This intervention should then, however, be performed in experienced centres to avoid damaging the catheter and infectious complications. A simultaneous implantation of a ventriculoperitoneal shunt must be avoided.

Anorexia nervosa and psychoses are still generally clear contraindications. In cases of a terminal illness, indication is only given under the palliative aspect of draining the stomach.

Preparation of the Patient

Preparation of the patient should be a standardized procedure at every hospital. Upon arriving at endoscopy, a checklist should be used to ensure the presence of everything required, before the patient is brought to the exam room. Patients receiving a PEG should be scheduled early to allow for discovering possible complications during the course of the day.

Preparing a patient for insertion of a PEG:

- Information: >24 h prior to intervention, signed legally valid informed consent, give out copy to the patient/guardian (**please note**: a guardian is required in cases where patient is not able to provide consent).
- Patient needs to remain fasting (at least 8 h), in case of a retention stomach up to 24 h.
- Stable venous access.
- Regular administration of antibiotic prophylaxis (e.g. cephalosporin first generation) 30 min prior to the intervention.
- Facultative: disinfection of the mouth/pharynx.
- If there is hair, shorten hair with hair cutter, if needed.
- Rule out contraindications.
- Current coagulation status: Quick >50%, PTT <40 s, platelets >50,000/mm^3).
- During endoscopy, positioning of the patient in supine position with the head sideways.
- Fixation of the hands using Velcro strips, if needed.

Personnel-Related Requirements

The following must be present during the examination: at least one person for sedation (usually a nurse experienced with sedation), an endoscopy nurse and two physicians for endoscopy and puncture. The physicians must be experienced in endoscopy and in the use of the various tube techniques, since, occasionally, depending on the site, changing of the application technique might be required.

Instrument-Related Requirements

- As is the case in every interventional endoscopy, continuous measuring of O_2 saturation (pulse oximetry), taking of the blood pressure with documentation and, in patients starting at ASA III, an EKG deviation are required.
- Additionally, a sterile table must be prepared especially for this examination, containing the following:
  - PEG set (PEG tube, scalpel, puncture cannula made of steel with a plastic sheath, external fixation plate, tubing clamp, application adapter (Fig. 7.7))
  - Incise drape
  - Gauze pads
  - Dressing set with y-gauze pad
  - Syringe 10 ml with local anaesthetic and puncture needle size 1
- For sedation, prepare midazolam (5 mg syringe) and propofol (200 mg syringe).
- Prepare standard gastroscope.
- Surgical standard with sterile gloves, clamp or tweezers for washing off and solution for skin disinfection.

Practical Development

After disinfection of the abdomen, intubation of the endoscope and ruling out of relevant illnesses of the proximal gastrointestinal tract (such as ulcer, pylorus stenosis, etc.). In a darkened room, after extensive insufflation of air in the area of the anterior wall of the stomach, in oral direction of the angulus fold, searching for a diaphanoscopy. Required is the following: a circumscribed, clear and clearly identifiable diaphany with clearly positive fingerprint and no problems with reproduction (Fig. 7.8). It might be helpful to position the patient flat or with exposition of the lower thoracic aperture, so as to allow a secure puncture of the stomach. The examiner must be aware of the insufflation changing the stomach's topography and that the most secure puncture site is slightly left to the epigastrium, yet at least 2 cm from the left coastal arch.

7.3.1 Thread Pull-Through Method

After local anaesthesia of the abdominal wall, puncture of the stomach's lumen. The puncture site is located in the middle area of the left upper abdominal quadrant. Especially in the case of insecurities regarding the puncture, aspiration is possible while advancing the local anaesthesia

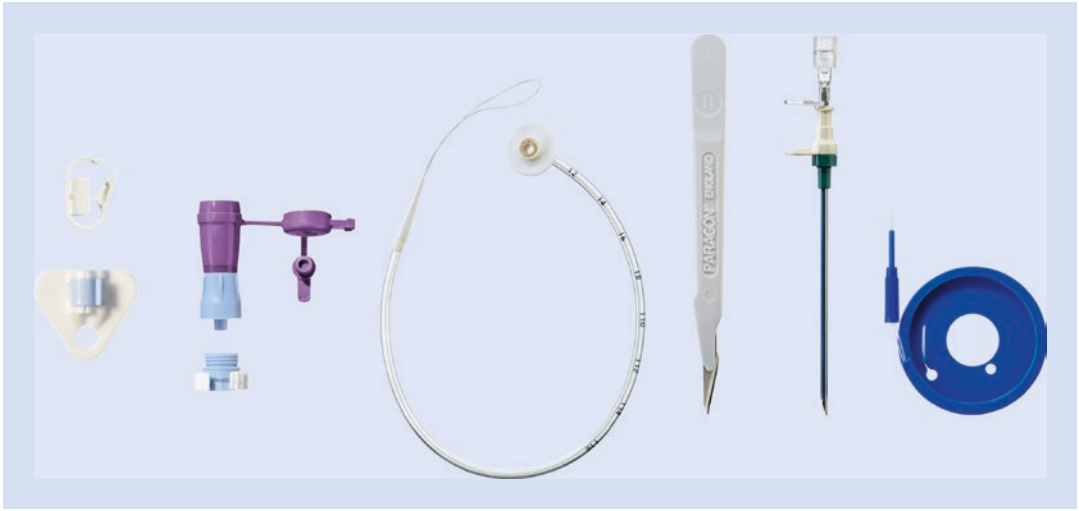

Fig. 7.7 PEG set CH 15 Freka (Courtesy of company Fresenius)

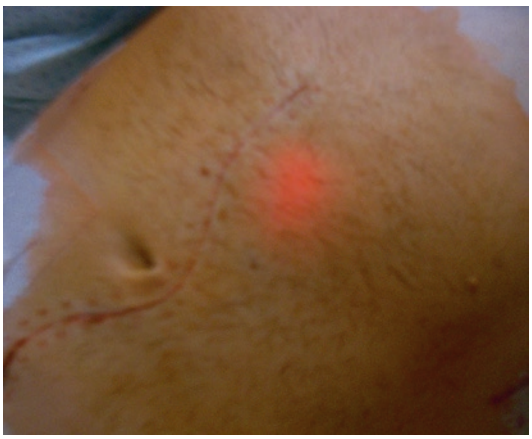

Fig. 7.8 Diaphanoscopy prior to insertion of PEG

needle. If blood or air is aspirated without the tip of the needle being visible in the stomach's lumen, the puncture site must be changed (negative needle aspiration test) (Fig. 7.9a). The puncture needle is then directed into the stomach to determine the length and direction of the future stoma canal. Afterwards, deep puncture incision is done, about 1 cm in width, and puncture cannula of the regular set is introduced (Fig. 7.9b). After retreating the puncture needle, the introductory sheath remains in the stomach. Through the same then, introduction of the pulling thread is done, which is grabbed using forceps and then pulled in oral direction (Fig. 7.9c, d). The PEG tube is attached to the end of this thread and pulled through the oropharynx into the stomach (Fig. 7.9e). The base of the tongue is protected by inserting one finger between the thread and the actual tongue. The thread is pulled with caution and continuously. At the end of the intervention, the internal fixation plate must be located at the anterior wall of the stomach. An endoscopic control is usually not required. In case of stenoses of the passage way, the internal fixation plate can be cut crosswise so as to facilitate the passage. Afterwards, application of the external fixation plate and application of a standardized dressing to the wound are done. The tube must be affixed using light pressure to ensure adhesion between the stomach and the abdominal wall. After 48 hours, loosening of the tube, turning of the same in the stoma canal and slight pulling prior to applying another dressing.

7.3.2 Direct Puncture Technique mod. According to Dormann

- **Indications/Contraindications**

From technical standpoint, the procedure deviating from the direct puncture technique (insertion of the tube from outside to inside) is better suited for the patients, since the fixation plate is not passing through the oropharynx (Russel et al. 1984). It is primarily indicated for the patient groups described below who benefit from this percutaneous access.

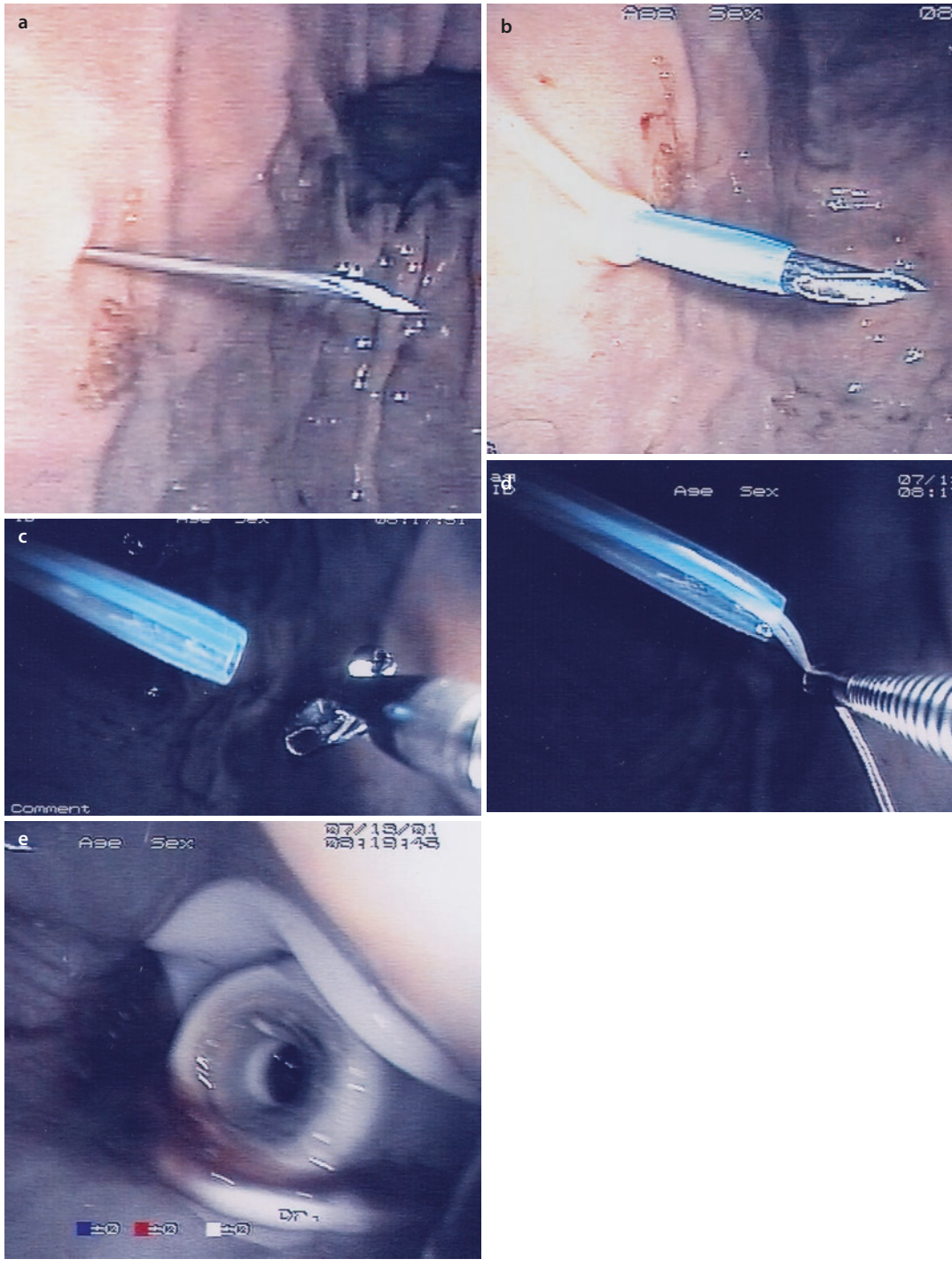

Fig. 7.9 Placement of a PEG via pull-through method of thread: **a** prepuncture, **b** cannula in place, **c** *cannula* with introduced forceps, **d** grasping forceps with thread grabbed, **e** temporary internal fixation plate through the oesophagus

This procedure exhibits the same contraindications as the pull-through PEG.

Patients with indication for direct puncture PEG:

- Primary nasal endoscopy
- High-degree stenoses in the oesophagus/oropharynx
- Danger of spreading tumour through pull-through PEG, especially in cases of curative therapy intentions
- Perioperative PEG insertion for a short period of time
- Oropharyngeal contamination with MRSA
- PEG insertion with gastropexy necessary in case of development of ascites (malignant or hypoalbuminemia)

Preparation of Patient

Preparations are the same as for the pull-through PEG.

Due to the minimal costs and proven efficiency, antibiotic prophylaxis to reduce local infections is, however, necessary.

Instrument-Related Requirements

- As is the case in every interventional endoscopy, continuous measuring of O2 saturation (pulse oximetry), taking of the blood pressure with documentation and, in patients starting at ASA III, an EKG deviation, are required.
- Additionally, a sterile table must be prepared especially for this examination and must contain the following:
  - PEG set (currently only commercially available set Freka-Pexact with PEG tube, scalpel, puncture cannula made of steel with peel-off plastic sheath, exterior fixation plate, tubing clamp, application adapter, suture set, thread set) (Fig. 7.10)
  - Incise drape
  - Gauze pads
  - Dressing set with y-gauze pad
  - Syringe 10 ml with local anaesthetic and puncture needle size 1
  - Sterile gloves, clamp or tweezers for washing off and solution for skin disinfection
- For sedation: prepare midazolam (5 mg syringe) and propofol (200 mg syringe).
- Prepare stenosis gastroscope (outer diameter of about 5 mm).
- Surgical standard for application with sterile gloves.
- Have available a guidewire with hydrophilic tip, e.g. Jagwire (Boston Scientific), in case of high degrees of stenoses.
- If needed, fluoroscopy option with C-arch, if the endoscope can only be inserted after wire passage.
- Have readily available dilation balloons or bougies with a diameter of about 7 mm.

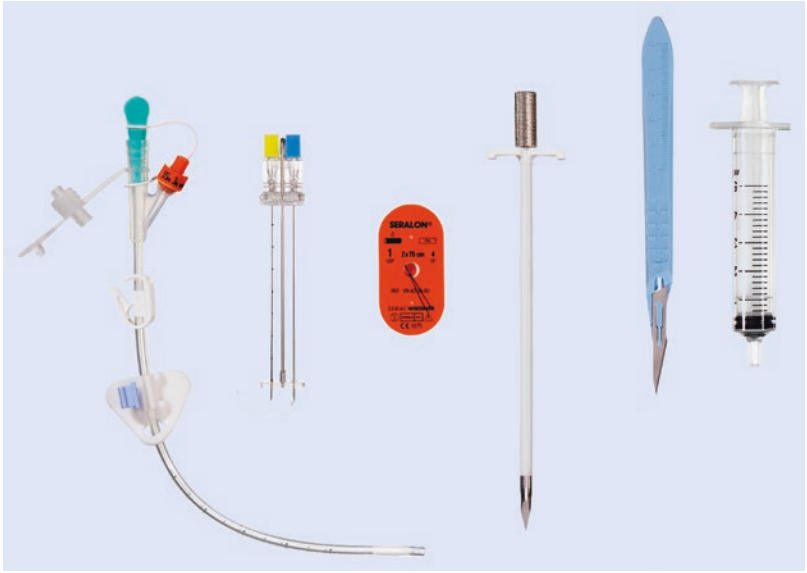

Fig. 7.10 Freka-Pexact set (Courtesy of company Fresenius)

Practical Course

Insertion of the direct puncture PEG depicted here using an example (Freka-Pexact) is a standardized procedure used in every patient (Fig. 7.11a–j). Gastroscopy is primarily performed through nasal or oral intubation. In cases of high degrees of stenoses, the guidewire (e.g. Jagwire, Boston Scientific, 0.035″) is initially guided through the stenosis, and the endoscope is then advanced under radiological control. After having ruled out a pylorus stenosis endoscopically and if there is evidence of the diaphanoscopy and/or positive needle aspiration test, administration of local anaesthesia will follow (10 ml xylocaine 1%). Under surgical conditions, the stomach is now fixed to the anterior abdominal wall via double-port gastropexy device. Once the gastropexy device is securely positioned intragastrically, the sling is opened, and the gastropexy thread is inserted; after fixation, the gastropexy device is removed, and a U-shaped suture is placed above the skin. A second gastropexy suture is placed 2 cm further. After the stab incision (width of the blade of a standard scalpel) between both gastropexies, the stomach is punctured using a trocar with a peel-off sheath. While doing this, a good endoscopic insufflation of air must be ensured so as to avoid injuries to the posterior wall of the stomach by the trocar. Additionally, the gastropexy threads can be used as retention threads of the abdominal wall, if the puncture turns out to be more difficult. Once a secure intragastric position is ensured, the balloon catheter is inserted through the sheath, blocked with 4 ml of 0.9% physiological saline solution, and finally, the endoscope is removed. Afterwards, the exterior fixation plate is fixed. In the end, the wound is disinfected and applied with a pathogen-free dressing (sterile plate and dressing).

Complications

We differentiate between slight and severe complications during the intervention, in the short-term follow-up up to 7 days and in the long run.

Complications During the Intervention

Disorders connected to the passage and pulling through the endoscopic access to the stomach can be more difficult due to stenoses but also due to the inserted metal stent with granulation tissue. An alternative procedure would be the direct puncture procedure. It includes the use of a wire-guided stenosis endoscope, possibly after dilation, or wire-guided dilation with a bougie. If needed, a radial cut can be made into the fixation plate, or it can be guided through the stenosis using grasping forceps (Figs. 7.12 and 7.13).

When pulling through, the sling might get caught up in the teeth, tongue, uvula and epiglottis, causing severe lesions. These complications can be avoided by guiding the thread using the finger inserted in the pharynx.

Puncture An incorrect puncture or loss of access predominantly occurs in badly sedated patients. If no bleeding develops, the intervention can be continued. Punctures of every organ have been described for cases of bad conditions. An inserted shunt can also pose a risk and should therefore be located prior to puncture (Fig. 7.14).

If, after surgery, the suspicion of an incorrectly performed puncture arises, cross-sectional imaging is required; simply and solely administering contrast agent via inserted PEG tube cannot answer the question regarding a possible injury to an organ along the tube.

Bleeding Bleeding is a rare (<0.01%) yet potentially severe complication. To reduce the risk of bleeding, a small depot with local anaesthetic should already be applied into the stomach's wall during the pre-puncture process, if needed, to achieve a local compression. In case of more severe bleedings, local haemostasis, e.g. with clip or injection, can be undertaken (Fig. 7.15); this is usually sufficient. During direct puncture, the patient can develop a severe bleeding during an incorrect puncture of the posterior wall of the stomach, and in those cases, a surgical intervention might be needed.

Tent Ceiling Phenomenon In the case of a tent ceiling phenomenon (Fig. 7.16), the mucous membranes of the stomach cannot be punctured when trying to insert the puncture needle, but instead, it is lifted as would the ceiling of a tent. An ideal insufflation of air to tighten up the abdominal wall reduces this phenomenon. To avoid this, the puncture should be performed using sudden movements. If that is not possible, the primary puncture needle can be affixed gastrically using the grasping forceps, and then the puncture can be performed, according to the technique of the PEJ (▶ Sect. 7.4).

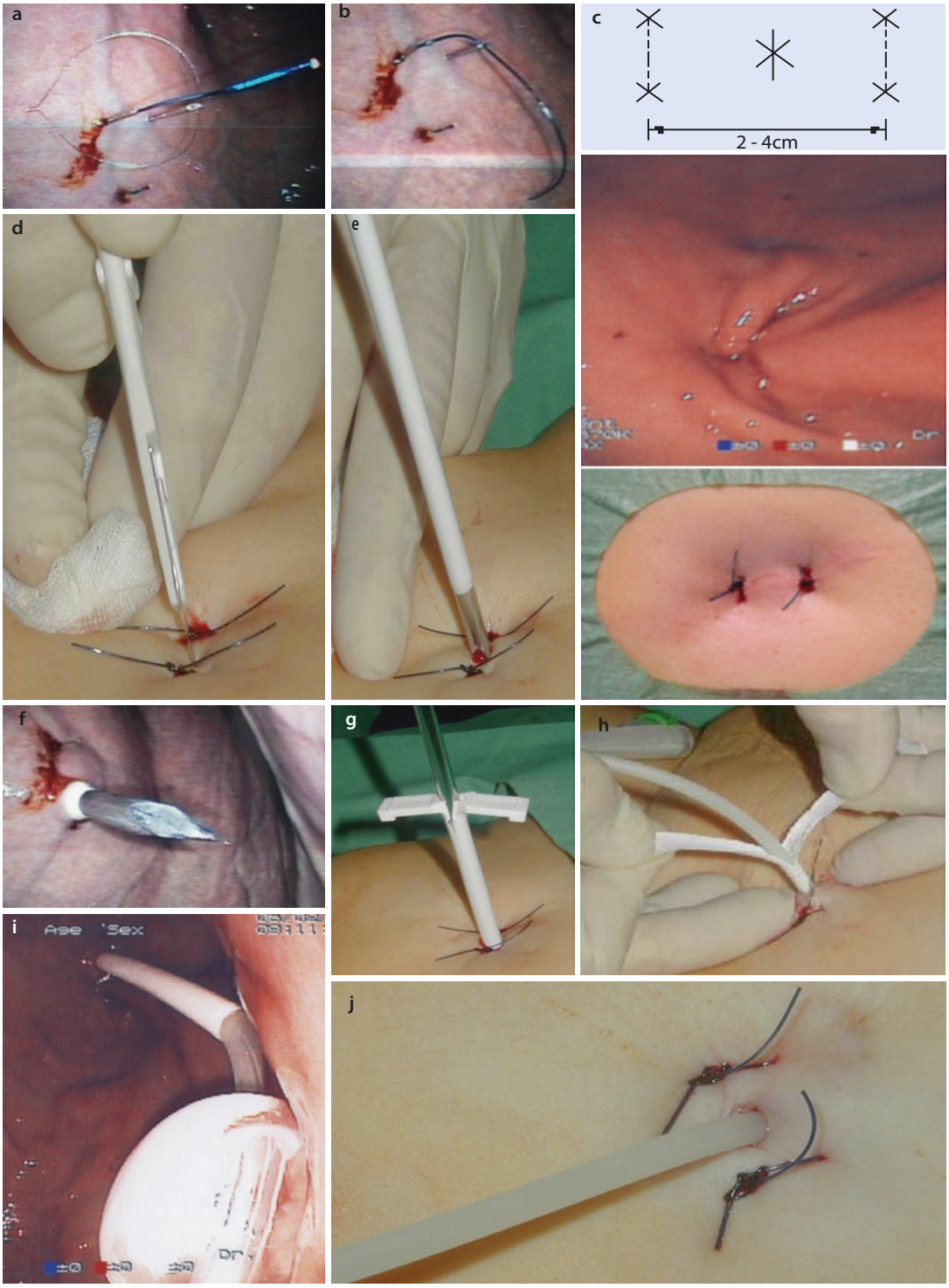

Fig. 7.11 Direct puncture technique for insertion of a PEG/PEJ: **a** gastropexy device in situ with opened sling, **b** grabbed suture thread, **c** double gastropexy from inside and outside with suture distance, **d** stab incision, **e** puncture with trocar, **f** trocar from gastric, **g** trocar with peel-off sheath, **h** peel-off of the sheath, **i** blocked balloon from the inside, **j** end of the procedure

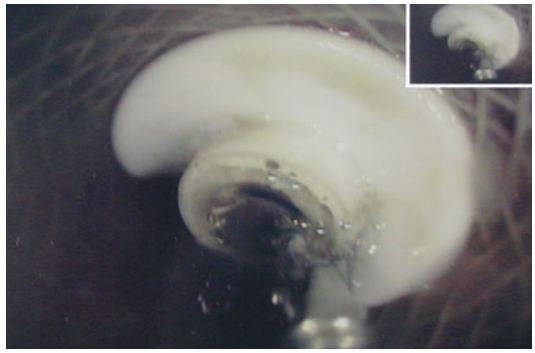

Fig. 7.12 Through the grasping forceps, the fixation plate leads to a self-expanding plastic stent (SEPS)

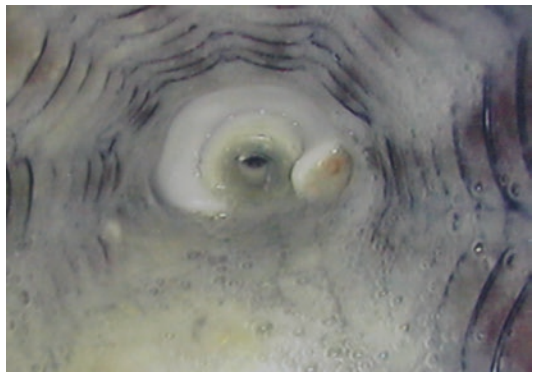

Fig. 7.13 Passage of PEG through self-expanding metal stent (SEMS)

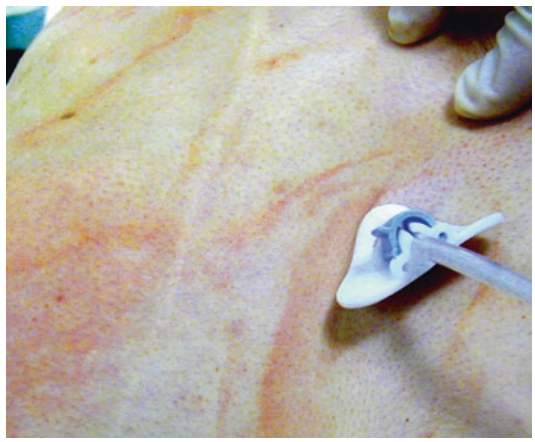

Fig. 7.14 Localization of a VP shunt

Pain About 30% of the patients develop pain after surgery, which is a reason to inspect the wound. A beginning peritonitis must be clinically ruled out. Initially, analgesics are used (e.g. tramadol). The patient should also be monitored.

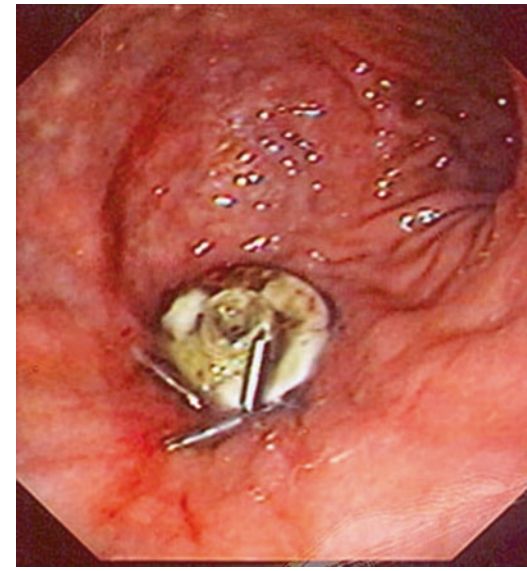

Fig. 7.15 Peristomal bleeding with clips

Fig. 7.16 Tent roof phenomenon

Pneumoperitoneum Often, a pneumoperitoneum also develops in cases of correctly inserted devices (CAT scans of the abdomen reveal that up to 50% of the patients are affected). There are usually no symptoms, and even if there are problems, it should not be a primary indication for a laparotomy.

Dermal Emphysema A dermal emphysema is a rarity and should be closely monitored.

Complications After the Intervention

Infections Within the first 7 days, local infections (Fig. 7.17) occur in about 30% of the interventions. The best predicative marker is the amount of secretion within the first 72 h. If the dressing is soaked more than three times daily during this timeframe, it must be assumed that

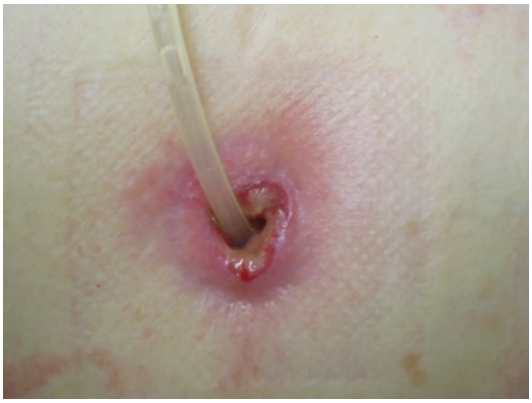

Fig. 7.17 Peristomal infection with granulation, secretion and development of pus

the patient developed an infection and that the stoma requires a more intense wound care. Severe complications usually include systemic infections such as aspiration pneumonia, peritonitis, fasciitis and local infections requiring surgical therapy. Aspirations can occur during the actual gastrostomy but also during the feeding phase. When inserting a feeding tube, this complication can be avoided through premedication, suitable positioning and permanent oral/pharyngeal suction. These severe complications always require systemic administration of antibiotics and can be reduced through preoperative prophylactic administration of antibiotics. Infections can also be observed in tubes that have been inserted for a longer period. If antibiotics and intensive wound care do not lead to success, the tube has to be removed in very rare cases and then inserted at another site (Fig. 7.18).

Inoculation Metastasis In patients with tumours in the oropharynx and oesophagus, there is evidence of inoculation metastases being placed in the puncture channel via thread pull-through method. To avoid this, a direct puncture procedure can be selected for patients with curative therapy concept.

Hypergranulations Peristomal hypergranulations can be treated with silver nitrate sticks or undergo local treatment with argon plasma coagulation (APC). A balloon system can also be inserted for decompression.

Tube Problems The tube can become occluded in cases of insufficient care (Fig. 7.19) or due to administration of medication. Correct flushing of

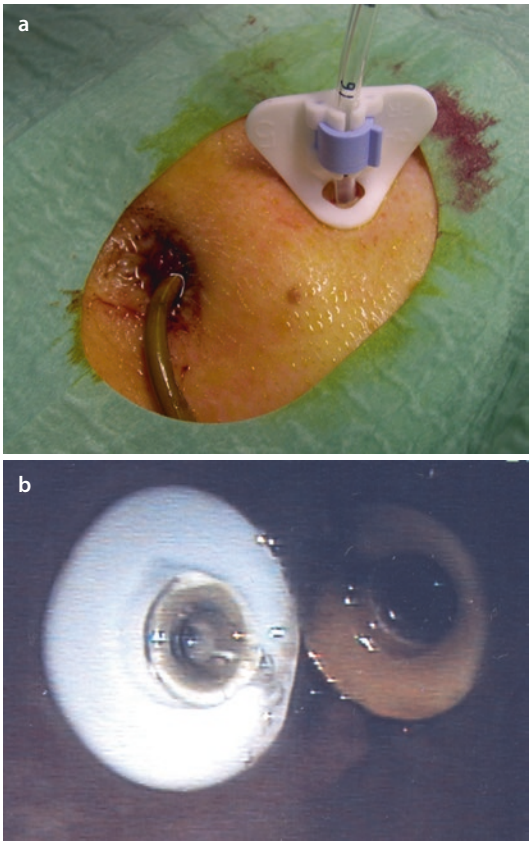

Fig. 7.18 Simultaneous removal and new positioning of an infected PEG: **a** gastric, **b** cutaneous view

the tube is therefore imperative to avoid this complication. Once the catheter is occluded, it can be attempted to make accessible the tube by administering mineral water, pepsin wine, Multibionta or Coca-Cola under pressure. Over time, changing of the tube is usually the best solution. If the tube is torn (Fig. 7.20) or if there is damage to the gastric part of the catheter, the tube must be removed endoscopically. In cases of proximal damage, the tube can be shortened and mended by a repair set.

Peristomal Leakage or Development of Ascites In these cases, a peristomal secondary fixation to the stomach wall using the gastropexy device is possible, so that the leakage developed due to ascites is neutralized (Fig. 7.21).

Buried Bumper Syndrome (BBS) Growing of the internal fixation plate into the actual stomach wall is a complication that can be avoided. BBS is a complication that can be avoided through adequate care

Fig. 7.19 Tube obstructed through food residues

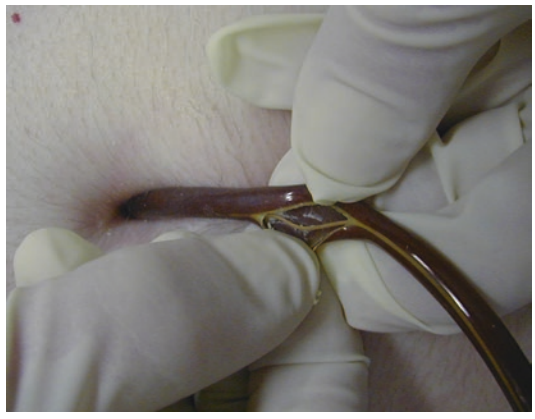

Fig. 7.20 Tear at the tube due to local therapy with PVP ointment

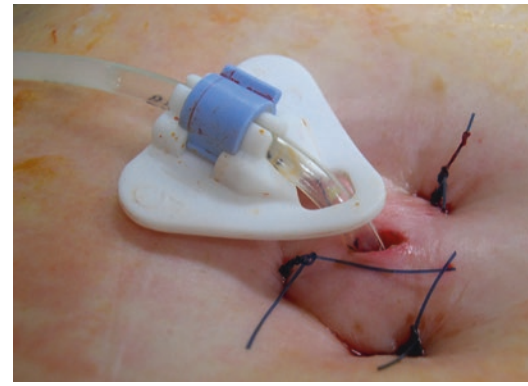

Fig. 7.21 Hybrid PEG through combination of pull-through and direct puncture procedure in case of development of ascites

and management of the PEG. Continuous pulling on the PEG and/or lack of regular mobilization of the plate can lead to the plate being buried by the stomach's mucous membranes, lowering of the plate into the stomach and abdominal wall and local chronic-inflammatory changes, which, in the end, can lead to an occlusion of the feeding tube. This can occur as early as 2–4 weeks after initial insertion of the feeding tube. Various therapeutic methods are available for treatment: surgical repair through laparotomy, local surgical removal via radial cut along the tube and plate from the outside and removing the plate by pulling from the outside (so-called pull method) or endoscopic removal of the plate from the inside. In recent years, a new endoscopic procedure (push method) has been established to expose the ingrown plate (Müller-Gerbes et al. 2009): Under endoscopic control, the ingrown plate is freed via papillotomy via the inserted PEG (Fig. 7.22a–d). Then, the patients receive a gastrotube (high-volume-low-pressure concept) via the already existing stoma or get a new PEG, and the stoma can heal.

Aftercare Following Tube Insertion

The dressing is changed after 24–48 h, under sterile conditions, while mobilizing and turning the tube, which is then fixed again while slightly pulling. A standardized procedure is required. During the first week, after insertion of the tube, the dressing should be changed daily and, after that, 2–3 times per week. Sometimes, a dressing is not necessary. If the wound is free of infection

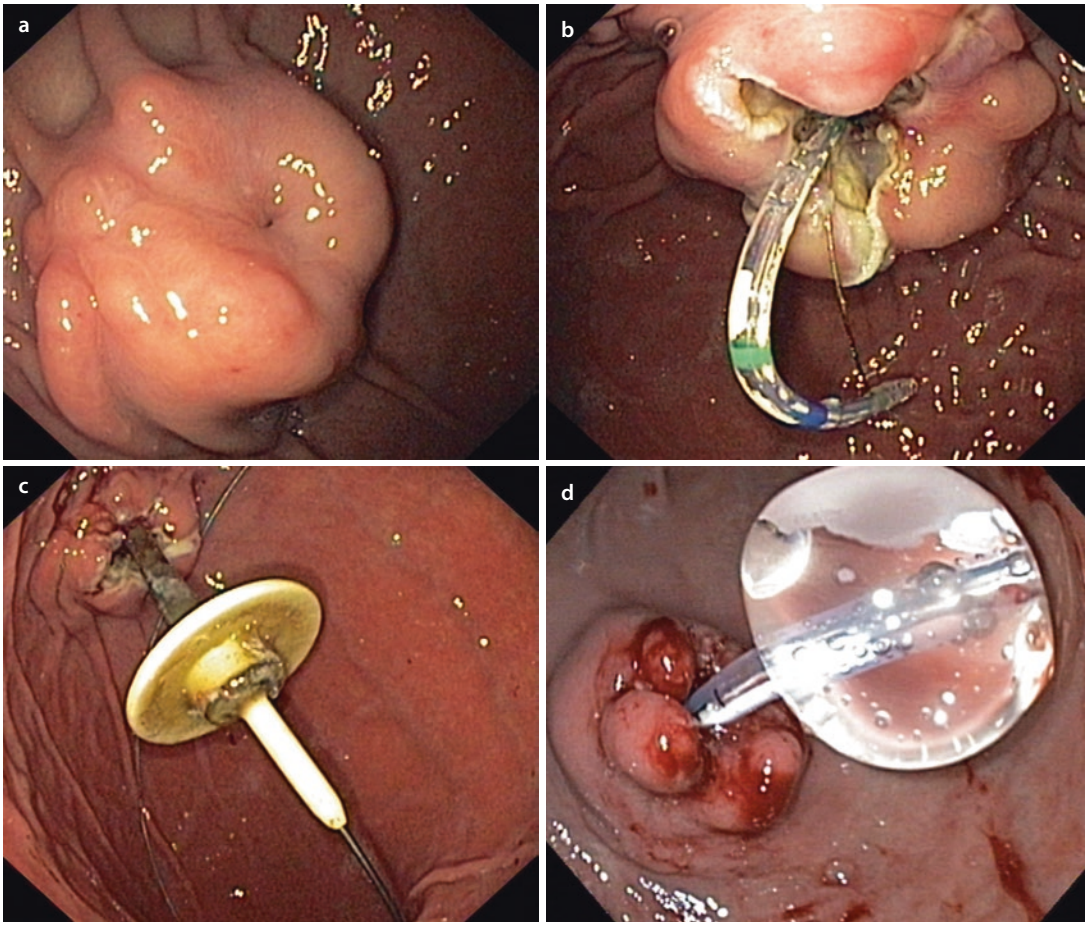

Fig. 7.22 Performing push method for the management of BBS: **a** BBS, **b** cut with papillotomy in four segments, **c** dilation via bougie and freeing of the internal fixation plate (push method), **d** gastrotube in situ (high-volume-low-pressure concept)

and inflammation, normal body hygiene is not limited. Bathing and showering is usually possible 1 week after insertion of the tube. After the application of food and before and after administration of medication and at least once a day if no feeding has taken place, the tube needs to be flushed with at least 20 ml of water. In addition, the adapters should be cleaned daily using clear water.

Beginning Feeding via Tube Tea or suitable enteral nutrition can be administered via tube, 4–6 h after insertion of the tube. Increase of food intake should primarily take place via pump with low drip rate.

Changing the Tube A particularity of the direct puncture PEG is that the holding suture must be removed after 10 days and that the primary balloon system should be changed into a secondary system after 30 days (▶ Sect. 5).

The pull-through tube is only exchanged when needed, e.g. in case of mechanical damage or dysfunction (▶ Sect. 4).

7.4 Jejunal Percutaneous Tubes (PEG with Jejunal Port/PEJ)

Indications/Contraindications

Additional endoscopic procedures to the jejunal transcutaneous tube insertion include the percutaneous endoscopic jejunal tube (PEG with jejunal port: lengthening of the PEG via jejunal catheter) (Fig. 7.1) and the percutaneous endoscopic jejunostomy (PEJ: insertion of a PEG tube into the jejunum). With the excep-

Table 7.2 Indications for percutaneous jejunal tube insertion

PEG with jejunal port or PEJ	PEJ	PEG with jejunal port
Recurring vomiting Aspiration Reflux Gastroparesis Retroperistalsis Pylorus stenosis	(Partial) stomach removal PEG not possible	Gastric deviation *and* jejunal feeding required

tion of patients with a removed stomach, the indication for a jejunal tube is usually determined using the clinical development and usually in the case of problems associated with an inserted PEG (e.g. reflux, aspiration, pylorus stenosis, motility disorders, etc.) (Table 7.2). Currently, there are no clear guidelines for the primary placement of a PEJ. The indication in case of recurring aspirations due to reflux is not proven. Nowadays, the procedure used more often is the PEG with jejunal port. The contraindications correspond to those of a PEG insertion (▶ Sect. 7.3) (Fig. 7.23).

Preparation and Prophylaxis of Complications

The same conditions apply as for the pull-through PEG. To reduce a local infection, antibiotic prophylaxis is required in the PEJ, and it corresponds to that used during PEG insertion.

Preparation of the Patient

→ Corresponds to that of inserting the PEG

Personnel-Related Requirements

→ Corresponds to that of inserting the PEG

Instrument-Related Requirements

As is the case in every interventional endoscopy, continuous measuring of O2 saturation (pulse oximetry), taking of the blood pressure with documentation and, in patients starting at ASA III, an EKG deviation are required (Figs. 7.24, 7.25, 7.26, 7.27 and 7.28).

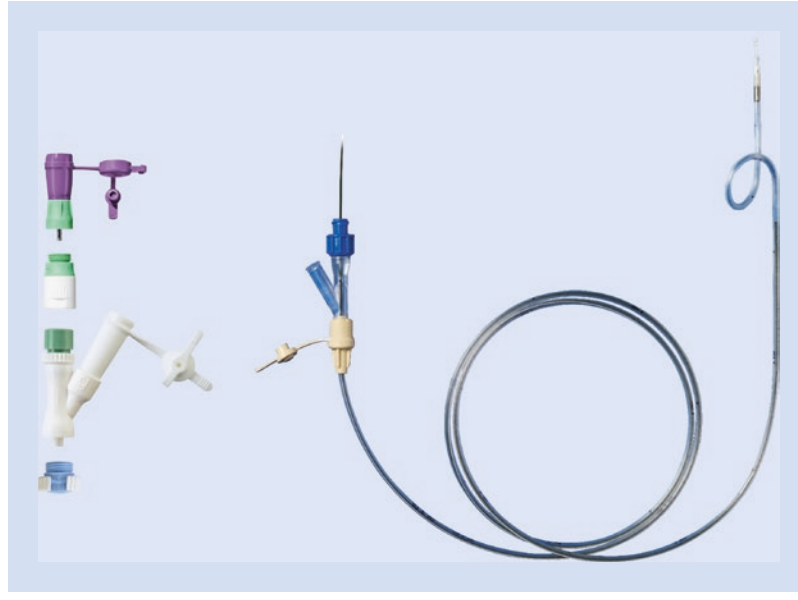

Fig. 7.23 Jejunal port Feka 9CH (Courtesy of company Fresenius)

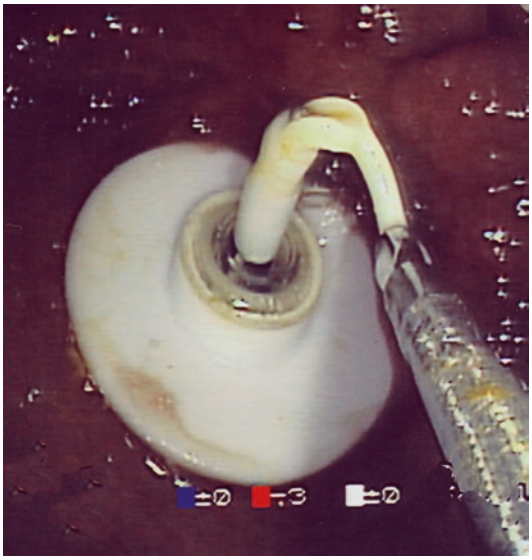

Fig. 7.24 Grabbed distal end of the PEG

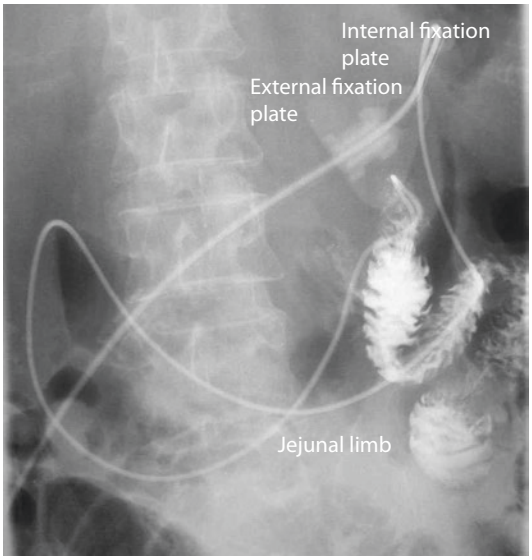

Fig. 7.26 PEG with jejunal port in situ

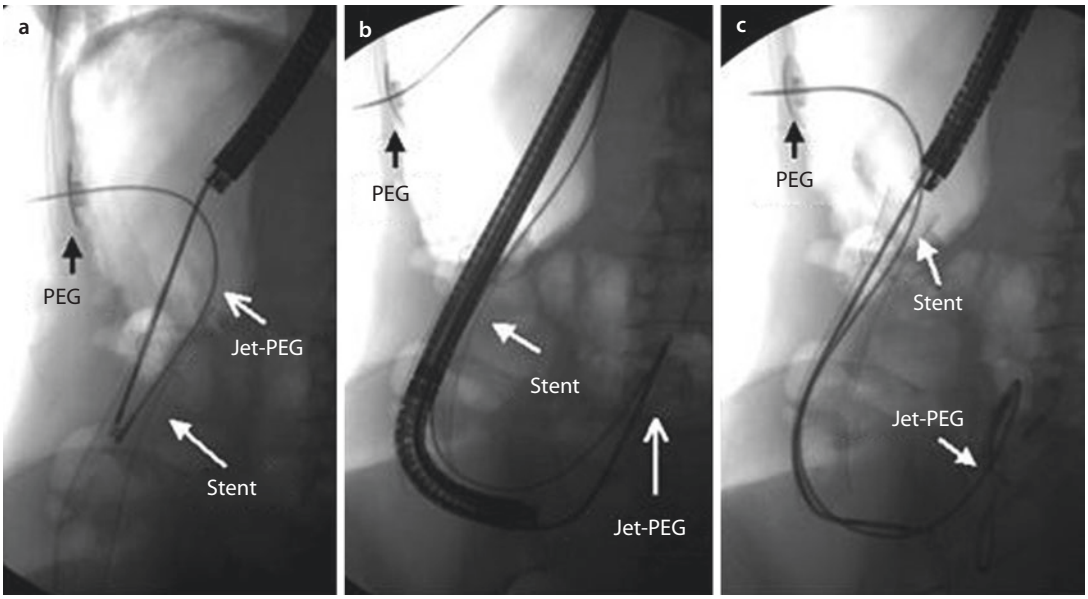

Fig. 7.25 Insertion of a PEG with jejunal port (Jet-PEG): **a** grabbing of the tube and beginning of advancing, **b** passage through the stent and further advancing, **c** retreating of the gastroscope and freeing of the tube

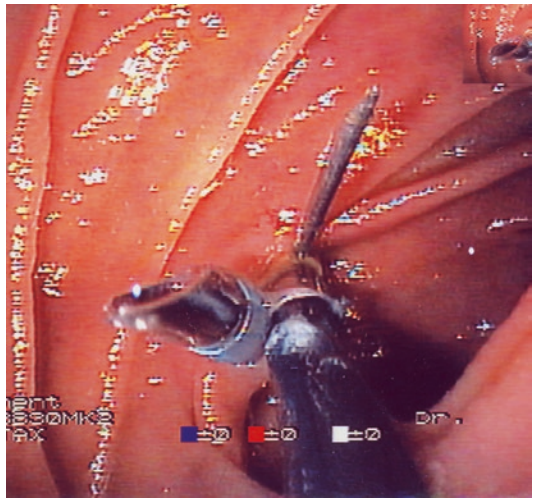

Fig. 7.27 Affixed anaesthesia needle during puncture of the small intestine

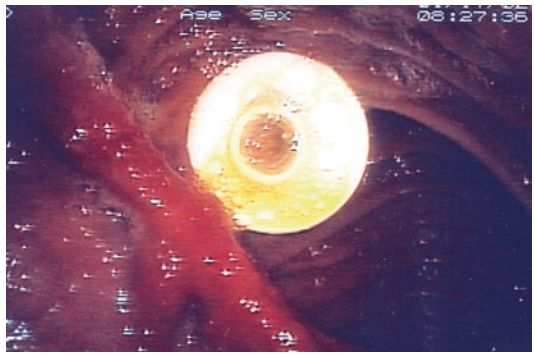

Fig. 7.28 PEJ tube in Billroth II surgery in situ

Particularities of PEJ insertion:

- Spasmolysis: immediately prior to puncture, administration of N-butylscopolamine to suspend the vivid peristaltic of the small intestine.
- Endoscopy may not be performed if there is no diaphanoscopy.
- The local anaesthesia needle and later on the trocar needle are affixed in the small intestine using the forceps (Fig. 7.27).
- The position should be checked endoscopically or radiologically after having pulled through.

PEG with Jejunal Port

If a PEG CH 15 is inserted, it should be exchanged for a PEG set 20 CH. This procedure requires a standard set PEG CH 20 as well as the jejunal port with 9 CH (Fig. 7.23), which is particularly recommended when a gastric deviation is required in addition to the jejunal feeding. If it involves feeding only, a CH 12 insertion tube can be inserted into the CH 20 PEG, the position of which is more stable and does not clog up as often.

In addition, the following are required:

- Long endoscope (prepare paediatric colonoscope or colonoscope)
- Strong grasping forceps for the jejunal port
- Sling for removing the PEG (with a diameter of about 3 cm)
- Fluoroscopy option, e.g. C-arch

PEJ

The preparations for a PEJ correspond to that of a PEG (▶ Sect. 3). The following are required:

- N-Butylscopolamine 10–20 mg
- Long endoscope (prepare paediatric colonoscope or colonoscope)
- Surgical standard for application with sterile gloves
- Fluoroscopy option, e.g. C-arch

Practical Development: PEG with Jejunal Port

Initially, the inserted PEG (usually CH 15) is exchanged for a bigger one (usually CH 20). That makes sense, since less problems develop over the course of time (occlusion) caused by the internal catheter to be then placed. Technically, insertion of a 9 CH insertion tube into a 15 CH PEG is also possible.

To change the PEG, grab it with a sling from gastric direction and shorten it to about 3 cm above the abdominal wall. Prior to that, attach the pull-through thread to the PEG tube on the outside and then place the new PEG corresponding to that of the pull-through method. Finally, a jejunal catheter (usually CH 9) can be inserted through this PEG, in gastric direction.

Usually, the insertion technique «beneath the scope» (BTS) is used here. This procedure includes endoscopic gastric grasping of the distal end of the inserted tube using strong and long

forceps (Fig. 7.24), and then using the device, it is guided towards intestinal direction. If further endoscopy is not possible, maximum advancing of the forceps along with the affixed tube, which then remains in situ, is done, and at the same time, the device is pulled back. Once the endoscope is in the stomach, the forceps are loosened and slowly reintroduced into the device. This technique is particularly helpful when inserting intestinal tubes, e.g. a jejunal tube (▶ Sect. 4) (Fig. 7.25), which is the reason why these tubes are inserted under radiological control. A successful outcome is dependent on a secure jejunal placement as well as on avoiding the intragastrical formation of loops (Fig. 7.26). If the jejunal port of the tube is positioned in the area of the proximal duodenum, the tube might return, which, in the worst-case scenario, causes an aspiration.

Practical Development: PEJ

As opposed to that procedure, the preparation and insertion of a PEJ using the pull-through method by and large corresponds to that of a PEG being placed in the jejunum. That is a significant advantage compared to the PEG with jejunal port, since a secure placement of the tube in the jejunum is achieved.

During the initial insertion, the diaphanoscopy in the area of the duodenojejunal flexure or in aboral direction of the same is determined using a long endoscope (paediatric colonoscope, colonoscope, enteroscope). In rare case, depiction of the diaphanoscopy is very difficult and is often only possible in very dark rooms. Afterwards, the intestinal peristaltic is decreased using Buscopan, and trial puncture is performed using a thin cannula. If the cannula is securely positioned intraluminally, it is grabbed with the grasping forceps, thus ensuring that the intestine is securely affixed to the abdominal wall. Now, puncture the intestine positioned next to the cannula using the puncture cannula from the standard PEG set. If the cannula appears intraluminally, the introduction aid is advanced, the grasping forceps are removed from the cannula, and the thread positioned in the introduction guide is grabbed. This thread is then moved in oral direction, and the tube is affixed to the same and moved into the final position via pull-through technique as is done when inserting a PEG. Compared to the PEG with jejunal port, the significant benefit of this procedure is being able to achieve a secure placement of the tube in the jejunum (Figs. 7.28 and 7.29).

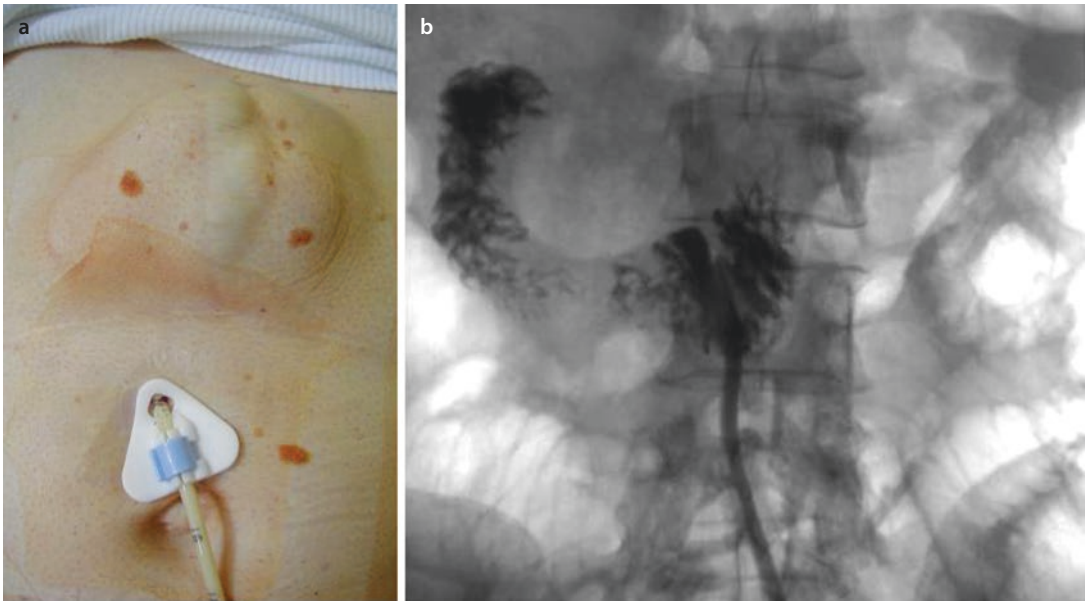

Fig. 7.29 PEJ insertion at large gastric hernia: **a** view from outside, **b** radiological control of the position

Complications and Management of the Same

Complications of inserting a PEG with jejunal port are due to the endoscopy being performed while the patient is lying on his back and, in the case of longer-lasting interventions, the danger of aspiration.

Complications occurring after surgery are comparable to those after the insertion of a pull-through PEG, whereas intestinal injuries do occur more often.

Standardized Aftercare After Insertion of Tube

Wound care and aftercare are identical with that of the PEG. Initiation and increase of food intake can also be started after 4–6 h, whereby the maximum rate of the enteral nutrition that must always be administered via pump may not exceed 150 ml/h; otherwise, the patient can develop diarrhoea.

The tube must be well cared for, which is a requirement for successful use. Dislocation of the jejunal port is the first sign of incorrect care. For example, if the tube is turned, it may end up with knots in the jejunal port (Fig. 7.30).

Application of medication should be avoided. The deciding advantage of this procedure is the possibility of a gastric decompression at parallel jejunal feeding. This way, enteral feeding also becomes possible for problematic patients (especially neurosurgical patients with extensive retroperistalsis).

All other procedures of the sonographically or radiologically controlled tube insertion are only indicated in patients where insertion of a PEG is impossible.

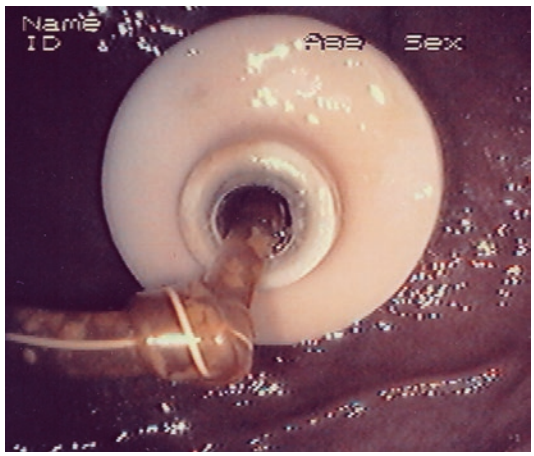

Fig. 7.30 Knot at the internal fixation plate when attempting to pull back

Surgical procedures should only be used in cases where no tubes can be placed using endoscopic or alternative procedures. When effectively using the available techniques, that would amount to less than 1% of the cases.

The **fine-needle catheter jejunostomy** (FNJ, lap-FNJ = direct surgical insertion of a jejunal tube) is an exception. If the patient is undergoing a laparotomy, this tube procedure should be used so as to avoid a second intervention. Emergency patients with abdominal trauma or elective patients with visceral surgical interventions (removal of the oesophagus or stomach) would be predestined for this. These tubes can then also be used for temporary postoperative feeding as is the case with other jejunal tubes. They cannot, however, be exchanged. If endoscopic procedures are not possible and long-term tube feeding is planned, the classic procedures according to Witzel and Kader that can, of course, also be performed laparoscopically can be used.

7.5 Secondary Techniques (Button, Gastrotube)

Gastrostomies are used for long-term feeding of patients suffering from various underlying illnesses. In these cases, the catheter varying in size penetrating the abdominal wall due to constant swivelling and shear movements can lead to local problems such as leaking, infections or granulations. If the application of a dressing becomes necessary in these situations, it reduces the patient's comfort, but on the other side, it can also result in complications such as irritation of the skin, allergies or macerations. A reflux from the gastrostomy canal or the catheter can also have the disadvantage of being an odour nuisance or causing skin irritations. In some patients, these problems lead to a generally critical opinion regarding long-term enteral feeding. In addition, many patients are significantly limited and stigmatized in their general state of health and their social integration. This applies to children and people being actively integrated into social life, in particular.

The so-called valve button or button systems (synonyms: button gastrostomy, «skin-level gastrostomy/device,» «gastrostomy replacement button») are improvements compared to permanently inserted stomach catheters, which have been used as secondary systems after initial PEG insertion

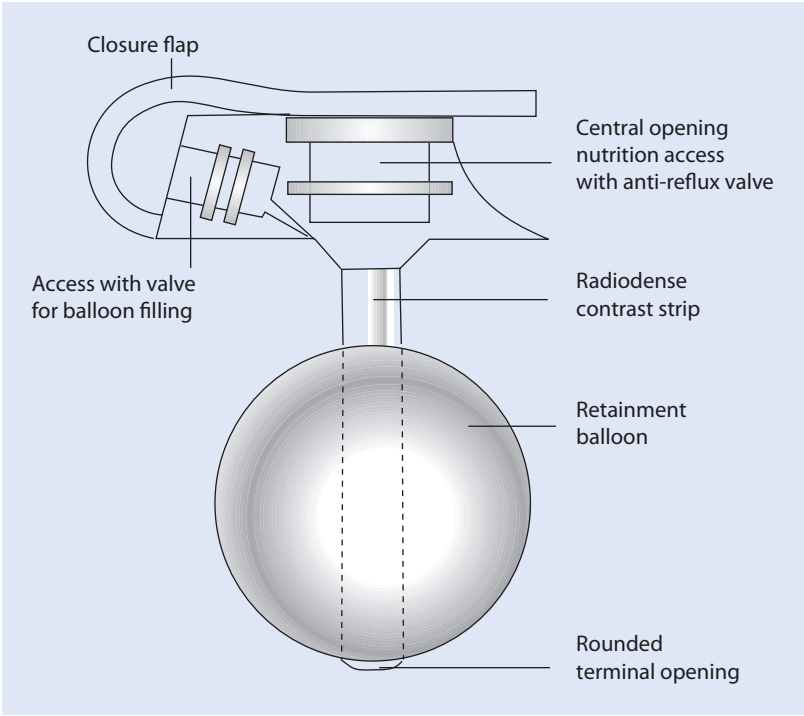

Fig. 7.31 Setup of button

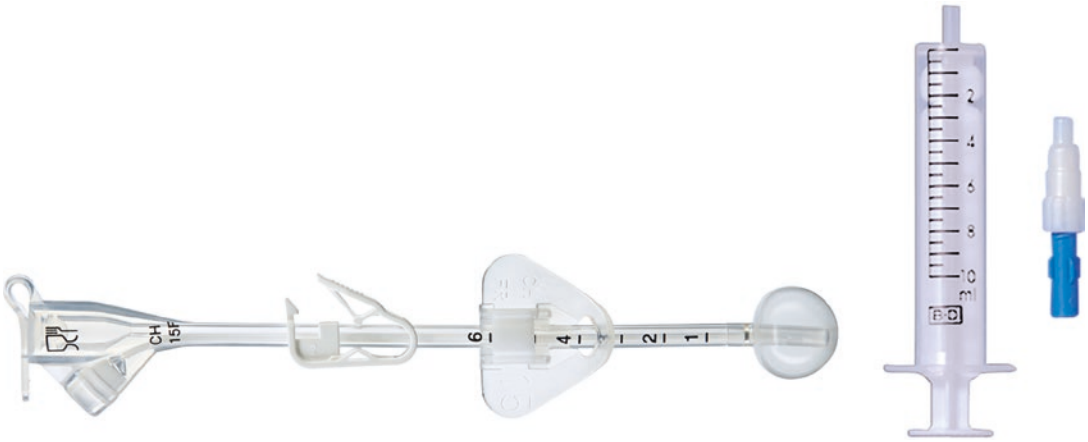

Fig. 7.32 Fresenius gastrotube (Courtesy of company Fresenius)

since 1984 (Gauderer et al. 1984). These systems are significantly smaller than PEG systems, are less obvious and therefore provide the patient with the possibility of an improved cosmetic result while at the same time increasing mobility.

Button and gastrotube systems are replacement and secondary systems that can be changed 4 weeks after insertion of a gastric PEG, if the stoma canal is free of infection and inflammation. The typical button is made of latex-free silicone rubber, and a balloon serves as a retention mechanism (Fig. 7.31), which is filled with isotonic saline solution administered through a lateral valve. Other systems are not established in Germany and are therefore not depicted.

The gastrotube is a balloon catheter that can be placed as a secondary system or that can be placed in the stoma replacing defective tubes (Fig. 7.32).

Use and indication correspond to that of a button; the longer tube is beneficial for many patients, facilitating the attaching of enteral nutrition.

Indications

Indications for insertion of a button:
Local problems:
- (Pressure) ulcer
- Eczema
- Allergies (e.g. bandages)
- Peristomal granulations
- Leaks

Other reasons:
- Cosmetic reasons
- Social stigmatization in children and adolescents
- Protect from injuries (children and geriatric patients)
- Desire for more mobility

A clear indication is a requirement when using secondary systems, as is the case when inserting a PEG. Some patient groups are predestined for the insertion of a button due to their underlying illness and mobility (Dormann et al. 1998).

As per our experience, button stomas are indicated in the case of local stoma problems, which affect about 10% of the patients. The problems usually consist of care-related problems, caused by allergies to bandages and/or care products that partly also lead to chronic eczemas. Sporadically, we also saw pressure-related granulations that healed after the implantation of a button system. In cases of leaking and peristomal leaking, insertion of a button can directly lead to the arrest of secretions leaking and thus proves to be a clear indication. Usually, however, the button systems are used for cosmetic reasons or due to the patient's desire for more mobility.

Primary patient groups receiving a button system include patients exhibiting a sufficient compliance and who benefit from the system. That includes paediatric patients and adolescents, in particular, who benefit from cosmetic advantages. But risk patients, e.g. children under haemo- or peritoneal dialysis, can also receive a button system. It must be noted, however, that the button can become dislodged in toddlers while crawling. Neurological patients, especially patients with isolated swallowing disorders, e.g. at amyotrophic lateral sclerosis, are also suited for the insertion of a button. The same applies to patients suffering from tumours of the hypo- and oropharynx and of the oesophagus. Nowadays, it is usually a standard procedure for these patients to receive a PEG prior to initiation of a chemo- or radiotherapy. During the therapy breaks, a button system can be inserted. In patients that can eat again during the remission of a primarily non-curable carcinoma, the button serves as a placeholder and can be used again for enteral feeding therapy when there is another progression.

Using a button system in geriatric and psychiatric patients who may accidently dislodge a PEG system protects the patient from experiencing stoma injuries. In this case, the use of a button can also make sense.

Contraindications

An active stoma infection is a contraindication for the elective insertion of a button when pathogens can enter the fistula and cause an exacerbation of the infection. In these cases, it is better to eradicate the local infection through intense, locally disinfecting or possibly also systemic antibiotics and to then implant the button. A PEG that is no older than 2–4 weeks should not receive a button primarily, since a good formation of the stoma canal is a prerequisite. Inserting a button sooner is not recommended, since malpositionings are possible. A long (>4.5 cm) or very curvy fistula canal can also lead to significant problems incl. perforations of the stoma canal and extragastric placement of the button. Should placement of a button not be possible, another placement of a PEG would be indicated.

Based on own experiences, patients, whose insertion of a PEG was primarily very difficult or endoscopically impossible, should not receive a button system. Due to defective material but also due to accidental dislocations, the patients can experience occlusions of the stoma within a short period of time, so that another insertion cannot take place. In this case, another PEG must be placed, which has significant negative consequences in some cases, such as another surgery.

If a PEG system must be replaced, a gastrotube can be used instead of a button, especially in the case of local infections.

Preparing the Patient

Only very sensitive patients require sedation.

Personnel Requirements

During an endoscopy, at least one endoscopy nurse or experienced staff and one physician must be present. The physicians must be experienced in endoscopy and in the use of the application technique required, since, depending on the site, a modification might be necessary. If the patient still has a pull-through PEG, an endoscope must always be used to remove the fixation plate, which requires analgosedation of the patient. This must be discussed during the planning phase.

Instrument-Related Requirements

- A sterile table must be prepared especially for this examination, containing the following:
  - Button/gastrotube set (Figs. 7.23 and 7.33c)
  - Seldinger wire set
  - Incise drape
  - Gauze pads
  - Dressing set with y-gauze pad
  - Syringe 10 ml with NaCl 0.9%, for blocking
- Endoscope, standard.
- Sling for removing the PEG.
- Bougie for increasing to 15 CH, if the stoma is too narrow.
- Scissors.

The intervention can be performed with a fluoroscopy option to check on the position; otherwise, x-rays must be performed afterwards.

In most cases, the insertion can be performed on an outpatient basis. As opposed to the primary implantation of a PEG and other interventions at the gastrointestinal tract, a periinterventional antibiotic prophylaxis is not required, since the already-present stoma canal can be used (Dormann et al. 1999).

Practical Course: Button (Modified Seldinger Technique)

The initial application of the buttons as secondary system after placement of a PEG usually takes place under endoscopic control and is similar in all button systems.

Later, a possibly necessary changing of the button can, if the respective experience is present and if the stoma is in a good condition, also take place without endoscopy. The secure gastric placement must then, however, be clinically proven through sure aspiration of gastric content and if there are any doubts radiologically.

The endoscopic procedure provides the possibility of safely removing the internal fixation plate, and on the other side, the internal stoma can be inspected, so as to rule out pathological changes, such as an ingrown fixation plate. The passage of the button in gastric direction can be controlled endoscopically, and malpositioning can thus be avoided. Initially, the Seldinger wire is inserted through the inserted tube, so that a safe passage can be ensured. The PEG is then endoscopically removed, by grabbing the sling and cutting it above the abdominal wall back to about 4 cm. After that, it is being pulled back into the stomach using the gastroscope.

At the same time, the length-measuring device is inserted into the stomach, through the stoma, via the inserted wire, to determine the required shaft length of the button. The length is determined while the patient is lying down and also while sitting. A button shaft length of 10–15 mm longer than the measured stoma length is ideal. The length-measuring device remains in the stoma as a placeholder, while the button to be inserted is checked (Fig. 7.33). The function of the balloon is checked with a Luer syringe containing 6.0 ml of 0.9% NaCl. If it functions, the balloon's complete contents must be sucked out of the balloon so as to allow a good passage of the stoma. If a guidewire is present, which can be helpful in the case of a narrow stoma, it must be advanced through the button, for easier placement into the stoma. Measuring the length of the device and advancing of the button covered in lubricant into the stomach follow immediately thereafter. If the button becomes endoscopically visible in the stomach, the balloon can be filled with 5–7.5 ml of NaCl 0.9% through the lateral valve. The guidewire and the wire are then removed from the button. When pulling out the gastroscope, the physician also removes the cut PEG.

In rare cases, when the passage of the button through the stoma is more difficult, a guidewire (e.g. 0.035″) can be used as a splint. If the stoma is too small, a guidewire might have to be used for dilating the stoma canal. This procedure requires some experience in the use of button systems and should only be used in rare cases.

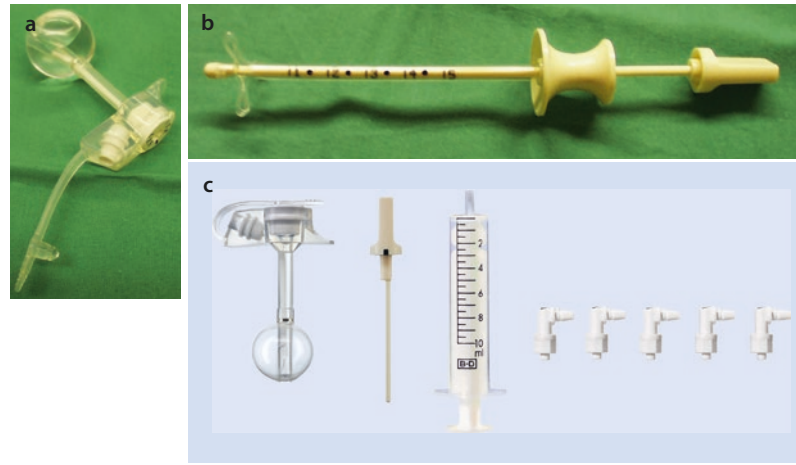

Fig. 7.33 **a** Blocked button, **b** measuring device to determine the length of the stoma, **c** button set with mandrin and adapter (**c** Courtesy of company Fresenius)

The length of the button and the filling volume must be documented in the patient pass, which must be handed to the patient after the intervention.

Changing of the Button If a defective button is to be exchanged under good local conditions, trained personnel can perform the same via Seldinger technique, without another gastroscopic control. Hereby, however, the danger of the button not being positioned intragastrically does exist and might lead to the administration of enteral nutrition into the free abdominal cavity. The longer the already-present stoma canal, the greater the danger of malpositioning. In cases of longer button systems (>3.0 cm), dislocations in the stoma canal might occur (Romero et al. 1996). With an obligatory clinical, endoscopic or radiological control of the position, this complication can be avoided for sure.

■ Practical Course: Gastrotube

The gastrotube is a balloon tube for percutaneous gastrostomy. Insertion of the gastrotube corresponds to that of the button insertion, also using the Seldinger technique. The only difference is that determination of the length is not required.

■ Complications and Management of the Same

Complications are rare and must be controlled. Complications of insertion occasionally include a stoma being too small, which can be dilated via inserted Seldinger wire using a bougie. In cases of bleeding, local haemostasis is usually sufficient.

When the patient experiences lasting pain, the correct position and length of the button should be checked again; if the button is too small, a pressure ulcer can develop within 1–2 days.

■ Standardized Aftercare After Insertion of the Tube

After initial insertion, the blocking of the balloon must be controlled once more before the patient is discharged, so as to rule out a defective balloon. If the wounds are free of infection and inflammation, bathing, showering and doing sports are possible without limitations starting on the day of insertion.

Avoiding food or increasing food intake after insertion of a button is not necessary.

Application of nutrition and fluid is done through a regular application system. Systems that are connected to a screw connection with a special angular adapter and that are placed into the button (e.g. Freka button) are beneficial. For this, the lid of the button must be opened, and the angled adapter must be put into the central valve in such a way as to ensure that the black marks at the adapter and at the opening of the button are aligned with each other. Afterwards, the angled adapter is turned 90 degrees clockwise for fixation purposes, and the application of food or fluids can begin.

The angled adapter should be changed every 3 days and the tubular system, however, after 24 h. The angled adapter must be rinsed after every use or cleaned with a small brush, if needed.

Every commercially available enteral nutrition is suited for the application. Bolus as well as gravity or pump application can be used in the button. Bolus application is preferred especially by young, active patients. The pump application allows for a

very exact and secure dosing, also in the case of mobile patients. Due to the wide array of mobile systems available for enteral nutrition, the patient is free during pump application and can move around freely.

Flushing the button daily using a Luer syringe (20 ml of fluid, e.g. boiled or distilled water) is urgently required so as to avoid occlusion. The syringe filled with the rinsing fluid can be placed onto the central valve directly after opening of the closure, and the button can be flushed. The flushing fluid can also be administered through the extension tube for nutritional tubes or tubing systems. With the assistance of good training measures, changing of the button due to occlusion can be avoided in the long run. Medication is also administered through a Luer syringe that is inserted into the central opening of the button. Viscous fluids and strongly concentrated alcohol-based solutions must be diluted prior to application. Solid medication must be pulverized and completely dissolved in 10–20 ml of water. Before, in between and after administration of the various individual medications and flushing the button are of particular importance. If the wound is free of infection and inflammation, application of a dressing is not necessary.

Daily cleaning of the covered surface and of the puncture site, using mild soap and warm water, is advised, which must be followed by disinfection of the skin. The button should be turned and moved once a day so as to avoid pressure ulcers.

Every 4 weeks, the filling of the button balloon should be checked by a trained person. The filling amount must always be documented. If the initial amount is not present anymore, the valve must be checked for leaking. If further volume is lost within 24 h, the button must be exchanged. In cases of a spontaneous rupture of the balloon or if the button falls out, it should be retained in the stoma using dressing (if possible). Another insertion of the button after a short period of time is extremely important, since the stoma would otherwise close up within few hours. In some cases, e.g. while on vacation, it would be beneficial if the patient had an available replacement button, so that a fitting button would be available and could be replaced quickly in case of a defect.

If patients gain weight under administration of enteral nutrition, the button must be exchanged for a button with a longer shaft in a timely manner, so as to avoid pressure ulcers or infection of the stoma.

In addition to a good patient selection, precise training is a deciding factor for the long-term success. This should take place at the hospital, and the patient and people from this environment should be made familiar with the particularities of a button. A pass, information material and care standards provided by the manufacturers support these training measures.

7.6 Percutaneous Endoscopic Colostomy or Caecostomy

Indications and Contraindications

The percutaneous endoscopic colostomy/caecostomy (PEC) serves the purpose of decompression in the case of acute or recurring obstructions of the colon (e.g. Ogilvie syndrome) and other forms of intestinal pseudo-obstructions. This procedure can also be used in acute, therapy-resistant infections, e.g. for local therapy in case of *Clostridium difficile* (pseudomembranous colitis). The PEC can also serve as irrigation access in case of chronic constipation.

Intestinal necrosis/ischaemias and (suspected) intestinal perforation are absolute contraindications. The same applies to ascites and coagulation disorders.

Preparation and Prophylaxis of Complications

→ Corresponding to PEG, possibly primary use of PEG CH 20:

→ Have available colonoscope

→ Have available pull-through PEG tube and direct puncture set

Personnel and Instrument-Related Requirements

→ The same as PEG

Practical Course

Initially, endoscopy up to the coecal pole, if possible, insufflation of CO2. After depiction of the diaphanoscopy and local anaesthesia of the abdominal wall, the intestinal lumen is punctured. If the caecum position is identified without a doubt under the abdominal wall using diaphanoscopy and fingertip attempt, a cannula is usually used to puncture.

A modified measure includes a combination between pull-through technique and gastropexy-secured direct puncture procedure. For this, 2–3 security stitches are inserted prior to insertion of the puncture cannula, so as to securely fixate the intestine. Afterwards, deep punch incision about 1 cm in width and introduction of the puncture cannula from a regular set are done. After having retracted the puncture needle, the introduction sheath remains in the caecum. A pulling thread is introduced through the same, grabbed with the grasping forceps and then pulled through the instrumentation channel as completely as possible, from the endoscope towards anal direction, and when pulling back, the air is sucked out of the colon. The PEG tube is attached to the end of this thread and then pulled through the intestine. At the end of the procedure, the internal fixation plate must be at the intestinal wall. Finally, the exterior fixation plate and a standardized dressing are applied. The tube must be affixed with slight pressure, so as to ensure adhesion. Further wound care as per PEG care is followed (Dormann and Deppe 2002).

▪ Complications and Management of the Same

The most important complications correspond to those associated with the insertion of a PEG. The tube can be used immediately for deviation and 4–6 h after the insertion for application. Due to the very thin wall of the colon, only slight pressure should be used for the fixation of the exterior fixation plate, so as to avoid ischemia. For these reasons, insertion of a combination procedure is recommended.

7.7 Endoscopic Procedures in Metabolic Illnesses

Besides personal reasons for the reduction of obesity, there are also medical reasons for planning an obesity therapy, which particularly applies to diabetics. This therapy often encompasses a multimodal concept. In addition to a nutritional and movement therapy as well as medicamentous therapy, surgical procedures offer the best success rates nowadays. In recent years, endoscopic therapy of obesity has become part of the therapeutic concepts of weight reduction. Reducing weight can help overweight patients prevent or delay the onset of type II diabetes mellitus. The weight reduction leads to an improved metabolic condition, which is often reflected in the decreased need for medication, to include insulin. Consequently, reducing excessive weight can even lead to insulin-dependent type II diabetes patients not needing insulin anymore. The following should therefore depict the possibilities of endoscopic therapy in the case of obesity.

7.7.1 Gastric Balloon

The oldest and best-known endoscopic intervention for treating obesity includes the insertion of a gastric balloon. In 1982, this intervention was performed for the first time. Since then, the technique has evolved and has spread to obesity centres. The gastric balloon is made of a soft and expandable material. Prior to insertion, it is very small, so that it can be inserted through the mouth without any problems. The main indications for a gastric balloon are patients who cannot be subjected to a planned surgery due to their extreme obesity, since they would otherwise be exposed to unjustifiable surgery risks. A gastric balloon can therefore be inserted prior to a planned surgery. After this intervention, it is usually easier for the patient to lose the required weight. Usually, the gastric balloon remains in place for 6 months. Manufacturers recommend the gastric balloon not to remain in place for more than 6 months. Over time, the acid-containing gastric content weakens the balloon material and leads to a deflation of the balloon. Should longer treatment be required in special cases, the gastric balloon has to be exchanged every 6 months.

▪ Insertion of a Gastric Balloon

A gastric balloon is inserted during a gastroscopy, under analgosedation. It is important that the periinterventional risk of sedation is assessed prior to the intervention and that an anaesthesiologist is present, if needed. The gastric balloon is placed into the stomach during the endoscopy and under view is filled with fluid. By filling the balloon, it expands to its final size (◘ Fig. 7.34a–c). Depending on the desired degree of expansion, the balloon is filled with 400 to 700 ml of fluid. Newer balloons can also be filled afterwards, thus increasing the volume gradually. The fluid can be stained to take on a blue colour, so that a possible defect of the balloon can be detected. Should the balloon lose fluid due to some type of damage, the coloured fluid is absorbed through the intestines

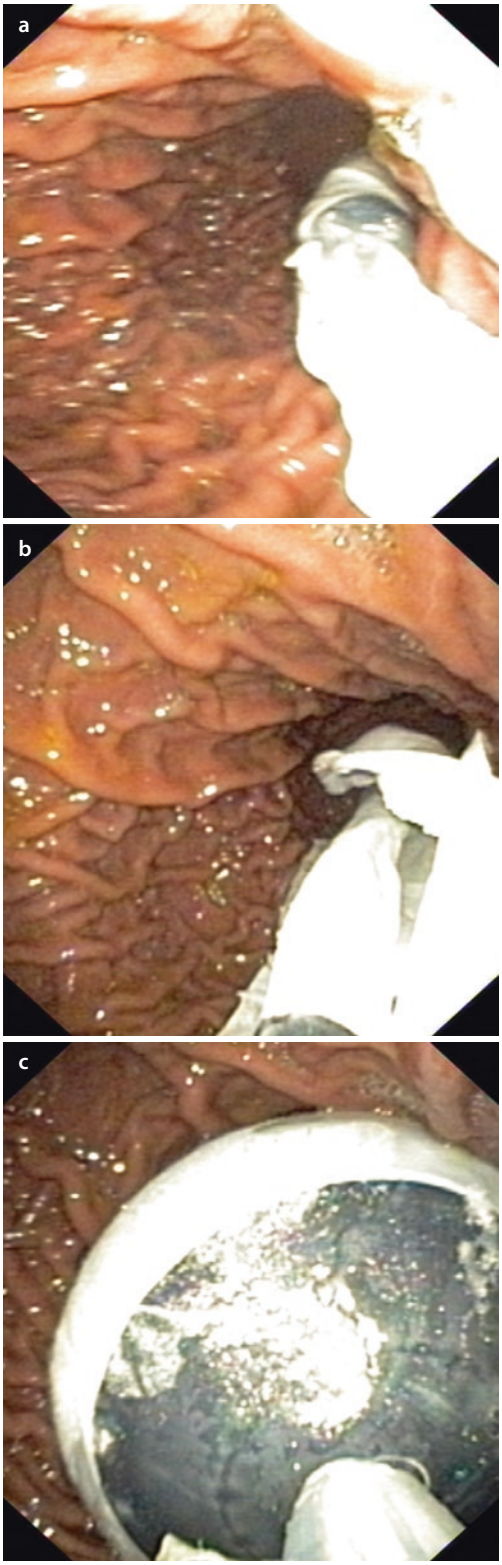

Fig. 7.34 Insertion of the gastric balloon: **a** gastric balloon prior to unfolding in the stomach, **b** beginning of filling, **c** final state of balloon in situ

into the blood and then excreted via the kidneys. The discoloured urine reveals the defect of the gastric balloon. A defective balloon must be removed.

Risks

During the passage, the oesophagus and stomach can be injured, either through direct contact with the instruments being used for inserting the balloon or through the gastric balloon itself. Due to the increased production of acid in the stomach, the patient can also experience reflux or develop ulcers. Further problems can include severe pain; bleeding and perforation of the gastric balloon are very rare. A bacterial contamination of the balloon fluid can lead to infections, fever, cramps and diarrhoea, if the contaminated fluid reaches the intestine after a rupture of the balloon or when removing the same. Developing an ileus poses another risk, when the spontaneously moving balloon obstructs the intestines.

Aftercare

The patient can experience some problems during the first few days, since the stomach has to get used to the balloon, e.g. nausea, vomiting or diarrhoea and feeling of fullness. In rare cases, the ailments may lead to exsiccosis or electrolyte imbalances requiring therapy. It can take up to 2 weeks until the ailments subside. During this time, the patient often voices the request of having the balloon removed.

Subsequently, in the majority of cases, the insertion of a gastric balloon often leads to a significant reduction in weight.

Removing the Gastric Balloon

If there are no complications, the gastric balloon is usually removed after 6 months. Removing as well as inserting a gastric balloon is an endoscopic intervention with little risks involved. It does, however, require a special kit, with which the balloon is completely emptied via puncture and then extracted with a special grasping instrument.

7.7.2 EndoBarrier

The EndoBarrier method is an endoscopic procedure for treating type II diabetes and for losing weight. It imitates the effects of a bypass surgery according to Roux-en-Y and reduces contact between the food and duodenum/proximal jejunum to 60 cm in length (functional temporary

short intestine syndrome). For this, a flexible tube prosthesis is anchored in the duodenal bulb using a metal wreath with barbed hooks, and the duodenum and the upper jejunum are covered with a foil. It is im- and explanted endoscopically and is always part of the nutritional-medical overall concept.

Implantation of the EndoBarrier: Indications

The EndoBarrier therapy is used for the treatment of patients with type II diabetes, whose diabetes is difficult to control and whose BMI exceeds 30. The EndoBarrier method is intended for a maximum implantation duration of 12 months.

Implantation of the EndoBarrier: Contraindications

The EndoBarrier method is contraindicated in the following patients:

- Long-term anticoagulation therapy
- CED
- Pancreatitis
- Active ventricular or duodenal ulceritis
- Severe reflux disease (GERD)
- Current infections
- Symptomatic CHD
- Severe COPD
- Haemorrhagic diathesis or coagulopathy
- Oesophagus or stomach varices
- Congenital or acquired telangiectasia in the gastrointestinal tract
- Earlier gastrointestinal surgeries that could influence the placement or function of the device
- Symptomatic kidney or gallstone issues
- Insufficient compliance
- Planned or possible pregnancy

Implantation of the EndoBarrier: Preparing the Patient

Three days prior to implantation and up to 2 weeks after removing the EndoBarrier, the patient must take a proton pump inhibitor (e.g. 40 mg omeprazole twice a day). No anticoagulants (aspirin, heparin, NSAID, etc.) are to be taken within 10 days prior to the implantation of the EndoBarrier and during the entire treatment duration. To reduce the risk of infection, intravenous administration of a single dose of 1 g of ceftriaxone (or an equivalent dose of another medication) 30–90 min prior to the intervention is recommended. The patient must be fasting. A secure i.v. access must be present. Sedation with midazolam/propofol or intubation anaesthesia must be carried out.

Implantation of the EndoBarrier: Personnel-Related Requirements

The EndoBarrier may only be used by physicians that are experienced in endoscopic procedures and have received practical training especially for the implantation of the EndoBarrier. The procedure should be performed by two people. Anaesthesia should be performed by an anaesthesiologist.

Implantation of the EndoBarrier: Technical Requirements

Possibility for fluoroscopy; fluoroscopy unit; gastroscope with a working canal of 2.8 mm; Gastrografin, Renografin or equivalent water-soluble fluoroscopy contrast agent; 60 ml, 50 ml and 20 ml syringes; 200 ml of sterile saline solution; and 0.035 inch extra-stiff Nitinol guidewire, e.g. Jagwire Boston Scientific.

The EndoBarrier system is shown in Figs. 7.35, 7.36 and 7.37.

Implantation of the EndoBarrier: Practical Course

The gastroscope is introduced into the duodenum while the patient is lying on the left side, and the area is inspected. Then, under fluoroscopy, the guidewire is advanced into the duodenum. While retaining the wire position, the gastroscope is removed over the wire. While retaining the position of the guidewire, the catheter capsule is advanced via the guidewire into the duodenum. If required, the guidewire can be retracted slightly, so as to lift the capsule into the pylorus. The gastroscope can be used when placing in the pylorus. Then, the guidewire is removed (Fig. 7.38).

The internal catheter is then slowly advanced by pushing the button at the handle (Pos. 1) and by slowly pushing forwards the handle piece. Over time, the button is released so as to pull back the handle; this procedure is repeated. The internal catheter is advanced under fluoroscopy control until it is completely extended up to the most outer distal reference marker at the internal shaft (Fig. 7.39). If there is resistance, pressure is applied forwards, and peristaltic movement is waited on to advance the catheter.

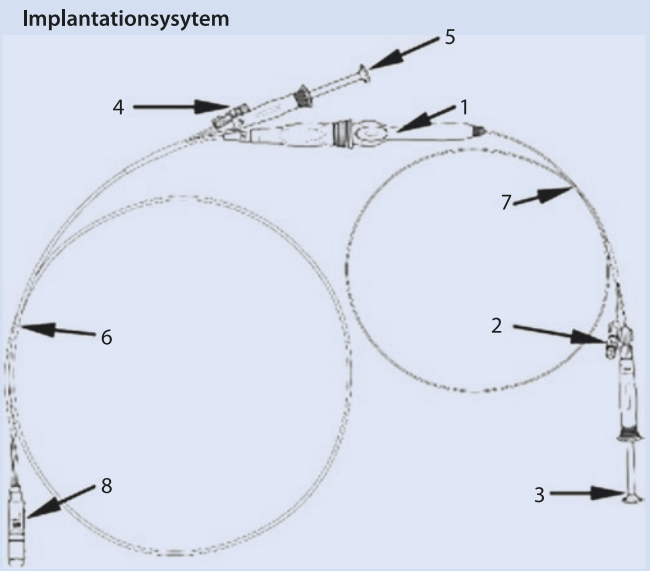

Fig. 7.35 Implantation system EndoBarrier (Courtesy of company GID)

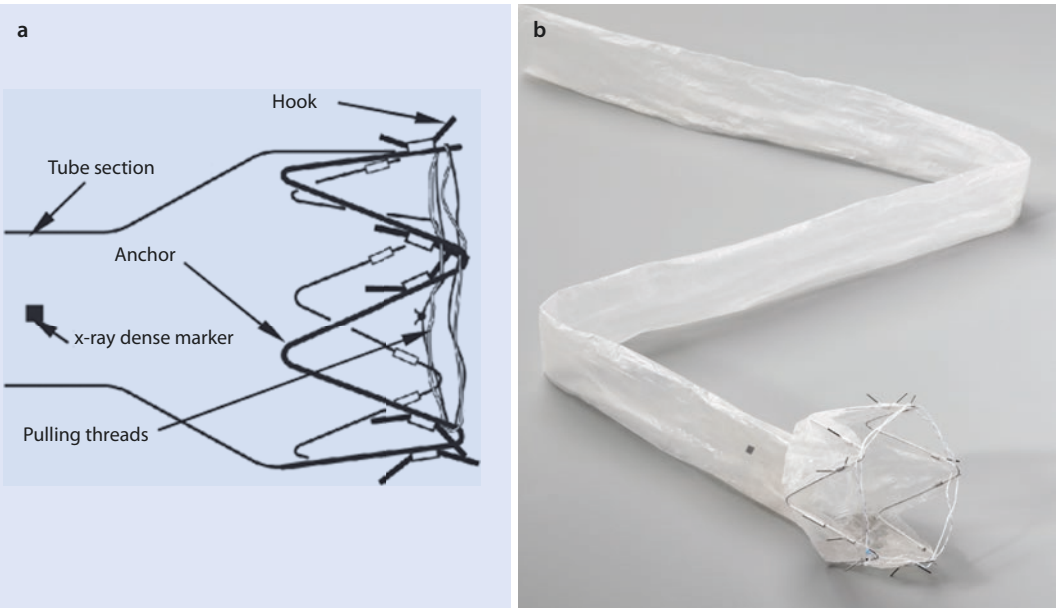

Fig. 7.36 **a**, **b** Fixation tool (Courtesy of company GID)

Then, the blocking wire (pos. 2) at the internal catheter is retracted 10 cm, so as to loosen the distal ball and the tube (Fig. 7.40).

The stiffening wire (pos. 3) is advanced so as to loosen the ball from the distal end of the catheter. It is then checked via fluoroscopy whether the ball is actually removed. If that is the case, the stiffening wire (pos. 3) is retracted back into its stopper position. The gastroscope is then reintroduced into the stomach, and it is assured that the implantation capsule is positioned all the way in the bulb. The blocking wire (pos. 4) of the anchor is then retracted by 10 cm, so as to loosen the anchor. Position the capsule under endoscopic

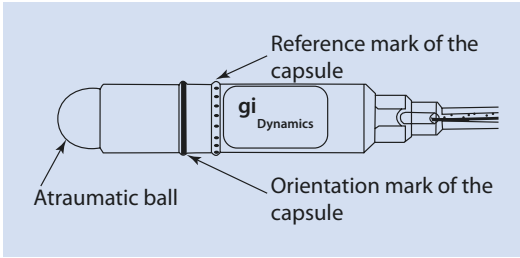

Fig. 7.37 Capsule with system (Courtesy of company GID)

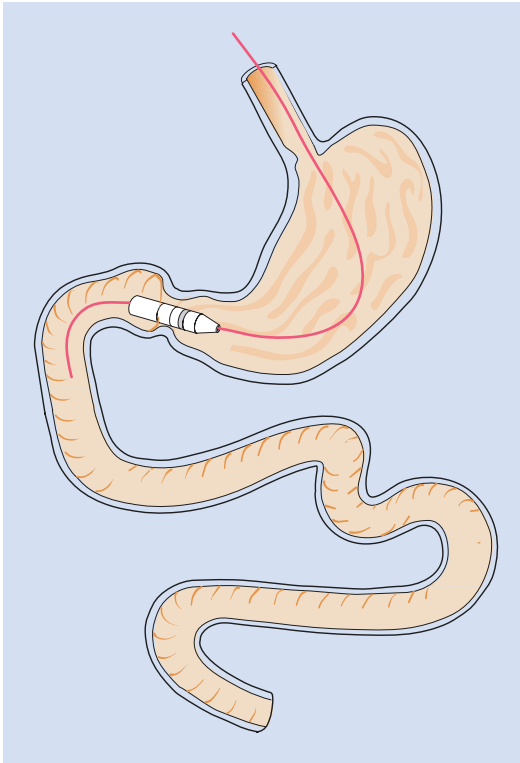

Fig. 7.38 Capsule in situ

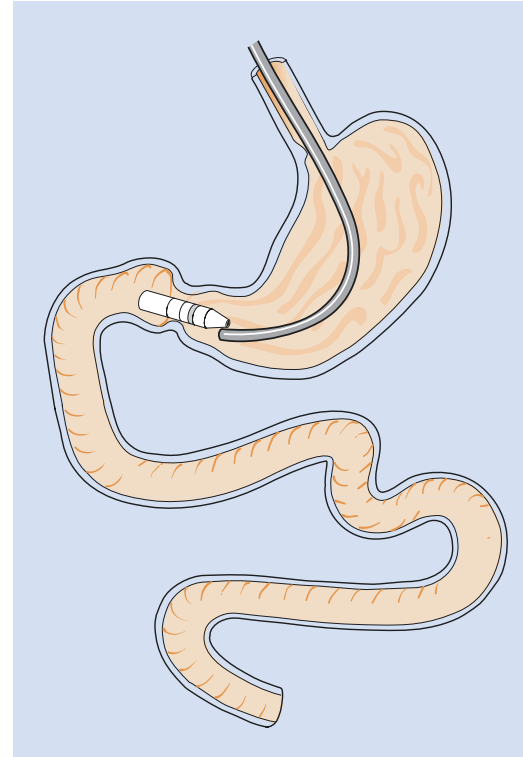

Fig. 7.39 Positioning of the capsule

view, so that the predetermined black capsule marker corresponds to the proximal side of the pylorus. The anchor piston (pos. 5) is advanced to partly push the anchor out of the capsule. The position of the capsule is checked, and the anchor implantation handle (pos. 5) is then implanted by advancing the anchor (Fig. 7.41).

The stiffening wire (pos. 3) is removed from the internal catheter. About 60 ml of saline solution or 20% Gastrografin solution is injected into the catheter through the connector, so as to fill the EndoBarrier with fluid. Then, about 60 ml of air is injected through the same connector to separate the internal catheter from the tube. The internal catheter is removed from the exterior catheter, and under fluoroscopy it is observed whether the implant is puffed up backwards. The gastroscope and the outer catheter are then removed from the patient. The gastroscope is reintroduced, and the EndoBarrier is checked in the duodenal bulb: 60 ml of 20% Gastrografin solution is flushed into the EndoBarrier through the working canal of the gastroscope, to confirm that the product is passable and to smooth out the system's tube area (Fig. 7.42).

Explantation of the EndoBarrier: Personal-Related Requirements

Basically, the same requirements as in the case of implantation. The team must, however, be aware of the explantation being associated with more complications than the implantation.

Explantation of the EndoBarrier: Technical Requirements

EndoBarrier explantation system (Fig. 7.43), gastroscope with a working canal of 2.8 mm, fluoroscopy unit, 20 ml and 60 ml syringes and 200 ml of sterile saline solution

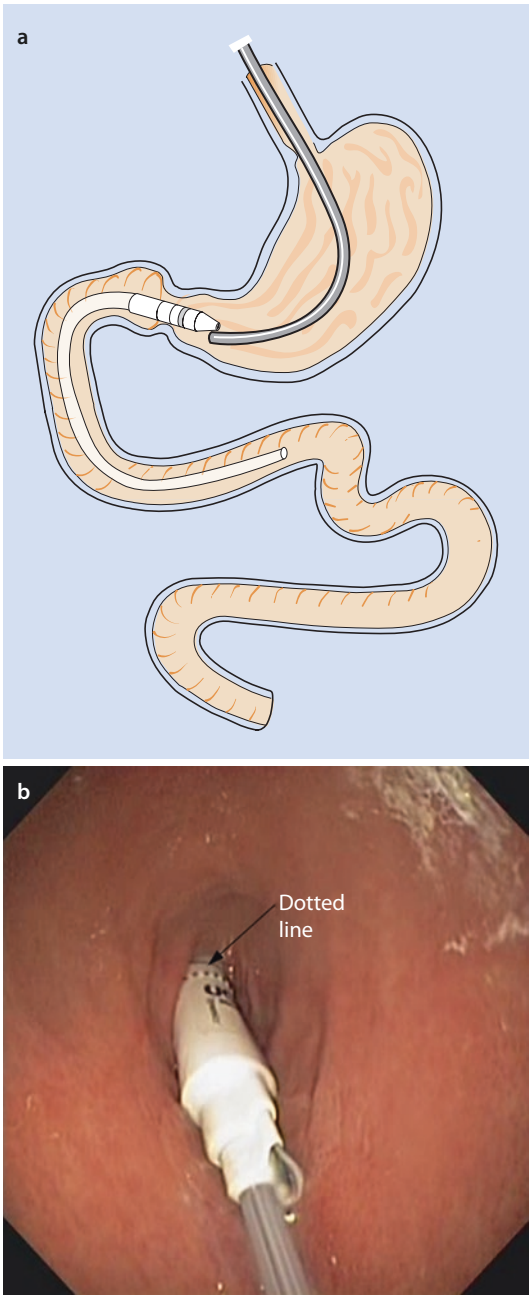

Fig. 7.40 **a**, **b** Release

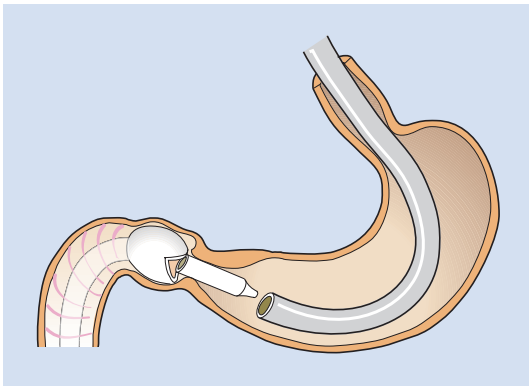

Fig. 7.41 Fixation of the system in the bulb

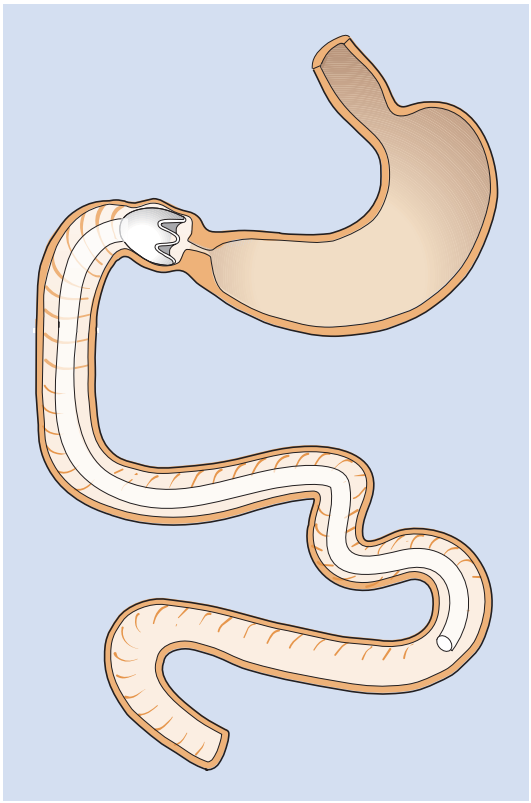

Fig. 7.42 System in situ

Explantation of the EndoBarrier: Practical Course

The patient is positioned on the left side and the gastroscope is introduced. If required, flush with saline solution, to be able to see the retrieval threads. The gastroscope is then removed, and the explantation cap is then attached to the tip of the gastroscope. Then, the gastroscope is introduced into the duodenum and placed so that the anchor and the retrieval threads are visible (Fig. 7.44).

The retrieval grasper (Fig. 7.44) is advanced through the gastroscope's working canal until it is positioned distally to the explantation cap. It must be ensured that the blocking at the retrieval grasper's handle is in non-blocked position. With the

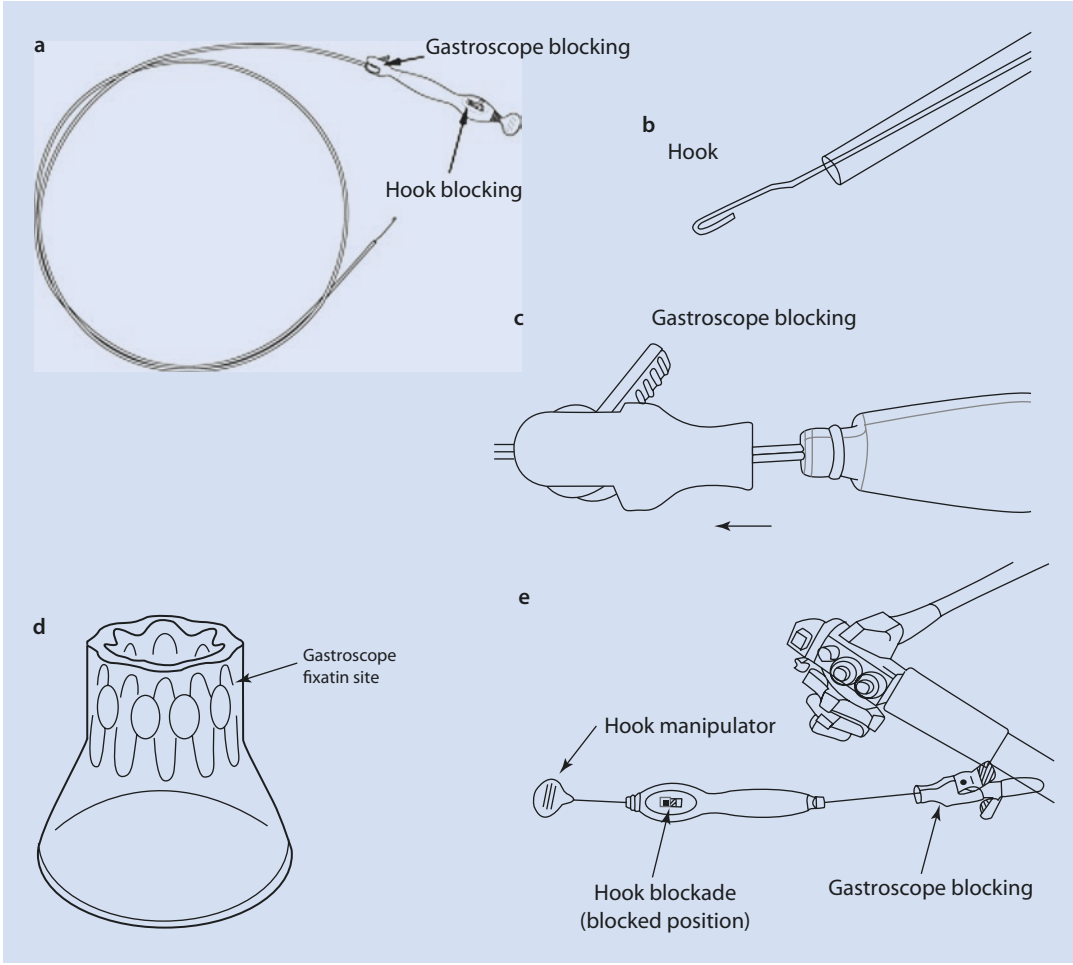

Fig. 7.43 **a–e** Explantation set (Courtesy of company GID)

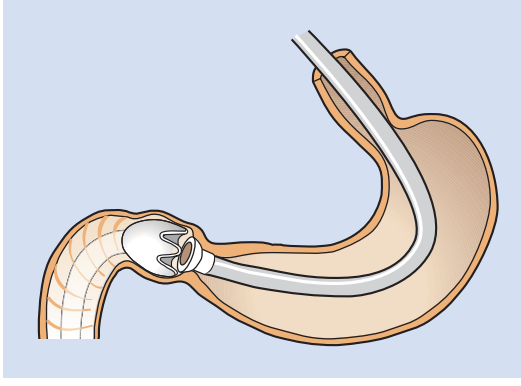

Fig. 7.44 Gastroscope in situ prior to explantation

help of the gastroscope, the grasper hook is then positioned around one of the retrieval threads. The grasper hook is pulled back with the handle, and the retrieval thread is therefore positioned into the inside of the sheathing. The sheathing with the partly retracted retrieval thread is then advanced so that the tip of the sheathing is located within the internal diameter of the implantation hook. The grasper with the endoscope is then placed in the middle of the anchor. The hook is slowly retracted, so as to completely compress the anchor. When doing this, it must be ensured that the endoscope and the cap are positioned proximally of the compressed anchor and are

free of the same. If the anchor is completely compressed, the hook blockage at the retrieval grasper's handle is put into blocked position to secure the compressed anchor. The grasper is held, and the explantation cap is moved over the proximal anchor hook, until it is enclosed in the explantation cap (Fig. 7.45). The compression of the anchor must be monitored under fluoroscopy to ensure that all hooks are enclosed in the cap.

The gastroscope blocking is then advanced distally from the end of the retrieval grasper's handle, until the endoscope is reached. The grasper is attached to the endoscope. The device enclosed in the cap is stopped in the stomach, and under fluoroscopic observation it is ensured with the endoscope that the cap is correctly enclosed in the cap (Fig. 7.46). Under fluoroscopic control, the gastroscope, retrieval grasper and implant are then pulled out while exerting slight traction.

In the end, the explantation site is endoscopically checked for haemorrhages. If required, flush with saline solution.

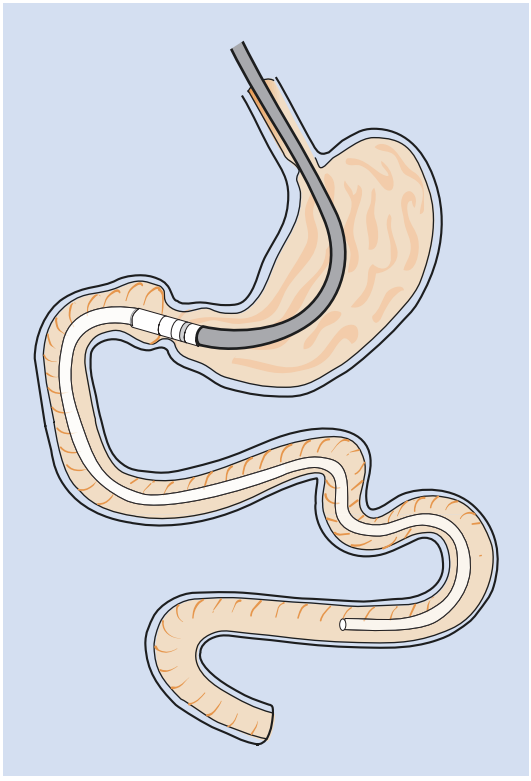

Fig. 7.45 Fixation

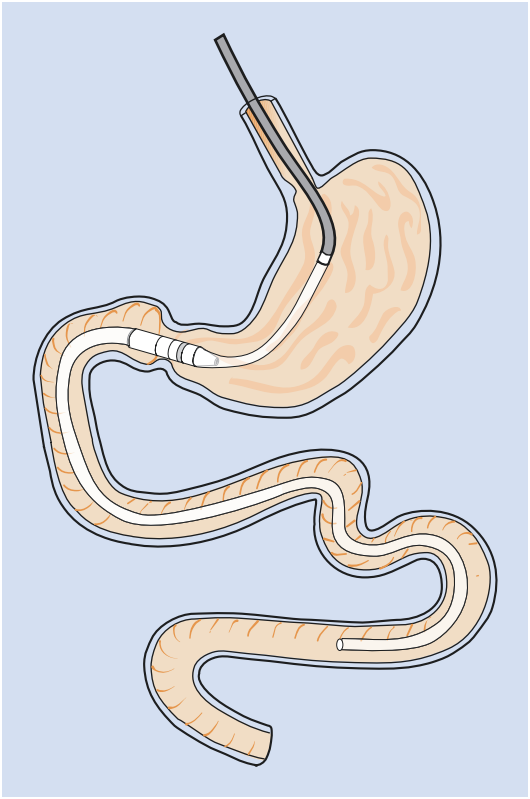

Fig. 7.46 Extraction

Possible complications during implantation and explantation:

- Laceration of the gastrointestinal tract
- Perforation of the oropharynx
- Perforation of the oesophagus
- Perforation of the stomach
- Bleeding
- Aspiration
- Infection

Possible complications during the implantation:

- Obstruction of the small intestines, migration of the EndoBarrier
- Erosion, bleeding
- Constipation, feeling of fullness, diarrhoea, flatulence
- Infection

- Hypo-/hyperglycaemia
- Gastrointestinal pain, cramps, nausea, vomiting
- Back pain
- Local, inflammatory tissue reaction
- Oesophagus, duodenitis, ulcer
- Perforation of the stomach or intestine
- Bezoar, GERF

Possible complications during and after the explantation:

- Laceration of the gastrointestinal tract
- Perforation of the oropharynx, oesophagus, stomach or intestines
- Bleeding
- Aspiration
- Infection

Complications

The few clinical studies revealed the following adverse events that occurred the most often:

- Nausea
- Vomiting
- Abdominal pain

Other improbable, but possibly occurring, risks can include:

- Infection
- Bleeding

Aftercare

During treatment, the patient must be accompanied, receive consultation and be cared for by a multidisciplinary medical team. This ensures that the patient's treatment plan is well coordinated and therapeutically effective. The following belongs to the team:

- Endoscopic specialist, metabolic surgeon or gastroenterologist
- General practitioner
- Endocrinologist and diabetologist
- Nutritional team

The members of the multidisciplinary team must always consult each other and exchange information regarding the patient's clinical and general state of health. The following needs to be discussed:

- Individual objectives regarding weight loss – depending on the patient's weight at the time of implantation
- Objectives regarding the improvement of diabetes based on the monitoring of the blood glucose levels and regularly performed HbA1c tests

Medication at Type II Diabetes Mellitus

Soon after the placement of the EndoBarrier, patients with type II diabetes detect a rapid improvement of the glycaemic control and their HbA1c levels. It is therefore recommended to adapt the TIIDM medication correspondingly at the time of implantation. Based on clinical studies, the following reductions were performed:

Sulfonyl Urea At the time of implantation, the dose of sulfonyl urea must be reduced by 50% so as to avoid possible hypoglycaemic episodes. Should a hypoglycaemic episode occur, an additional reduction by another 50% or discontinuation of the same is recommended, if the patient is already taking the lowest dose possible.

Insulin At the time of implantation, the insulin dose must be reduced by 50% so as to avoid possible hypoglycaemic episodes. Should a hypoglycaemic episode occur, an additional reduction by another 50% or discontinuation of the same is recommended, if the patient is already taking the lowest dose possible.

Metformin During the entire treatment duration, the metformin dose can remain unchanged, unless the sulfonyl urea and/or the insulin has already been discontinued and the patient's fasting glucose levels on 3 consecutive days are below 4 mmol/l. In this case, the metformin dose must be reduced by 50%. If the patient still experiences cases of hypoglycaemia after this reduction, it is up to the physician to change the metformin dose again or to suspend it completely.

After these initial reductions, the endocrinologist/diabetologist can change the type II diabetes medication according to the standard algorithm and based on the glucose levels and symptoms.

Recommendations Regarding Diet and Nutrition

The EndoBarrier is supposed to facilitate a healthy and nutritious diet. The treatment success, however, depends on the patient's willingness to adopt healthier eating and lifestyle habits. The patients must adhere to a diet immediately after the implantation, which is similar to that recommended to other bariatric procedures. At the beginning, this diet does, however, also encompass liquid foods, followed by a diet with pureed foods.

General recommendations for the first 2 weeks after implantation of the EndoBarrier:

Days 1–7

- Clear or artificially sweetened fluids
- Salty fluids
- Clear broth
- Sugar-free popsicles
- Fluids with solid parts including:
  - Fat-free milk, mixed with whey or soy protein powder (max. of 20 g of protein per portion)
  - Lactose-free milk
  - Soy milk mixed with soy protein powder
  - Low-fat yogurt, mixed
  - Simple low-fat yogurt
  - Greek yogurt

Days 8–14

- Increase clear fluids by 1.5–2.0 l per day.
- Substitute fluids containing solids by moist, diced or pureed protein sources, depending on how they are tolerated.

After 14 days, the patients can change to solids, as recommended by a dietician.

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Endoscopic Extraction of Foreign Bodies

Peter Collet

G. Kähler et al. (eds.), *Therapeutic Endoscopy in the Gastrointestinal Tract*,
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Extractions of foreign bodies are a frequent entity in endoscopy. The diversity of possible foreign bodies is almost without limits. Even experienced endoscopists can be surprised by the multiplicity of items a human being is able to incorporate. As a result, an often very individual approach is mandatory. However, there are common considerations and tricks which will be clarified in the following chapter.

8.1 Overview

The necessity to remove a foreign body is a comparably frequent problem in endoscopy. In younger kids, with a maximum of events occurring between 6 months and 6 years of age, this may include various toys, toothbrushes, batteries, bones, and coins which have been swallowed. Psychiatric patients or people with reduced cognitive abilities have a higher incidence of these events. Prison inmates often present with an intentional ingestion of cutlery and/or razor blades (Fig. 8.1). Transanally introduced foreign bodies mostly show an (auto-) erotic background; due to their size and composition, considerable technical challenges for removal are frequent. So-called body-packing for illegal drug trafficking is rather rare in Germany but, however, more frequent in other countries; it then requires specific considerations (Fig. 8.2). In particular in patients who have been operated on before or in patients with stenoses, bolus obstruction by normal insufficiently chewed food may require an endoscopic recovery.

A rigid endoscopy, as used routinely in ENT, is usually not indicated. It should only be applied after failure of less invasive flexible maneuvers.

8.2 Foreign Bodies in the Upper Gastrointestinal (GI) Tract

Indications

Not all swallowed foreign bodies require endoscopic extraction. On the contrary, most will be discharged naturally. From pre-endoscopic times, we know that the spontaneous discharge rate is higher than 80% (Longstreth et al. 2001). However, there are emergency situations demanding immediate action for the removal of ingested foreign bodies (Table 8.1). Commonly these are objects where size and/or composition are likely to create injuries to the GI tract or where a spontaneous discharge is highly questionable. Foreign bodies that get stuck in the esophagus may cause ulcerations and subsequent perforation, with eventually deadly mediastinitis. A special situation is seen following the suicidal ingestion of quetiapine (Seroquel, AstraZeneca). But also magnets, with or without metal pieces, may cause pressure sores. Button-shaped batteries may erode their thin covering and provoke chemical burns. Especially in kids, larger batteries of this type can also provoke electrical problems (Fig. 8.3).

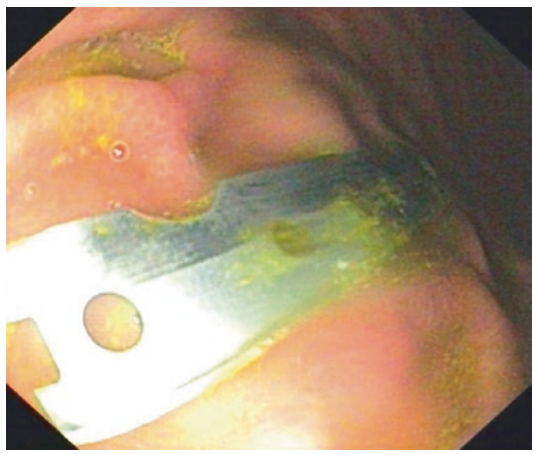

Fig. 8.1 Razor blade

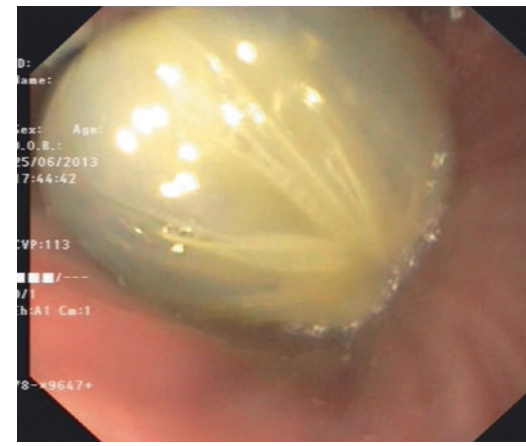

Fig. 8.2 Drug parcel in the stomach

Table 8.1 Indication for endoscopic removal of swallowed foreign bodies

Emergency	Urgent	Elective
Sharp foreign bodies in the esophagus Esophageal obstruction with aphagia Button-shaped battery in the esophagus Quetiapine overdose	Other foreign bodies in the esophagus without complete obstruction Sharp foreign bodies in the stomach or duodenum Large (>6 cm) objects in the stomach or duodenum Magnets	Asymptomatic coins in the esophagus (may be observed for up to 12 h) Foreign bodies of 2.5–6 cm in the stomach Batteries in the stomach may be observed for 1–2 days

Adapted from ASGE Standards of Practice Committee (2011)

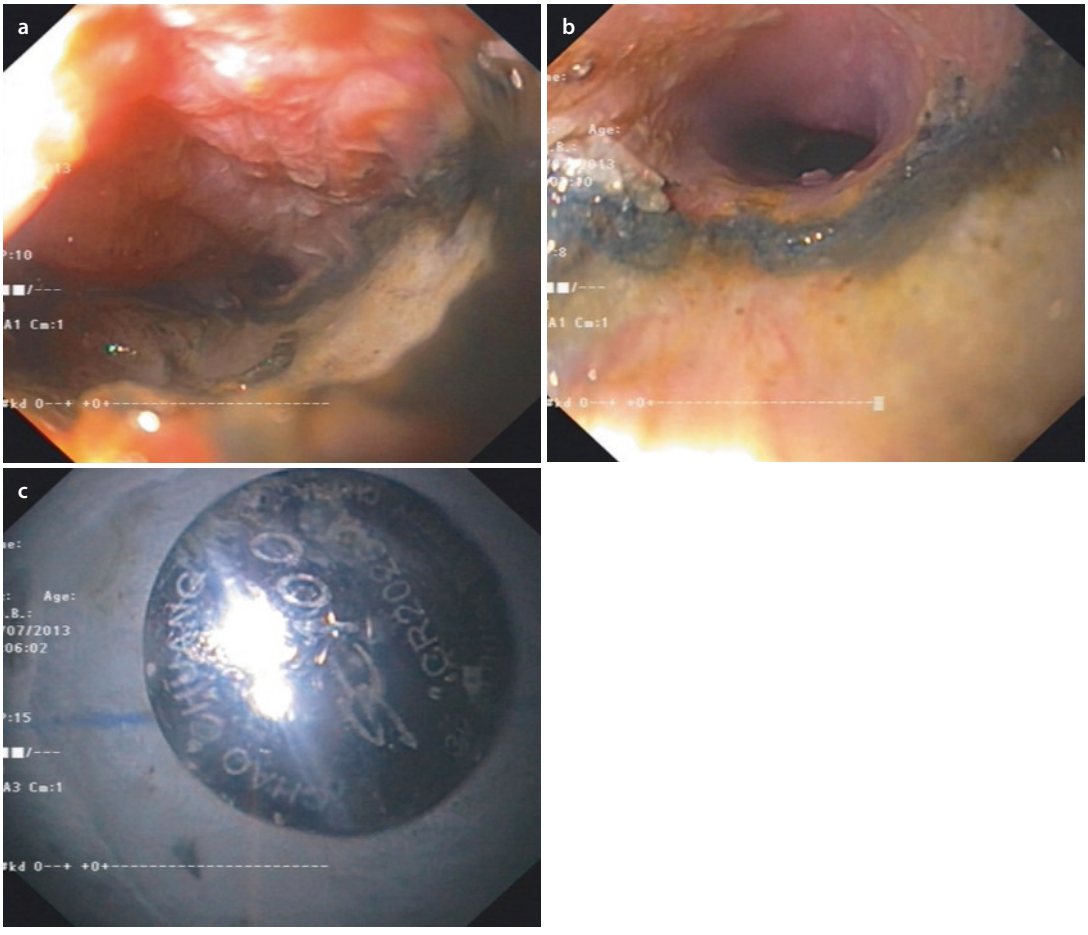

Fig. 8.3 **a** Esophagus after removal of a button-shaped battery. **b** Former position of the button-shaped battery in the wall. **c** Removed button-shaped battery

Contraindications for exclusively endoscopic extraction are very few and usually relate to manifest hollow organ perforations and body-packing of toxic substances. After having reached the jejunum, in patients without distant stenoses, these foreign bodies do usually not have to be endoscopically removed. If the clinical condition remains stable, these patients may be regularly monitored in an out-patient setting including weekly X-ray controls. At times, the complete passage might last up to 4 weeks.

Since endoscopic removal by an experienced team is very safe, the author recommends the primary endoscopic recovery in every doubtful case.

Personnel Requirements

Most endoscopic extractions require a standard sedation. Therefore, in addition to the staff member responsible for the surveillance of sedation, one additional auxiliary person is necessary. In cases with complete obstruction of the esophagus and total aphagia, the primary prophylactic endotracheal intubation to prevent aspiration is strongly indicated. Also in children, adequate maintenance by an anesthesiologist is advisable.

Technical Requirements

The vast variety of possible foreign bodies has demanded the development of multiple helpful instruments for the recovery of all types of items. Whenever feasible, the adequate instrument should be tested for its efficacy before the actual endoscopy by manipulation of a similar foreign body. The choice includes all types of forceps, polyp graspers, slings, and Dormia baskets. The use of a recovery bag may be very helpful (Fig. 8.4). When dealing with objects with sharp edges, sufficient protection of the mucosa is mandatory. For this purpose, overtubes or protective caps are the solution. In particular with small objects that might be lost in the hypopharynx and aspirated, overtubes are a proven safety feature (Fig. 8.5).

Organizational Requirements/Setting

First, the urgency of an endoscopic intervention has to be judged. From there, the choice of procedure and the contents of the informed consent have to be determined. The success of the endoscopic recovery is essentially depending upon the correct selection of adequate instruments which — together with alternatives — have to be available and must be mastered. Protection from iatrogenic injury and aspiration is of highest priority and must be taken into account prophylactically as well by having additional tools available and providing preparations for anesthesia. In addition, management of potential complications such as bleeding or bronchoscopy in case of aspiration should be prepared for.

Fig. 8.4 Recovery mesh

Fig. 8.5 Overtube

Practical Procedure

Whenever possible, a pre-interventional practical test of usefulness and handling of the chosen tools should be done on a similar object, since this will facilitate the procedure considerably. Due to the type and consistency of the foreign object, possible complications and counteractions have to be taken into account (securing airways, protecting mucosa in sharp items).

Practical Procedure: Recovery of Sharp Objects by Means of a Safety Cap

This option is only possible if the foreign body lodges distally of the lower esophageal sphincter.

In patients with large axial hernias, the correct function of the cap may be of limited value. Before placement of the safety cap, an orienting endoscopy should be carried out to visualize the object and to exclude preexistent injuries. The complete removal of secretions and ingesta by repeated suction is highly advisable to prevent aspiration. If an endoscopic removal seems possible, the safety cap is mounted onto the distal end of the scope so as to lie closely adjacent to the scope. The application of a lubricant gel onto the cap facilitates the gentle intubation of the upper esophageal sphincter. After the object has been grasped in an axial direction and the endoscope has been pulled backward, the cap will flip over by passing the narrow zone of the cardia and should sufficiently protect from injury to the mucosa in the esophagus and hypopharynx by solidly covering the foreign body (Fig. 8.6).

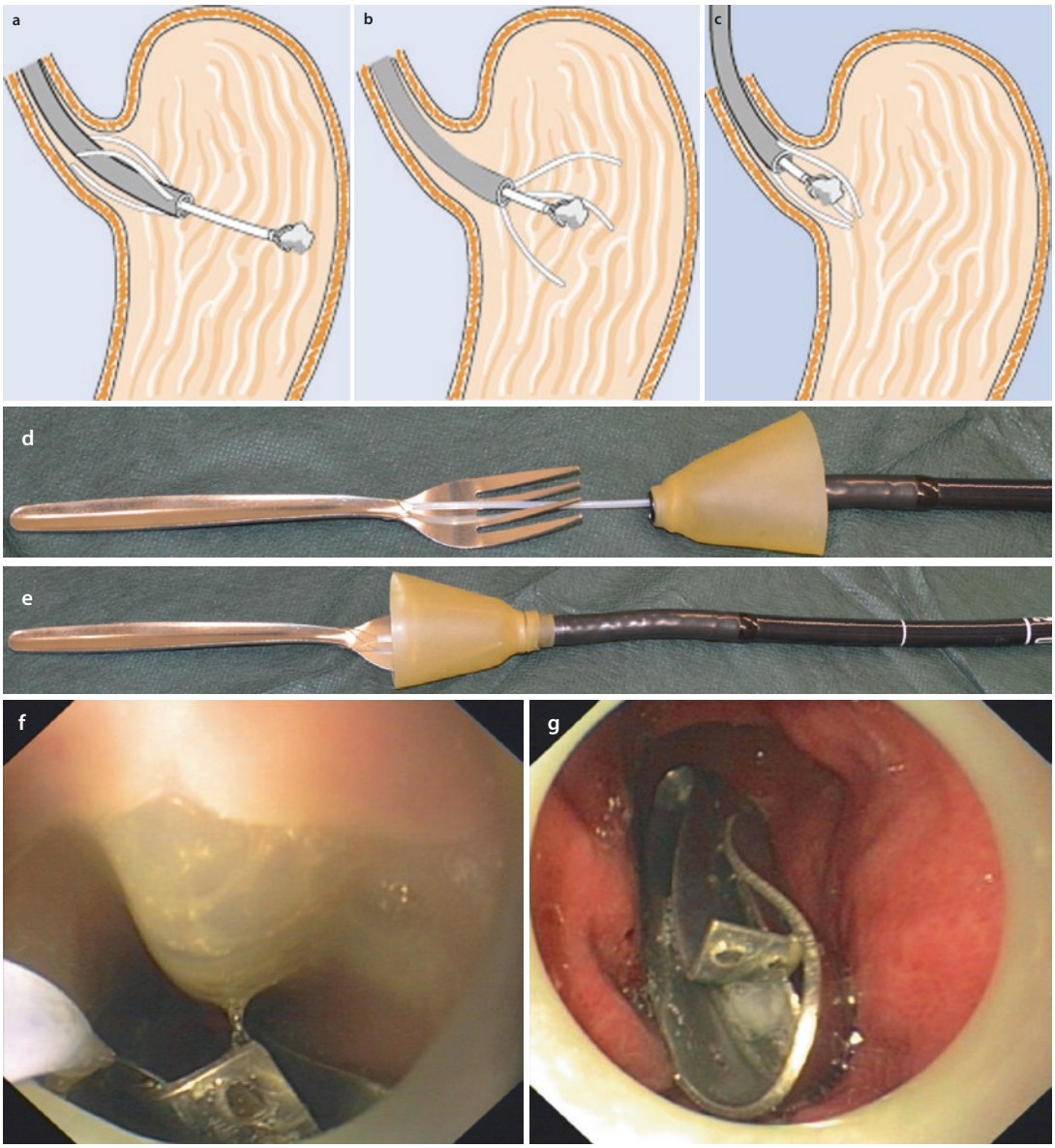

Fig. 8.6 Removal of a foreign body by means of a protective cap. **a** Introduction of the endoscope with the protective cap. **b** Eversion of the cap. **c** Retrieval of foreign body inside the closed cap. **d**, **e** Flipping-over of the protective cap around the foreign body, as occurring during pullback of the cap through the cardia. **f** Grasping of a metallic item inside the stomach, penetrating the protective cap. **g** Extraction of the metallic item under the protection of the flipped-over cap

Tip

Longitudinal foreign bodies (e.g., toothbrushes) have to be grasped at their end to be able to extract them along the axis of the esophagus; an oblique position at the cardia level has to be avoided. For the passage of long and rigid objects through the hypopharynx, a sufficient reclining of the head will help; at times, the use of a Magill forceps is necessary.

When objects are within the esophagus or when a large axial hernia is present, alternatively transparent safety caps (as used in capped mucosectomy) may be used if they are large enough to virtually wrap round the foreign body.

Tip

A removal of the endoscope against increased resistance must be avoided. Occasionally, deepening of sedation and the injection of Buscopan or glucagon may be helpful.

Practical Procedure: Recovery of Sharp Items with an Overtube

The most elegant method is the use of conical overtubes which are directly mounted onto the endoscope (Fig. 8.5). The endoscope then functions like an internal rod. During introduction of the scope, potential injuries or anatomical variants such as Zenker's diverticulum in the proximal esophagus can be detected. In addition to protection of the upper esophagus, this overtube provides safe protection from aspiration. In infants its use may be limited, though.

After grasping the foreign body in an advantageous axial orientation, the endoscope together with the grasped object is retracted into the overtube. In the case of large objects where the extraction via overtube is not completely possible, both overtube and the endoscope with the grasped foreign body are removed together.

Practical Procedure: Esophageal Food Bolus Obstruction/Quetiapine overdose

Here the danger of aspiration is highest. Therefore the use of an overtube is also strongly recommended unless endotracheal intubation for whatever reason is indicated. Soft and mashed food and Seroquel may only seldom be able to be removed during one single passage, requiring repeated endoscopic maneuvers. The use of an overtube is very helpful in most of these instances. For introduction of the overtube, see the preceding chapter.

The recovery of residual food or of Seroquel, due to the soft consistency, is best done by means of recovery bags or meshes. In these cases, a commercially available coating of the meshes with a plastic foil should be chosen as compared to standard meshes. The latter get stuck and occluded very fast, especially when Seroquel has to be removed from the stomach, making a repeated use very tedious. If one has managed to remove large parts of the bolus, the remaining parts might be pushed forward into the stomach. The use of force must be avoided at all costs. Since an esophageal stenosis is very often the underlying cause, this technique is not always an option. Occasionally, this stenosis can be dilated during the same session. However, following longer impaction of a bolus with ulcer formation, this procedure should split into one or more dilatations because of the risk of perforation.

Complications and Their Management

The protection of the mucosa from direct injury and prophylaxis of aspiration avoids possible complications. In the case of an aspiration, an immediate bronchoscopy with removal of the aspirate and a lavage should be carried out. Any further manipulations should then only be done under endotracheal intubation and anesthesia. Most injuries to the mucosa result in self-limiting bleedings. In the case of reduced coagulability or in the presence of esophageal varices, the standard techniques for endoscopic hemostasis should be employed as described elsewhere in this book (▶ Chap. 3).

Following iatrogenic endoscopic perforation, an immediate endoscopic closure by a covered SEMS or by clips (EndoClip, OTSC) can be attempted. If the reaction is immediate and there is an absence of significant contamination of mediastinal structures, the prognosis is excellent. In all cases, this event must be presented to an experienced surgeon.

8.3 Foreign Bodies in the Colorectum

Indications

In contrast to swallowed objects, here an (auto-) erotic manipulation with loss of the device is usually

the cause. The need for removal of swallowed foreign bodies from the colorectum involves the presence of an impeded natural passage. Rectal stimulation in the case of mostly larger objects bears a comparably higher risk for injury and perforation, which in turn may cause a serious life-threatening condition. Due to the consistency of the rectally introduced objects, their removal might be more difficult than in the upper GI tract. The often extraordinary size of the objects requires additional deliberation. Lastly most patients only present after frustrated attempts to remove of the objects themselves, mandating professional efforts for recovery. As soon as there is the suspicion of perforation, a plain abdominal X-ray or better an abdominal CT scan should be carried out, since endoscopic attempts might unduly postpone necessary actions such as operation and might aggravate the situation by the inflation of air through the defect.

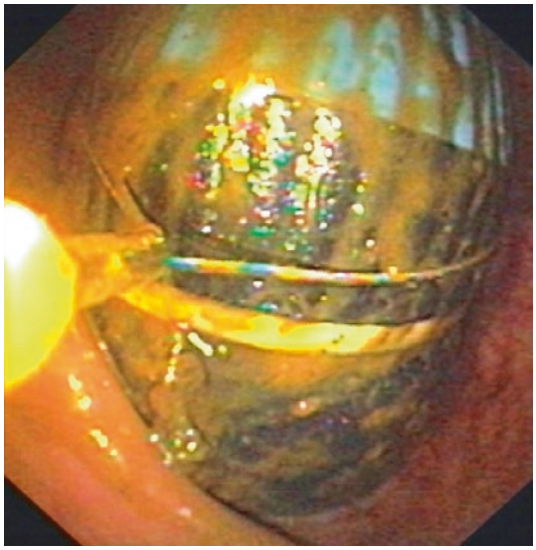

Fig. 8.7 Rectal foreign body: vibrator

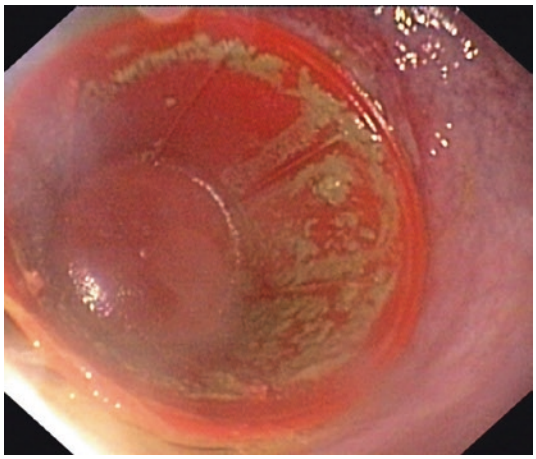

Fig. 8.8 Rectal foreign body: plastic lid

Personnel Requirements

For the removal of large, mostly smooth rectal foreign bodies, experience in proctology is an advantage. An extraction only by flexible endoscopic technique is only seldom successful; usually dilatation of the sphincter and manual support are required. In cases of very large objects with a blunt distal contour, anesthesiological standby with muscle relaxation or spinal anesthesia may be necessary.

Instrumental Requirements

Most usual instruments are — due to the sheer size of the objects — of no help at all. Loops or recovery meshes may be a solution in the last resort (Figs. 8.7 and 8.8). They might stabilize the object in an orthograde position to enable digital extraction. Sometimes the removal through the anus may be facilitated by anal dilators or even obstetric forceps. However, by far the most important instrument remains in the hand of the examiner.

Organizational Requirements/Setting

If a perforation of the colorectum is suspected, an operation instead of endoscopic intervention is warranted. In the absence of symptoms, after regular informed consent of the patient, the preparation for the endoscopic removal may be initiated. Depending on the size and external contours of the foreign body as well as on the ability of the patient to relax the sphincter, the help of the anesthesiologist should be considered. A complete relaxation of the patient is an enormous help for the extraction maneuver. The lithotomy position is very suitable. Contrary to the usual left-sided position, the elevation of the thorax and abdominal pressure can help during the extraction. Nevertheless, if a left-sided position is preferred, a squatting position by bending of both legs is helpful.

Sometimes there is bleeding from the swollen hemorrhoidal plexuses which should easily be controlled; usually, a temporary anal tamponade will suffice.

Practical Procedure

A pre-interventional enema should not be done. At best, it has no effect at all. The foreign body might, however, be pushed orally. The stools proximal to the foreign body are hardly influenced. Here, an endoscopic irrigation with a pumping device may be of greater support.

If possible, a pre-interventional practical test of the suitability of the available instruments for the recovery of an object similar to the impacted foreign body may be very helpful. Depending on the properties of the foreign body, potential complications from this object and troubleshooting should be considered (e.g., open bottles that might be further immobilized by an applied suction, protection of the mucosa from sharp items).

As mentioned before, the author prefers the patient to be in the lithotomy position. The first step should always be a gentle dilatation of the sphincter, respecting the size of the object. Smaller objects with sharp edges may be extracted endoscopically after securing the anal canal by an anal dilatator or an overtube. In most cases, however, the objects are too big for a sole endoscopic removal. Here, the procedure should be divided into two phases. Firstly, the object has to be brought into the rectal ampulla by means of suitable instruments, positioning, or manual abdominal support during problem delivery. Thereafter, the extraction through the sphincter may be accomplished by digital guidance. In many cases, however, sole manual removal is easier. If an attempt to position a loop around the foreign body was successful, this might be used to hold the object in its current position before it slips away again. An early call for anesthesia and relaxation should be made if unsuccessful.

Following extraction, an endoscopic control to find or exclude complications is obligatory. If there are none, in-house surveillance following sedation or anesthesia is indicated.

Complications and Their Management

Protection of the mucosa in the case of sharp items and prophylaxis of sphincter lesions by preceding dilatation are prophylactic against potential complications. Mucosal lesions are usually self-limiting bleedings. If there is compromised coagulation or bleeding from swollen hemorrhoids, the usual hemostatic endoscopical techniques are applied. An anal tamponade may possibly be helpful.

In the very rare case of an iatrogenic rectal perforation, a direct closure by OTSC can be attempted. But even if this is successful, a surgeon should always be informed about the case, since further operative steps might become necessary in the days to come.

8.4 Summary

Despite the fact that endoscopic extraction of foreign bodies is a comparably frequent event, there are almost no generally accepted standards. The reasons are, on the one hand, the variability of the objects involved and, on the other hand, a lack of necessity for that due to the low complication rates.

In daily practice, the gravest uncertainty is on the urgency of an endoscopic intervention; a survey is given in Table 8.1. In cases of doubt, the author prefers an early endoscopic intervention. A spontaneous discharge may take weeks, during which time the patients (and in the case of kids, their parents) get the feeling of living underneath the sword of Damocles. By all means, avoiding iatrogenic complications is of top priority. By utilizing the means and techniques mentioned, these complications should be reliably prevented.

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Proctological Interventions

Rüdiger Prosst

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Proctology has an interdisciplinary character with surgical, dermatological, and venereal disease conditions. In the true sense of the word, it is a marginal field for endoscopy; normal coloscopic techniques are not helpful. Nevertheless, most anorectal diseases that will be presented in this chapter may well be diagnosed and also treated by means of meticulous inspection, rectal digital examination, and proctoscopy.

9.1 Hemorrhoids (AWMF Hämorrhoidalleiden; Riss et al. 2012)

General Aspects: Anatomy and Physiology

Anatomically, hemorrhoids are an arteriovenous vascular conglomerate, called corpus cavernosum recti. They are located cephalad to the anal canal. Their vascular supply originates from the end arteries of the A. rectalis superior which runs along the tunica submucosa. The venous drainage is accomplished via small veins which penetrate the internal anal sphincter muscle and form larger venous collecting vessels within the intersphincteric region.

Hemorrhoids are physiological cavernous bodies which are responsible for achieving the so-called fine continence: during the continent phase, the corpus cavernosum recti have a firm elastic consistency, since the drainage of the blood is inhibited by the contracted internal sphincter. During defecation, the venous efflux is facilitated by a relaxation of the sphincter muscle, thereby reversing continence. Following defecation, this reflexive relaxation of the internal sphincter is discontinued, the hemorrhoidal cushions are filled with blood again, and the tight hemorrhoidal occlusion is restored.

Pathogenesis, Classification, and Symptoms

The hemorrhoids are kept in place in the upper anal canal by a scaffold of muscular and fibroelastic bands. Once this suspensory apparatus is destroyed, a permanent and irreversible distal dislocation of the hemorrhoids ensues. An additional hyperplasia of the hemorrhoids results in a pathologic anatomy and function of the anal canal. The causes of these changes of a physiological hemorrhoidal apparatus into a pathological one are, for example, unphysiological defecation conditions through pressure of the bowel contents against the still-filled hemorrhoidal cushions, mimicking chronic obstipation or forced defecation.

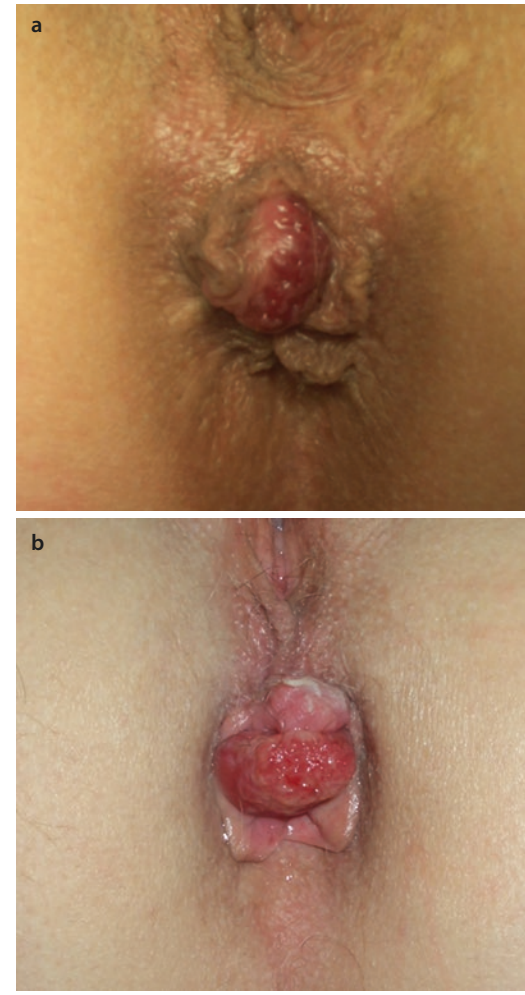


Fig. 9.1 **a**, **b** Segmental, third grade hemorrhoidal prolapse (digital reposition possible)

The staging of pathologically enlarged hemorrhoids follows the size and extent of distal dislocation, the so-called prolapse:

- First-stage hemorrhoids are filled yet elastic convolutes within the anal canal which do not prolapse through the canal even following provocation.
- Second-stage hemorrhoids prolapse during defecation to the exterior of the anal canal. Following defecation, however, they are automatically retracted into the canal.
- Third-stage hemorrhoids (Fig. 9.1) also prolapse through the anal canal during defecation. However, following defecation, they are not automatically retracted into the canal, requiring manual repositioning by the patient.

- Fourth-stage hemorrhoids are permanently dislocated through the anal canal; they are fixed in this position and scarred. This may coincide with an eversion of the distal anal canal (prolapse of anoderm or anal prolapse). Manual repositioning as in third-degree hemorrhoids is no longer possible.

The staging of hemorrhoids is carried out by thorough history taking and a meticulous proctological examination. In this case, proctoscopy is not a static diagnostic measure but a functional investigation.

Tip

Even if it might be unpleasant for the patient, only by pressing can the extent of prolapse and thus the correct staging be determined.

First-stage hemorrhoids are diagnosed exclusively by proctoscopy. Inspection or digital exploration alone is of no diagnostic value. Even coloscopy in inversion may not detect the correct stage, since the degree of prolapse remains obscured.

Based on permanent anatomical changes within the anal canal due to the enlarged and prolapsing hemorrhoidal vascular convolutes, a complex of symptoms ensues which is predominantly a consequence of a disturbed fine continence, the clinical hemorrhoidal complex. It is noteworthy that the symptoms caused by hemorrhoids may be very variable and may also be independent of the morphology of the hyperplastic hemorrhoids. A frequent symptom is hematochezia, which is a consequence of mechanical stress to the prolapsed mucosa during defecation. The visible, bright-red blood does not originate from the arteriovenous plexuses but from congested arterial mucosal vessels which run near the surface of the hemorrhoidal convolutes. The disturbance of fine continence produces wetting and stool soiling.

Tip

Soiling, once noticed, is often erroneously interpreted as sphincteric insufficiency.

As a result of temporary or permanent mucosal prolapse, a moist perianal milieu is produced, causing irritative–toxic anal eczema with pruritus. In addition, the prolapse causes a blunt pressing sensation similar to the impression of a foreign body in the anal area.

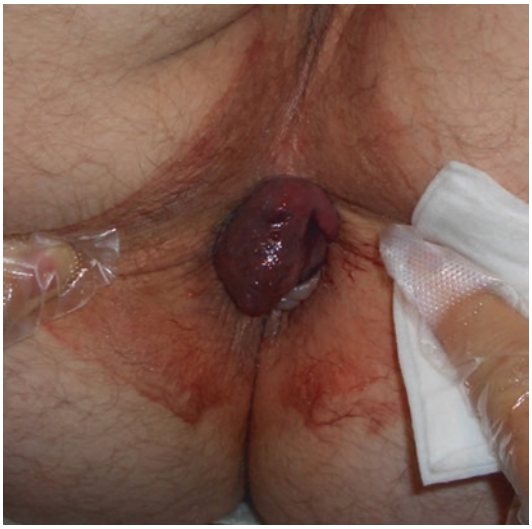


Fig. 9.2 Acutely thrombosed hemorrhoidal prolapse

Pains which are precisely localized are not characteristic for hyperplastic hemorrhoids. Exceptionally, they may be associated with a thrombosed hemorrhoidal convolute (Fig. 9.2).

Treatment

Hemorrhoidal disease is one of the most frequent proctological diseases and is often referred to as a civilization disease. It has been estimated that up to 40% of the population of an industrial nation suffer from enlarged hemorrhoidal plexuses. At least every sixth person is affected by symptoms and sequelae of hemorrhoidal disease.

The primary aim of treatment is a long-lasting or permanent resolution of hemorrhoidal symptoms by restoration of the original anatomical and physiological conditions, usually achieved by creating hemorrhoids of normal size.

Tip

The need for treatment of enlarged hemorrhoids is tightly linked to symptoms and the degree of suffering of the patient. In the case of asymptomatic enlarged hemorrhoids, treatment is not mandatory!

The treatment of hemorrhoidal disease is determined by the stage classification described before. Independently, some additional basic treatment is recommended. Its rationale is the regulation of bowel movements by fiber-rich diet, increase of stool volume, and teaching of physiological defecation. Furthermore, anal hygienic measures are of importance such as cleansing with normal tap water, avoidance of moist cleansing towels, and possibly the regular administration of skin-caring substances, for example, soft zinc paste.

The application of ointments/pastes and suppositories is no causative treatment, which means it has no influence on the hyperplastic hemorrhoidal convolutes. Topical substances may only influence and significantly reduce hemorrhoidal symptoms. A «restitutio ad integrum» may only be achieved by active medical intervention.

Tip

Hyperplastic hemorrhoidal convolutes are often misinterpreted as varices. There is, however, no plausible rationale for treatment with drugs that enhance the venous tonus, such as flavonoids which are useful for treating real varices.

The term «conservative hemorrhoidal therapies» comprises nonoperative procedures such as sclerosing therapy, rubber band ligation, and infrared therapy.

Conservative Treatment: Sclerosing Therapy

The sclerosing of hemorrhoids can be accomplished according to two different techniques, the method according to Blond and that according to Blanchard.

Indication Sclerosing therapy is the method of choice in first-stage hemorrhoids.

Personnel Requirements All conservative treatments may be, in principle, carried out by the treating doctor alone. For litigation reasons, however, it is advisable to have assisting personnel present.

Instrumental Requirements Generally, all proctological interventions may be carried out in lithotomy position, in side position, and in knee–elbow position. Most comfort to the patient is offered by a special examination and treatment chair which allows direct visual contact between the patient in lithotomy position and the treating doctor. Commercially available proctoscopes are the ones according to Morgan with an open front end and according to Blond with a lateral window. For the sclerosing procedure, a suitable sterile solution such as polidocanol is drawn into a 1-ml single-use syringe with a cannula (e.g., 20G/0.9 mm, 70 mm length). A suction device for removal of stool residues and an infrared coagulator (see below) for hemostasis may be helpful.

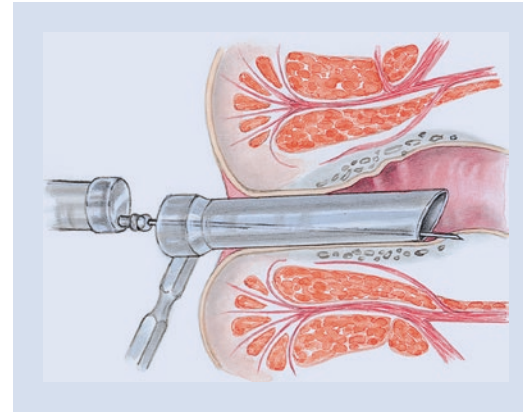


Fig. 9.3 Sclerosing therapy (From Lange et al. 2012)

Practical Execution With the Blond method, the sclerosing agent is submucosally directly injected into the hemorrhoidal tissue in a circular fashion. On the other hand, with the Blanchard method, the agent is injected next to the vessels in 3, 7, and 11 o'clock lithotomy position to reduce arterial inflow (Fig. 9.3). Treatment sessions should be repeated 3–5 times over several weeks.

Tip

Left out, because of no use for the English-speaking market!

Conservative Treatment: Rubber Band Ligation

Indication Rubber band ligation is the therapy of choice in the treatment of second-stage hemorrhoids.

Personnel Requirements As for sclerosing treatment

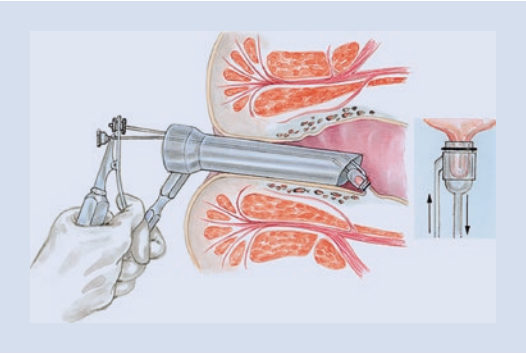


Fig. 9.4 Rubber band ligation (Barron procedure; from Lange et al. 2012)

Instrumental Requirements As in sclerosing treatment. Rubber band ligation requires a proctoscope with frontal opening and an applicator system for the rubber ring, either a rubber band suction applicator or a mechanical ligation instrument (e.g., according to Rudd or McGivney/Schütz) with a hemorrhoidal grasping clamp.

Practical Execution During rubber band ligation according to Barron (Fig. 9.4), by means of a special applicator, a rubber ring is placed around the base of a hemorrhoidal convolute through the proctoscope. In order to avoid a slippage of the rubber ring, an additional injection of a sclerosing agent into the occluded hemorrhoidal node may be done. The occlusion of the hemorrhoidal tissue results in a necrosis within a few days, with the result of a sequestration of the necrotic tissue during the following 1–3 weeks.

When applying the rubber band, it is of utmost importance to position it well above the dentate line in a pain-free area. If the patient expresses pain during or directly following application of the rubber band (ask!), the rubber band should be removed (use of fistula hook is helpful!) and placed a new some distance more orally from the previous position.

Clinically relevant hemorrhages due to sequestration of the necrotic tissue within 1–3 weeks are observed in less than 1% of cases. They may, however, become relevant in cases of anemia and then require an intervention, usually by stitch ligation of the bleeding spot.

Therefore, it is mandatory to inform the patient about the possibility of this rare complication and to supply emergency phone numbers and emergency addresses.

Tip

In patients with allergy to latex, special latex-free rubber bands should be used for the ligation.

For economic reasons, a simultaneous ligation of all enlarged hemorrhoidal convolutes might be desirable. However, this might be followed by an increase of potential complications such as bleeding, vasovagal syncope and disturbances of micturition and defecation.

Conservative Treatment: Infrared Therapy

Indication Infrared therapy is suitable for achieving hemostasis in first- and second-stage hemorrhoids.

Personnel Requirements As in sclerosing therapy

Instrumental Requirements As for sclerotherapy

Infrared therapy requires a proctoscope with frontal opening and an infrared coagulator (Fig. 9.5).

Practical Execution In infrared therapy, a pistol-shaped infrared coagulator with exchangeable protective cap is introduced via the proctoscope with a frontal opening. By direct contact of the coagulator tip with the bleeding site, by means of heat application, localized tissue necrosis with hemostatic properties is induced.

Tip

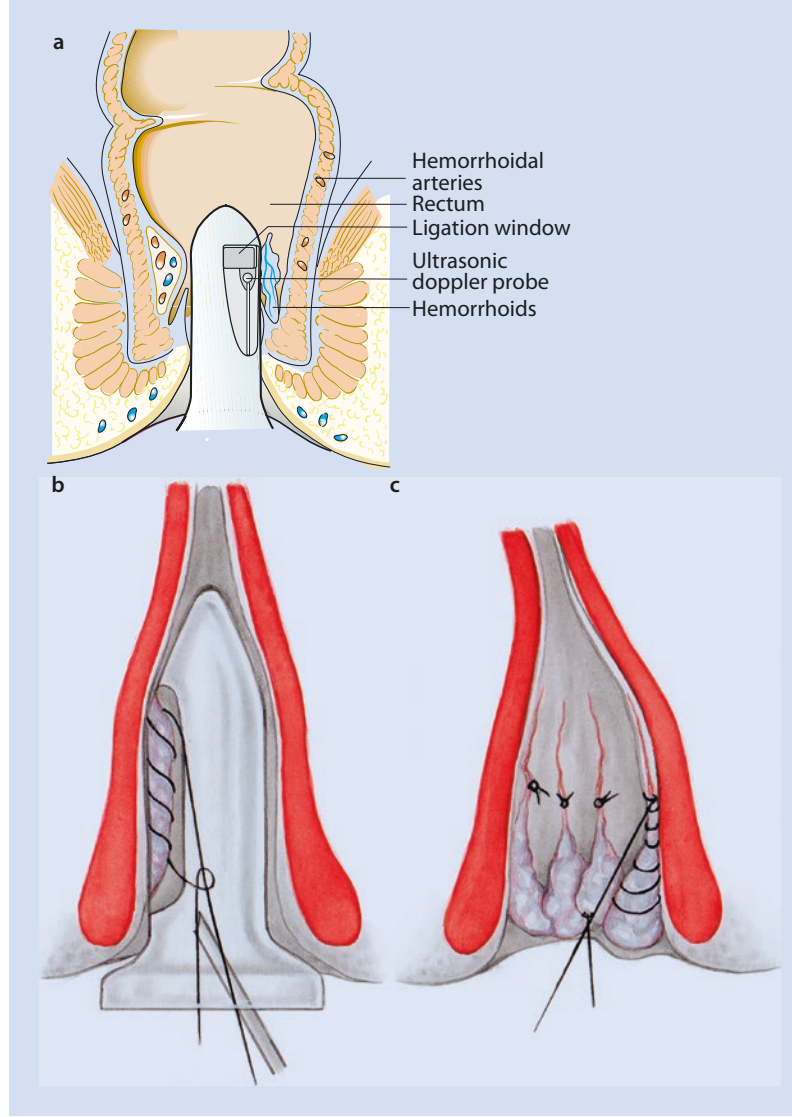
Infrared coagulation is also suitable for stopping bleedings arising from a stitch canal injury following sclerosing therapy.

Semi-operative Treatment: Doppler-Guided Hemorrhoidal Artery Ligation (HAL) with/without Recto-anal Repair (RAR)

In HAL (Fig. 9.6), second- and third-stage enlarged hemorrhoidal convolutes are treated in a semi-operative fashion, usually requiring brief anesthesia or analgo-sedation. Using a specifically designed proctoscope with a Doppler ultrasonic probe, the hemorrhoidal artery is localized and stitch ligated under sonographical control. Recently it has been advocated that HAL should

Fig. 9.5 **a**, **b** Infrared coagulator (**b** with permission from Lumatec)

Fig. 9.6 **a**–**c** Doppler-guided ligation of hemorrhoidal artery (HAL) (**b** and **c** from Lange et al. 2012). In the text: hemorrhoidal arteries, rectum, ligature window, ultrasound Doppler sensor, hemorrhoids



be combined with a recto-anal repair (RAR) where concomitantly the prolapsing hemorrhoidal convolutes are tied up.

The actual evidence concerning HAL with or without RAR is not solid enough yet as to recommend the strategy for a routine situation. HAL–RAR is to be looked at as an intermediate procedure between nonoperative and operative–resectional treatments, to be used, for example, as an option following unsuccessful rubber band ligation in second-stage hemorrhoids.

Operative Treatment

When third-stage hemorrhoids are diagnosed which do not retract spontaneously after defecation and therefore have to be repositioned manually, operative treatment is indicated.

The operative treatment is not an endoscopic procedure, but it appears to be essential to give an overview of the actual procedures, since endoscopic procedures might become necessary after the operation and knowledge about the differential indications in relation to conservative procedures is most relevant. For more details, textbooks for surgery should be consulted.

There are two different approaches for the operative procedures: anoderm-resecting and anoderm-preserving techniques.

Popular Operative Procedures

Anoderm-resecting procedures:

- Open hemorrhoidectomy according to Milligan–Morgan
- Closed hemorrhoidectomy according to Ferguson

Anoderm-preserving procedures:

- Submucous hemorrhoidectomy according to Parks
- Reconstructive hemorrhoidectomy according to Fansler–Arnold
- Supraanodermal hemorrhoidopexy (stapler) according to Longo

In the frequently applied open hemorrhoidectomy according to Milligan–Morgan (Fig. 9.7), the enlarged hemorrhoidal convolutes are excised together with the adjacent anoderm, leaving the closure of the defect to secondary wound healing.

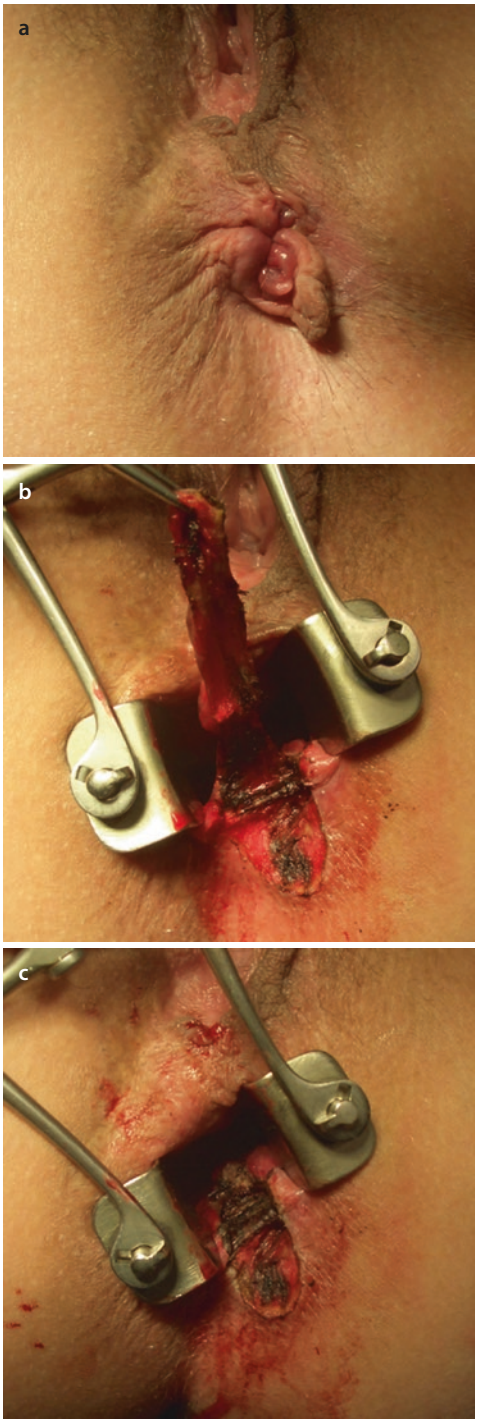


Fig. 9.7 Segmental hemorrhoidectomy (Milligan–Morgan operation). **a** Preoperative finding with segmental anal hemorrhoidal prolapse and mariscas at 5 o'clock lithotomy position. **b** Segmental resection of hypertrophic hemorrhoidal tissue preserving the adjacent M. sphincter ani internus. **c** Postoperative result

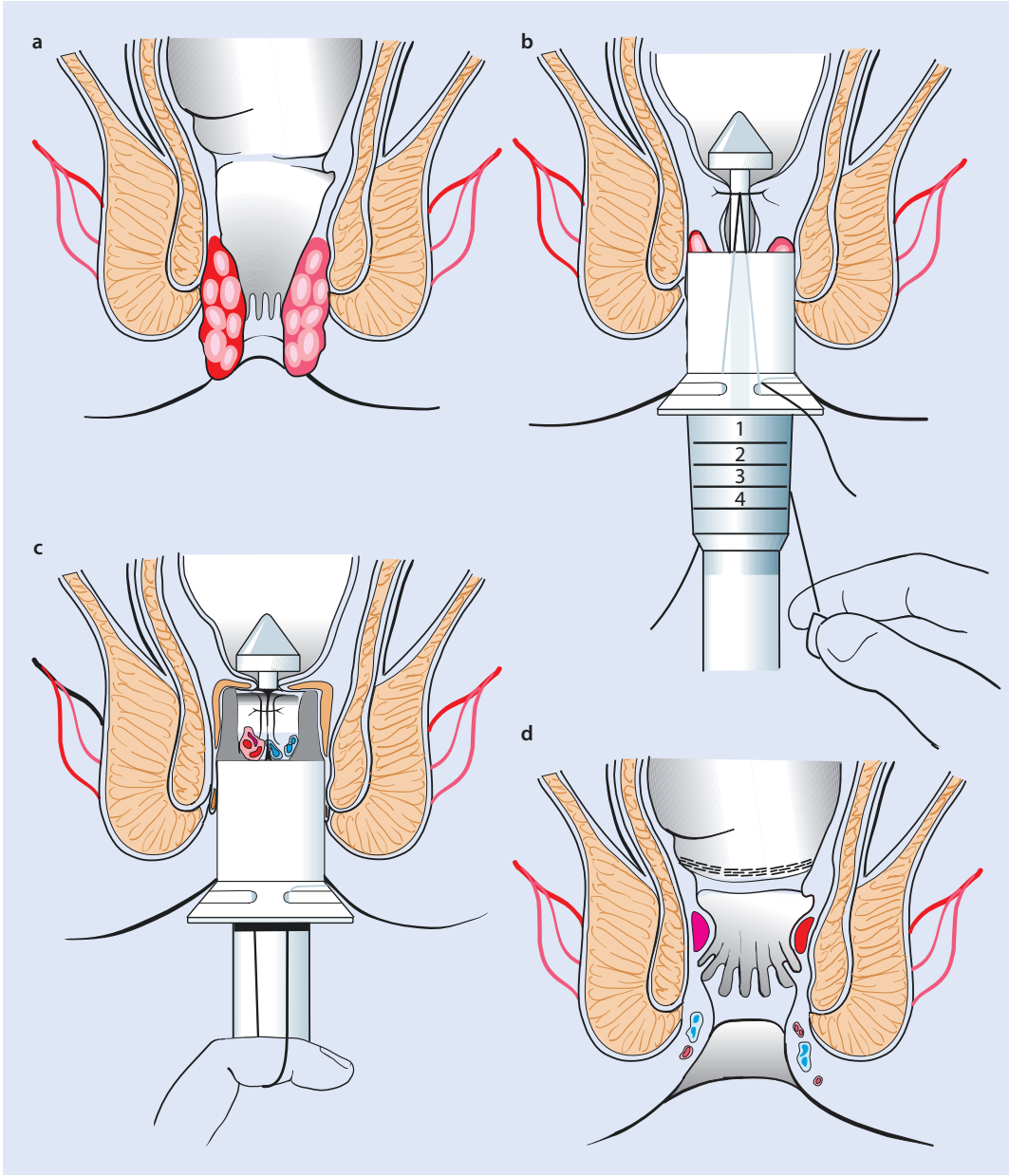


Fig. 9.8 Stapler hemorrhoidopexy (Longo operation)

The also frequently applied stapler hemorrhoidopexy according to Longo (Figs. 9.8, 9.9, and 9.10) combines the resection of the prolapsing hemorrhoidal convolutes with a lifting of the prolapsed hemorrhoids, avoiding injury to the pain-sensitive anoderm. The stapler procedure is therefore well suited for third-stage circular hemorrhoids which can be repositioned. This procedure is not indicated for fourth-stage fixed anal prolapse, however!

9.2 Anal Fistula (AWMF Kryptoglanduläre Analfisteln; Heitland 2012)

General Aspects: Pathogenesis and Symp toms

Anal fistulae (Fig. 9.11) usually originate from the anal cryptae in the area of the dentate line. Starting with a so-called «cryptoglandular» infec-

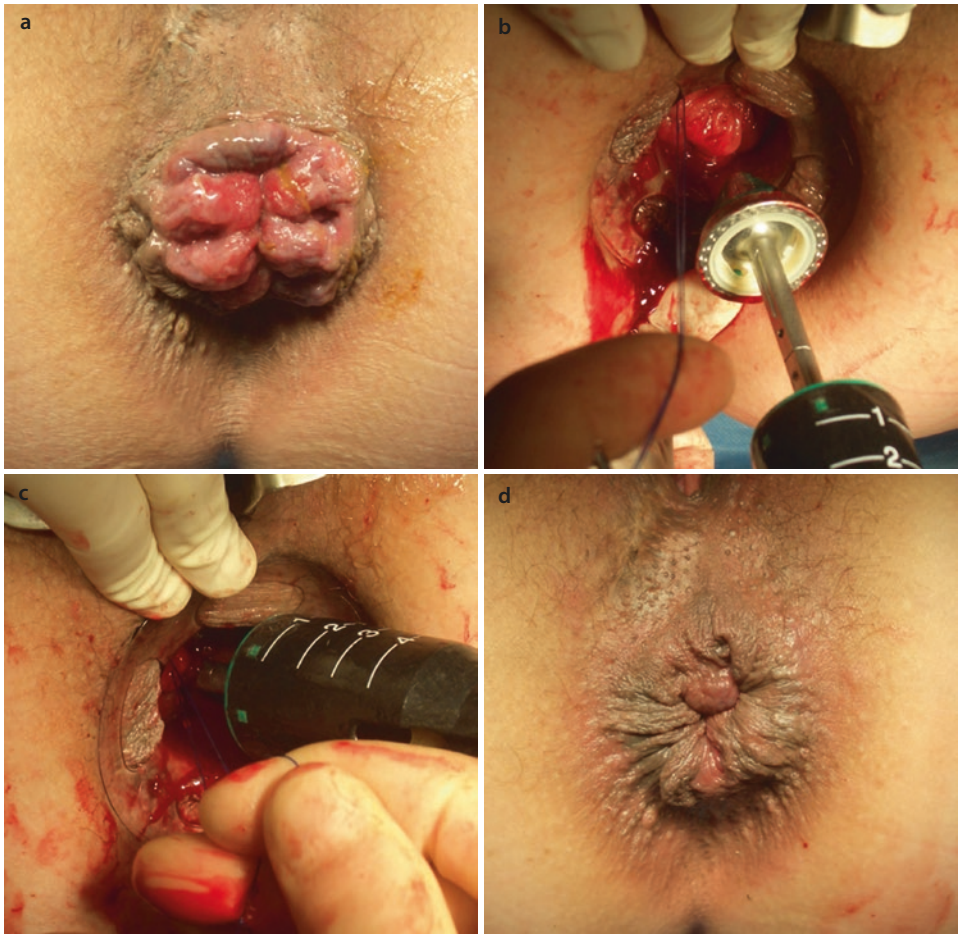


Fig. 9.9 Stapler hemorrhoidopexy (Longo operation). **a** Preoperative finding with circular anal hemorrhoidal prolapse. **b** Insertion of the opened stapler. **c** Before closure of the stapler and after tying the purse-string suture. **d** Postoperative result

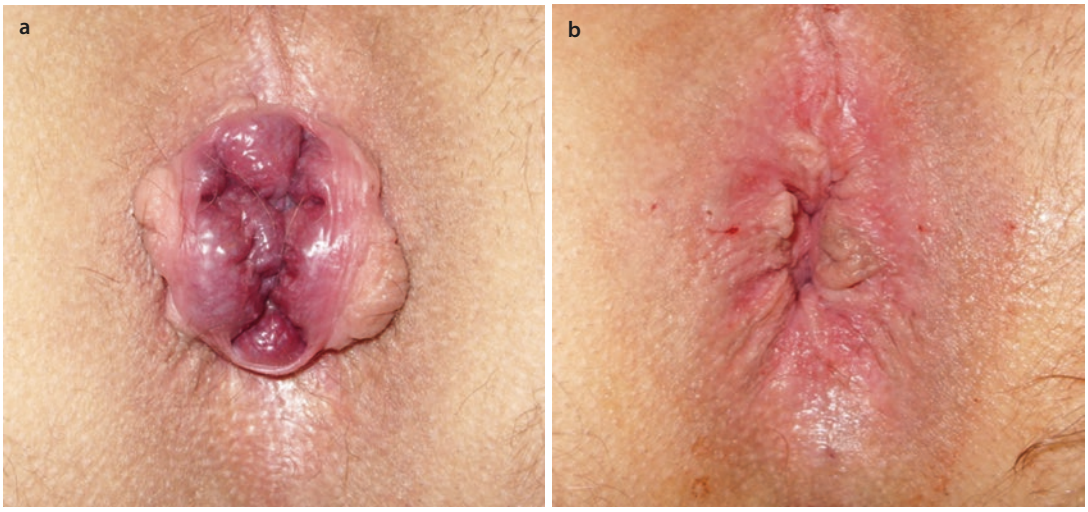


Fig. 9.10 Stapler hemorrhoidopexy (Longo operation). **a** Preoperative finding with circular prolapse. **b** Postoperative result

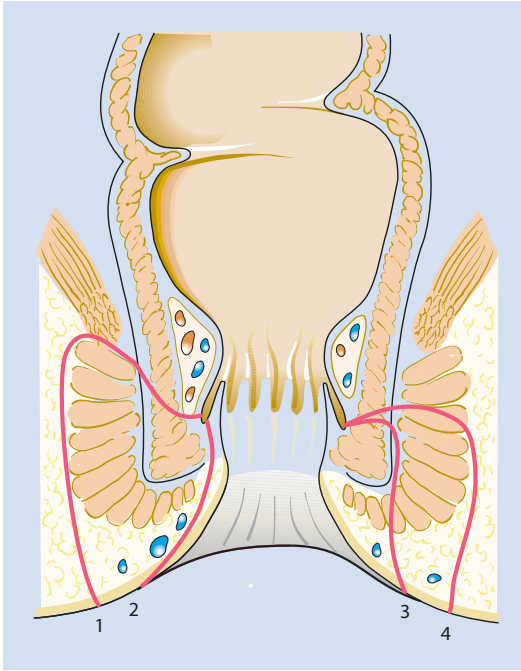


Fig. 9.11 Classification of anal fistulae: *1* suprasphincteric, *2* subanodermally, *3* intersphincteric, *4* transsphincteric

tion of the regional proctodeal glands, a primary abscess is established which normally shows an unapparent clinical course, resulting either in a spontaneous healing or a drainage into the anal canal. If, however, a propagation of the inflammation along regional structures and along the lowest resistance into different spaces is the consequence (submucosal, subanodermal, intersphincteric, transsphincteric, suprasphincteric), a secondary abscess ensues, causing the clinically apparent anal abscess. When this abscess spontaneously finds its way to the skin or neighboring structures, a fistula is constituted. Therefore, anal abscess and anal fistula, as far as etiology is concerned, are the same disease entity: the anal abscess is the acute and the anal fistula the chronic manifestation of the same underlying disorder.

Anal fistulae caused by Crohn's disease, trauma, or iatrogenic manipulation therefore very often have an atypical course and do not necessarily spread along the local anatomical structures.

While anal abscesses are acutely evident by intense pain with systemic signs of infection, the symptoms of perianal fistulae are determined by the changing inflammatory pattern of this chronic disease. Frequently, fistulae exhibit a varying mostly purulent secretion from perianal external openings (Fig. 9.12). As a consequence, anal hygienic problems with pruritus and anal eczema might follow.

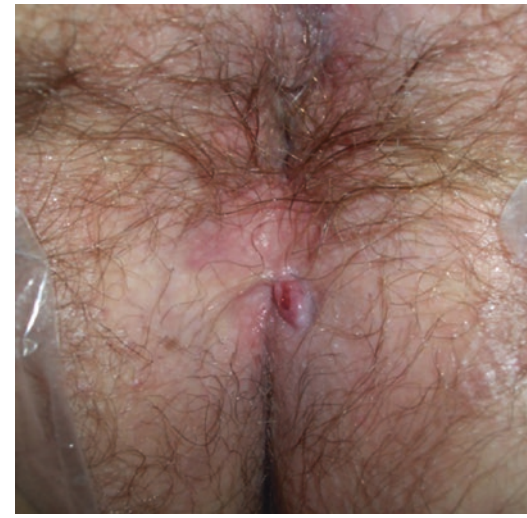


Fig. 9.12 External fistula opening at 6 o'clock lithotomy position about 3 cm away from the anocutaneous line

The external anal fistula ostium may temporarily be occluded by epithelial ingrowth. This should not be mistaken for a true spontaneous healing of the fistula: unfortunately, this will not occur!

Classification

- Anal fistulae are classified according to their relation to the sphincter:
- Submucosal/subanodermal/subcutaneous fistulae are located underneath the rectal mucosa, the anoderm, or the skin, respectively.
- Intersphincteric fistulae are located between internal and external sphincter.
- Transsphincteric fistulae penetrate both the internal and external sphincter; a further classification differentiates among high, intermediate, and low or distal position.
- Suprasphincteric fistulae usually ascend into the intersphincteric area, surround the external sphincter, penetrate the puborectal sling, and reach the perianal region via the fossa ischiorectalis.

The abovementioned anal fistula types are also called cryptoglandular fistulae because their internal fistula opening is located within the dentate line in the excretory channel of a proctodeal gland and appears to originate from a crypt. Roughly 85–95% of all anal fistulae run inter- and transsphincterically. A separate evaluation concerns the extrasphincteric fistulae, which may not be described by the abovementioned scheme. Here, the internal fistula

ostium is not located in the area of the dentate line but rather, for example, in the lower rectum. The fistula channel then penetrates the anal levator before reaching the perianal region.

Without adequate treatment, i.e., surgical intervention, an extension of the fistular disease with abscess formation and impaired sphincter function has to be expected.

Treatment

The treatment of anal fistulae usually means an operation. The rationale of all therapeutic efforts is either the healing or the closure of the fistula without additional impairment of continence. This means that the choice of the surgical procedure depends on the path of the fistula in relation to the sphincter apparatus.

In anal fistulae which do not affect vital proportions of the sphincter, such as submucosal, subanodermal, subcutaneous intersphincteric or distal transsphincteric fistulae, the fistulotomy (deroofing) does not endanger the sphincter function and is therefore, without dispute, the standard treatment of choice. The fistula roof is divided and the edges, containing the skin, mucosa, and subcutaneous tissue and maybe parts of the sphincter muscle, are reduced. A perianal enlargement of the wound into the so-called drainage triangle guarantees constant evacuation of secretions until the wound has completely healed.

In high transsphincteric, suprasphincteric, or extrasphincteric fistulae, a fistulotomy or fistulectomy is not possible, since this would invariably result in clinically relevant sphincter destruction with concomitant incontinence. Here, the temporary placement of a non-cutting seton, either a nonabsorbable thread or a rubber/silicone loop, into the fistula path has proven to be very effective in order to guarantee patency of the fistula, avoid retention of secretions, and achieve inflammation-free local tissue conditions. Only after this initial therapy, more sophisticated operative steps may take place to definitively close the fistula:

- The advancement flap is a plastic closure where, after debridement of the fistula path and suture of the internal opening, a u-shaped flap of mucosa/submucosa or even rectal wall is advanced to solidly cover this area from the inside.
- Another procedure is fistulectomy with primary sphincter reconstruction, where after division of the fistula roof and debridement or excision of the fistula, the sphincteric muscle edges are sewn together again.

Both procedures have a healing rate of about 70–80%, but there is a considerable risk of postoperative incontinence.

More recently, some minimally invasive, sphincter-preserving procedures have been developed over the last couple of years. Their purpose is occlusion of the fistula path (fistula plug, Fig. 9.13) and thermic destruction (FiLaC: laser; VAAFT: HF electrocoagulation), the interruption of the fistula path in the intersphincteric area (LIFT = Ligation of the Intersphincteric Fistula Tract), and the dynamic occlusion of the internal fistula opening by means of an elastic metal clip (OTSC proctology, Fig. 9.14).

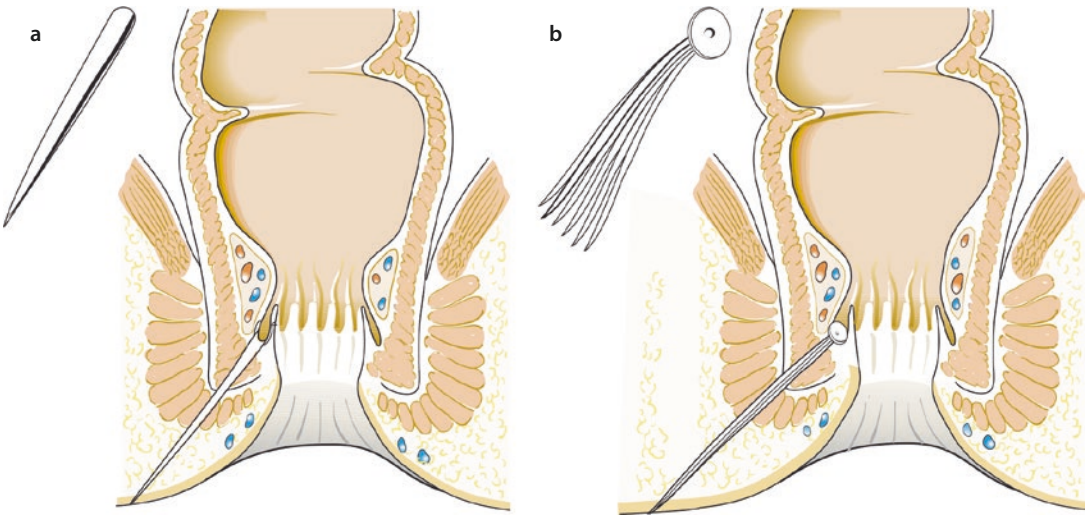


Fig. 9.13 **a**, **b** Fistula plugs

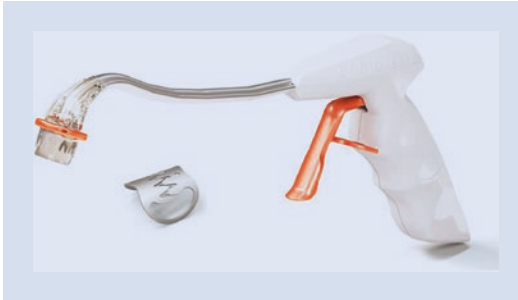


Fig. 9.14 OTSC proctology (By permission from Ovesco Endoscopy AG, Tübingen)

Indication For the endoscopist, aside from his diagnostic task, only limited therapeutic options are preserved. As a maximum, these are the deroofing of superficial fistulae under local anesthesia and/or the introduction of setons to avoid abscess formation and allow for reliable drainage.

Personnel Requirements Next to the acting doctor, the presence of one assistant is useful to manage the needed instruments, thereby reducing therapeutic time to a minimum.

Instrumental Requirements Apart from the usual proctoscopic tools, the following are to be prepared:

- Local anesthesia
- Fistula probe or hook
- Sharp curettage spoon
- Nonabsorbable woven thread (e.g., polyester or silk) or rubber/silicone seton (vessel loop)
- HF needle electrode and HF generator
- Dressing material

Practical Procedure If it is clear that the fistula runs superficially over a short distance (e.g., subanodermal, subcutaneous, or intersphincteric; Figs. 9.15 and 9.16) and thus may be divided, the first step is

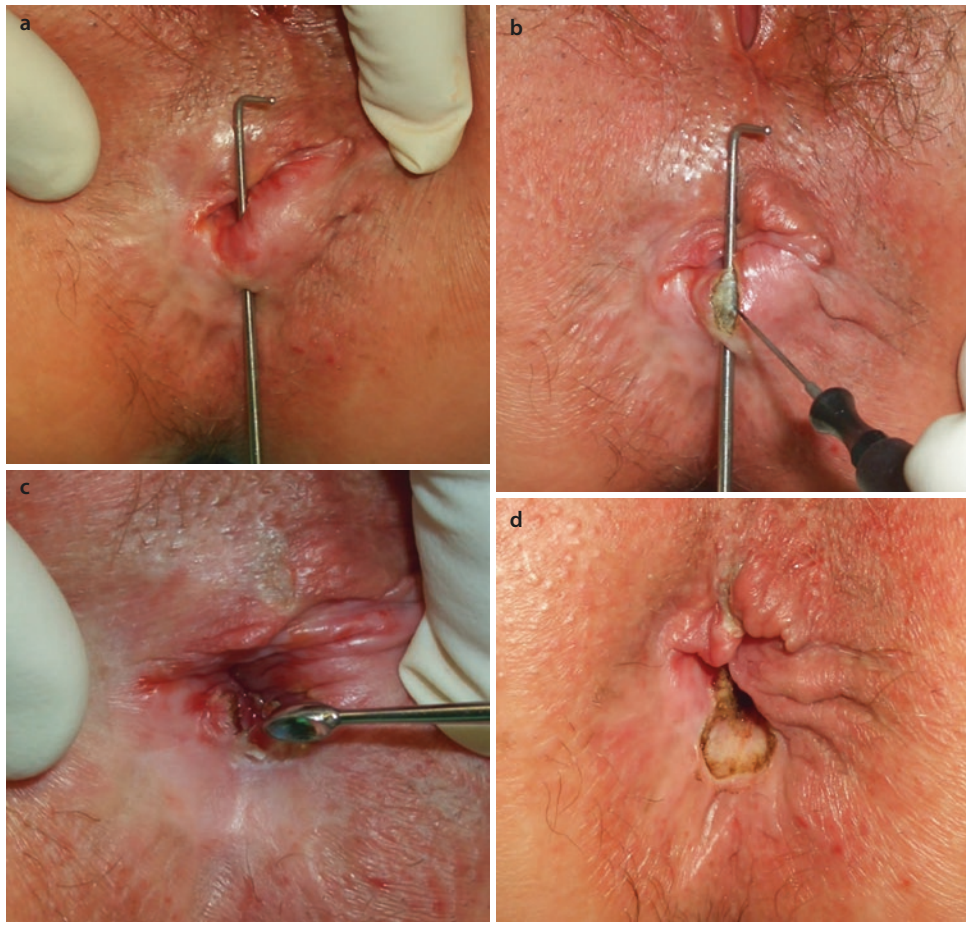


Fig. 9.15 Fistulotomy of a subcutaneous anal fistula in scar tissue: **a** preoperative situation with external opening at 6 o'clock lithotomy position, **b** fistulotomy by deroofing the fistula with the HF electrode, **c** debridement of the posterior fistula wall with a sharp spoon, and d postoperative result with external wound opening

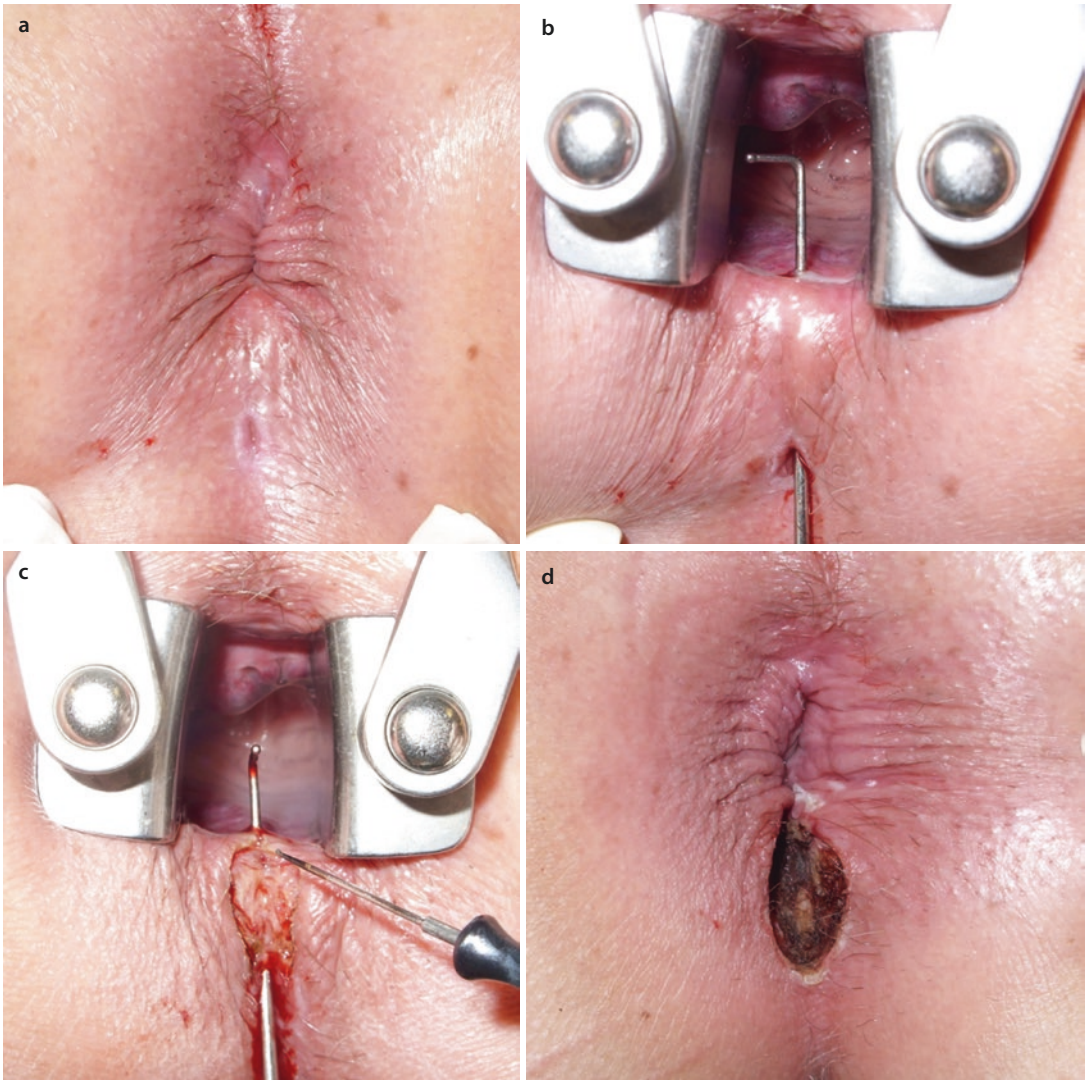


Fig. 9.16 Fistulotomy of a distal transsphincteric anal fistula (general anesthesia!). **a** Preoperative situation with external opening at 6 o'clock lithotomy position. **b** Retrograde probing with fistula hook. **c** Fistulotomy by deroofing with HF needle electrode. **d** Postoperative result with external wound opening

the infiltration anesthesia of the surrounding tissue including the highly sensitive anoderm. By retrograde probing, the fistula is intubated via the external opening. The fistulotomy is then carried out by means of HF electrode, followed by debridement of the posterior fistula wall. After reduction of the wound edges, the distal wound portion is enlarged to form an external drainage wound, in order to maintain an excellent drainage of wound secretions.

If inadvertently the probing of the fistula should show a more complex course resulting in a contraindication to the planned division, a non-cutting seton (thread, rubber/silicone drain; Fig. 9.17) should be introduced into the fistula. To achieve that, after clear identification of the internal opening, the nonabsorbable seton is tied to the tip of the probe and then pulled antegradely through the whole fistula. Either this thread is then tied to itself to create a closed loop, or it is used for the pull-through of a rubber/silicone seton or vessel loop which is tied as well.

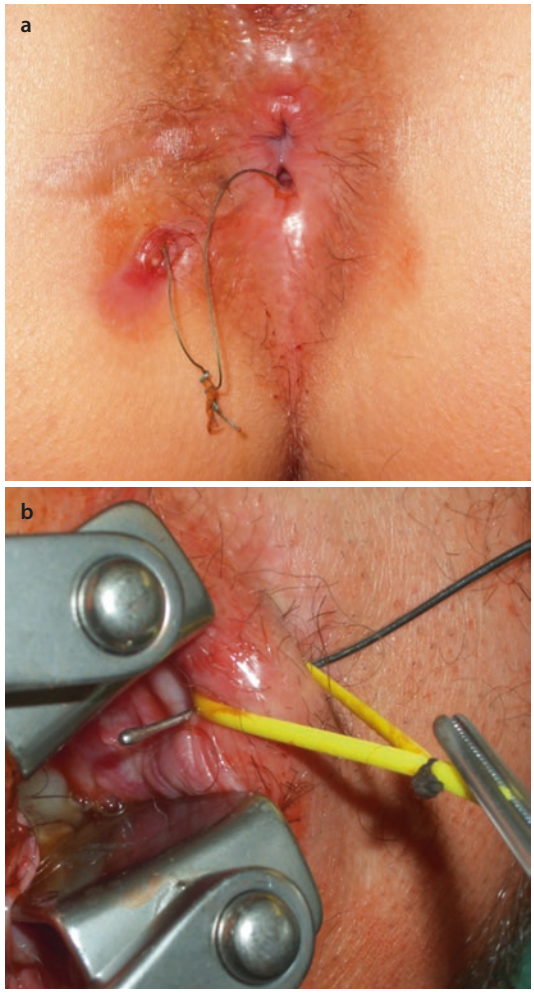


Fig. 9.17 Drainage and marking of an anal fistula **a** by a nonabsorbable suture and **b** by a silicone vessel loop

Tip

For better anal hygiene, a rubber/silicone loop for fistula drainage should be chosen rather than a woven, non-resorbable thread, even if the latter one is thinner. The rubber/silicone seton, however, should not be tied to itself because of the size of the resulting node, which might irritate the anal region. Just recently, silicone loops have been introduced that have a plug-in mechanism with no need for nodes.

9.3 Anal Polyps

Anal polyps typically are benign tumors of the anal channel which don't follow the adenoma/carcinoma sequence as rectal tumors do. Most anal polyps are hypertrophic anal papillae which originate from the dental line. They can occur singly or in multiples. Their shape is pedunculated (Fig. 9.18) or broad based (Fig. 9.19), and they can prolapse out of the anal channel due to steady growth (Fig. 9.20). Quite often they are misinterpreted as hemorrhoids (Fig. 9.21), particularly because the mechanical irritation can cause bleeding and faults of continence. Probably inflammatory lesions which cause proliferative

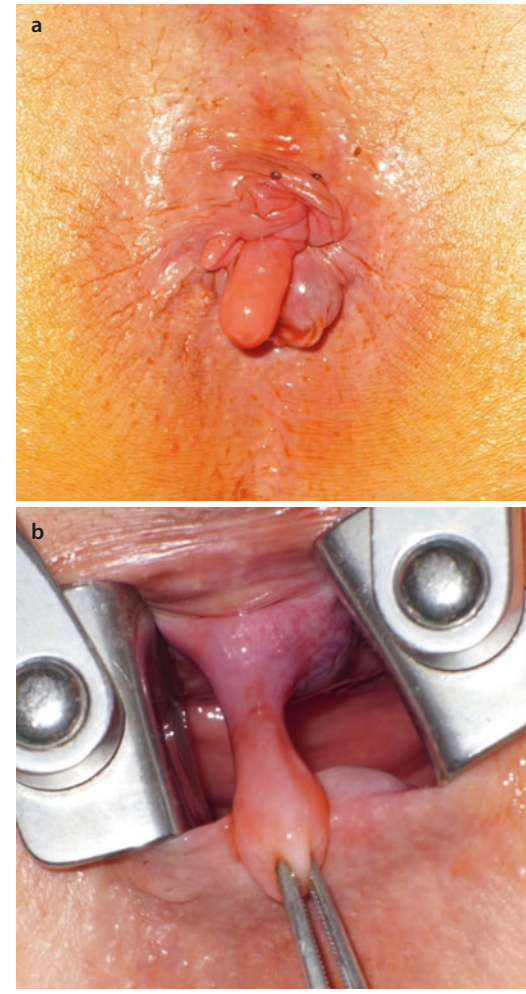


Fig. 9.18 **a**, **b** Longitudinal pedunculated anal polyp/hypertrophic anal papilla with prolapse

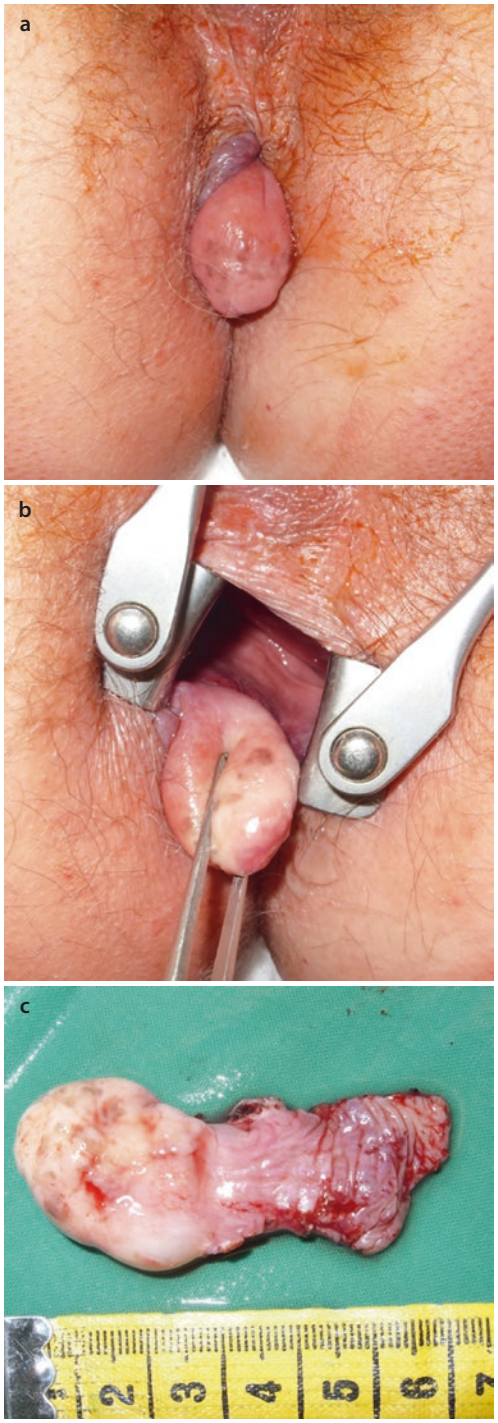


Fig. 9.19 **a–c** Large and wide prolapsed anal polyp

fibrosis of the anal papillae are the background to the development of anal polyps. A hypertrophic anal papilla can persist as a residuum of a chronic anal fissure.

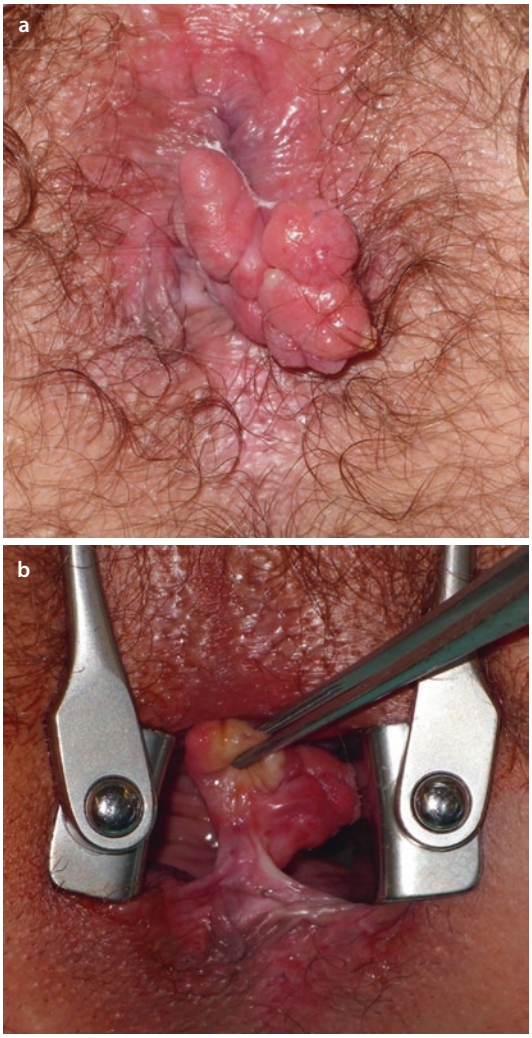


Fig. 9.20 **a, b** Prolapsed anal polyp with irregular polypoid surface structure

Indication The removal of a hypertrophic anal papilla may be indicated in cases with distinct prolapse with impairment of continence or with recurrent bleedings.

Personnel Requirements In addition to the acting physician, an assistant is recommended to provide the instruments. This is helpful in minimizing the intervention time.

Instrumental Requirements In addition to the usual proctological instruments (forward-looking proctoscope), the following are necessary:

- Local anesthetics
- High-frequency needle-knife or HF snare and HF generator

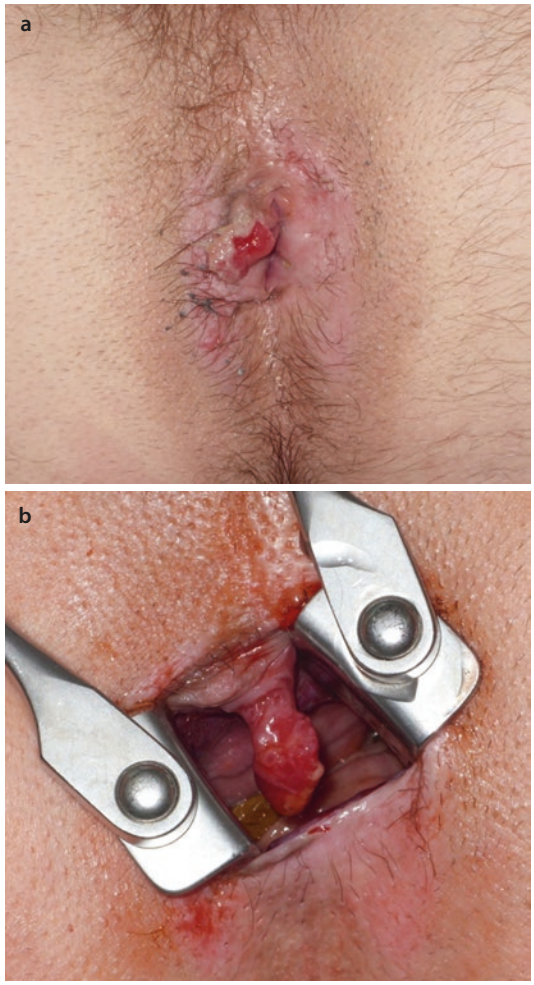


Fig. 9.21 **a**, **b** Vulnerable anal polyp with chronic inflammatory alteration of the surface (may be misinterpreted as bleeding prolapsed hemorrhoidal node)

Practical Course The anal polyp is exposed with the straight open proctoscope. After local anesthesia, the polyp will be cut close to its basis with the HF knife or the HF snare.

Tip

Removed polyps should be examined by histopathology to rule out anal intraepithelial neoplasias (AIN) or carcinoma.

9.4 Mariscas

Mariscas are frequently found skin flaps at the edge of the anus which can be solitary and multiple or even completely surrounding the orifice.

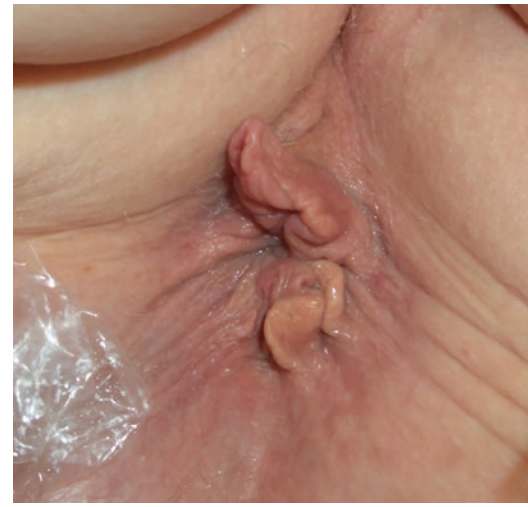


Fig. 9.22 Idiopathic mariscas

They are of varying size and, according to possible inflammatory characteristics, may be soft and lobulated, hard or edematous, and swollen.

Aside from idiopathic mariscas (Fig. 9.22) which are a hyperplasia of the skin of the anodermal area, they may be secondary to healed perianal venous thrombosis (Fig. 9.23; see ▶ Sect. 9.5) or be found in chronic anal fissures (in this case, they are called «sentinel piles» or «sentinel folds»; see ▶ Sect. 9.7).

Indication Mariscas may be removed if cleaning of the anus becomes difficult presenting an anal hygienic problem.

Personnel Requirements In addition to the acting doctor, the presence of one assistant is useful to pass the necessary instruments in order to reduce the required treatment time to a minimum.

Instrumental Requirements Instrumental requirements are:

- Local anesthetic
- Forceps
- Scissors or HF needle electrode with HF generator
- Dressing material

Practical Procedure After application of local anesthesia, the mariscas are either cut away by the HF needle or the scissors at the level of the surrounding perianal skin. The wounds, following hemostasis, should be left open for secondary healing.

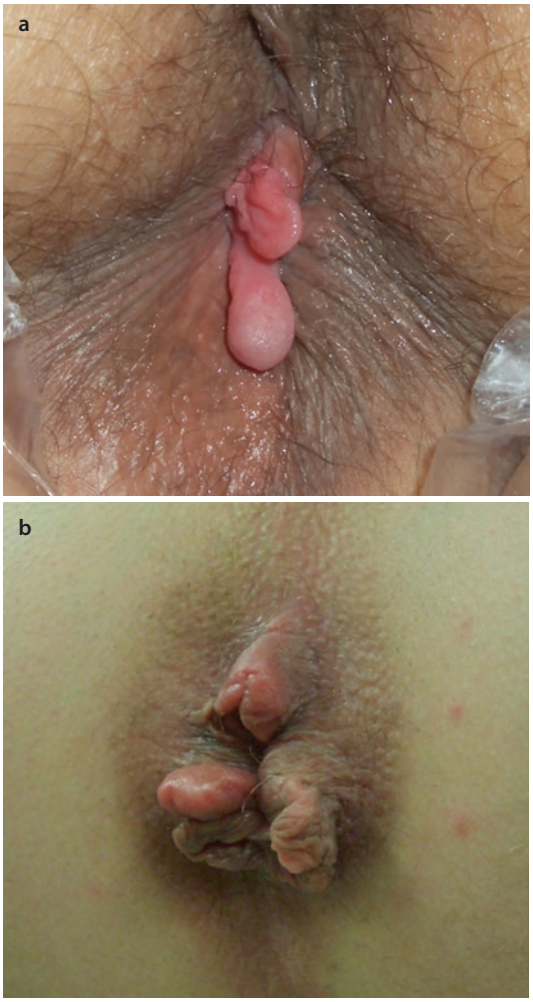


Fig. 9.23 **a, b** Mariscas as secondary alterations in chronic anal fissure (hypertrophic anal papilla)

Tip

In multiple or completely circular mariscas, a short general anesthesia means great comfort to the patient. The circular procedure is, however, prone to form a scar with stenosis. Therefore, multiple metachronous procedures rather than one single operation are recommended. Perhaps plastic surgical interventions may become necessary.

9.5 Perianal Venous Thrombosis

Perianal venous thrombosis is a local, intravasal thrombosis in veins running subcutaneously and subanodermally at the edge of the anus. Erroneously, these thromboses are often referred to as external hemorrhoids. This is incorrect since true hemorrhoids are made of an arteriovenous vascular conglomerate, the corpus cavernosum recti, whereas the perianal venous thrombosis is located inside true veins.

The reason for a perianal venous thrombosis, following Virchow's triad (stasis, endothelial alterations, hypercoagulability of the blood), are hemodynamic factors, for example, excessive pressure during defecation both in constipation and diarrhea. An additional contributing factor is increased pressure at the pelvic floor, which may occur during physical strain, exercise, long-lasting sitting during journeys, and during pregnancy or childbirth.

Perianal venous thromboses become evident as a sudden nodular and very painful swelling at the edge of the anus.

Morphologically, they show a blueish, pale, thrombotic color (Fig. 9.24). Their size might vary from a few millimeters to several centimeters. In their extreme form, by dislocation of the anoderm due to edema, they might present as a partly thrombosed anal prolapse (Fig. 9.25).

Tip

The differential diagnosis between perianal venous thrombosis and thrombosed hemorrhoid is made by palpation or by proctoscopy: in perianal venous thrombosis, the anal canal appears normal, whereas in a thrombosed hemorrhoid, the thrombosis has an extension along the complete anal canal starting internally and reaching distally.

Therapy of perianal venous thrombosis depends on the subjective pattern of patient's complaints. As long as the pain is tolerable, a conservative approach using topical anesthetic ointments, e.g., lidocaine ointment, and systemic analgesic drugs is justified. Within a few days, the lasting pain produced by excessive elongation of the anoderm will gradually subside. The thrombosis is dissolved within days or a few weeks by organization, resorption, and recanalization. In rare cases, the thrombosis may cause a pressure-induced necrosis, with subsequent spontaneous discharge of thrombotic material.

Indication If the pain is unbearable and the time for spontaneous dissolution of the thrombosis is expected to be too long, an operative intervention may be considered. The sole incision of the

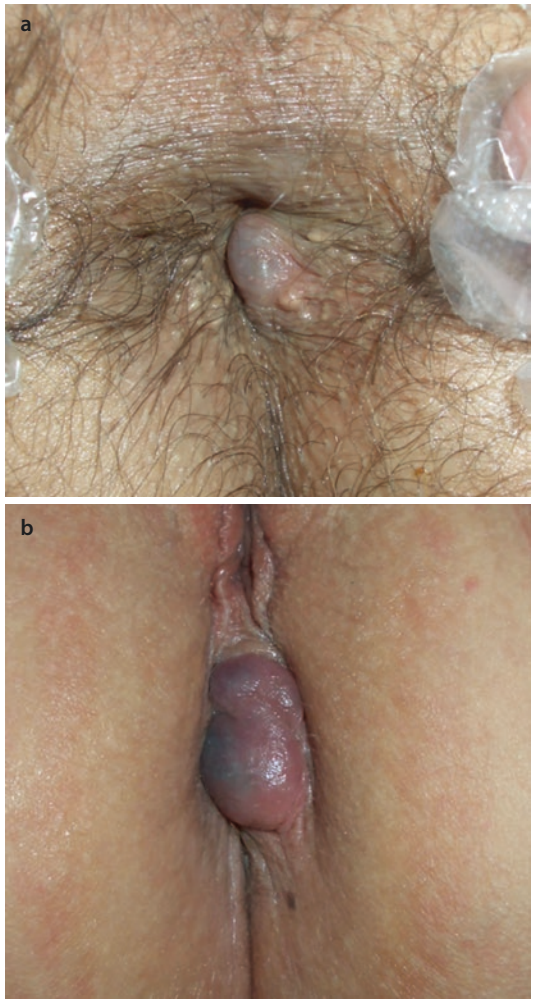


Fig. 9.24 **a**, **b** Perianal venous thrombosis

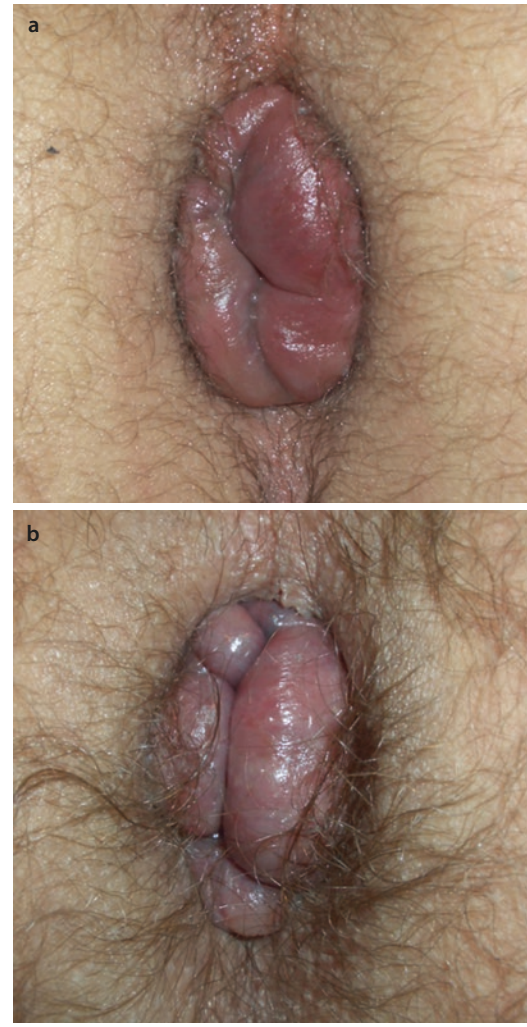


Fig. 9.25 **a**, **b** Anal prolapse with partial thrombosis

thrombosis with expression of the thrombus has a high recurrence rate and is therefore advised against. The adequate therapy is a wide deroofing of the thrombosed veins or the complete excision of the thrombosed vein.

Personnel Requirements In addition to the acting doctor, the presence of one assistant is useful to pass the necessary instruments, in order to reduce the required treatment time to a minimum.

Instrumental Requirements Instrumental requirements are:

- Local anesthetic
- Forceps
- Scissors or HF needle electrode with HF generator
- Dressing material

Practical Procedure Following local anesthesia of the base of the perianal venous thrombosis, a wide deroofing of the thrombosed vessel or a complete excision of the thrombosed vein is carried out, using scissors, scalpel, or HF needle electrode. Following hemostasis, the wound remains open for secondary wound healing.

9.6 Anal Neoplasias

9.6.1 Condylomata Acuminata (AWMF Anale Feigwarzen)

Condylomata acuminata are anogenital warts induced by human papilloma virus (HPV). They may occur peri- as well as intra-anally. (Fig. 9.26). The appearance and size vary greatly:

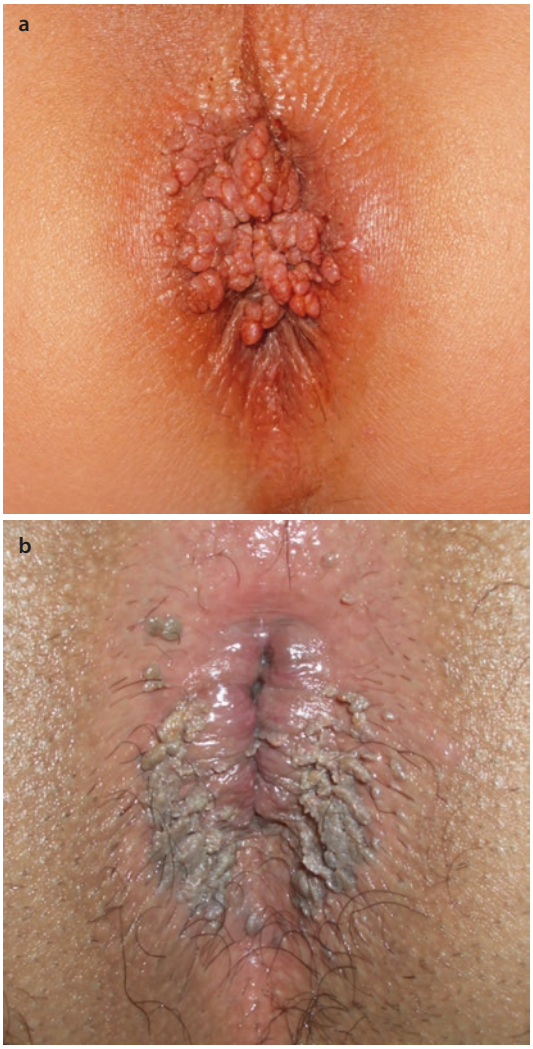


Fig. 9.26 **a**, **b** Multiple circular perianal condylomata acuminata

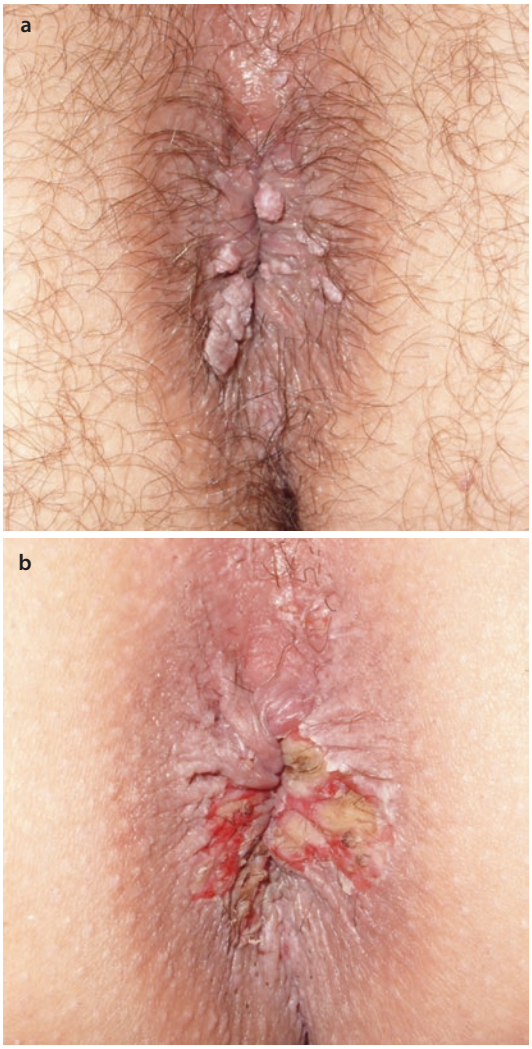


Fig. 9.27 Perianal condylomata acuminate, **a** before and **b** after excision using wet-field technique

from pinhead size and solitary up to multiple confluent circular and cauliflower-shaped large exophytic tumors, which at times may show special forms such as locally destructive Buschke–Loewenstein tumors or even anal carcinomas.

They are most often regarded as sexually transmitted disease by way of HPV types 6, 11, and 18, sometimes also caused by smear infection.

Partners of patients with condylomata acuminata should be screened proctologically, gynecologically, and urologically as well. In addition, immune-compromising diseases such as HIV or other veneric diseases must be excluded.

There is a spontaneous healing rate of about 30%. Small perianal condylomata may be treated topically, e.g., by podophyllotoxin or imiquimod cream.

Indication Larger, multiple, and intra-anal condylomata are operatively destroyed. Depending on the area involved, this may happen under either local or short-lasting general anesthesia. Since condylomata grow strictly intraepithelially, the treatment of choice is usually superficial heat destruction, e.g., by HF electrocoagulation. By a continuous water or gel application (wet-field technique, Fig. 9.27), a deeper thermal injury of the skin may be avoided (also known as wet-shaving technique). Due to their malignant character, more extensively growing

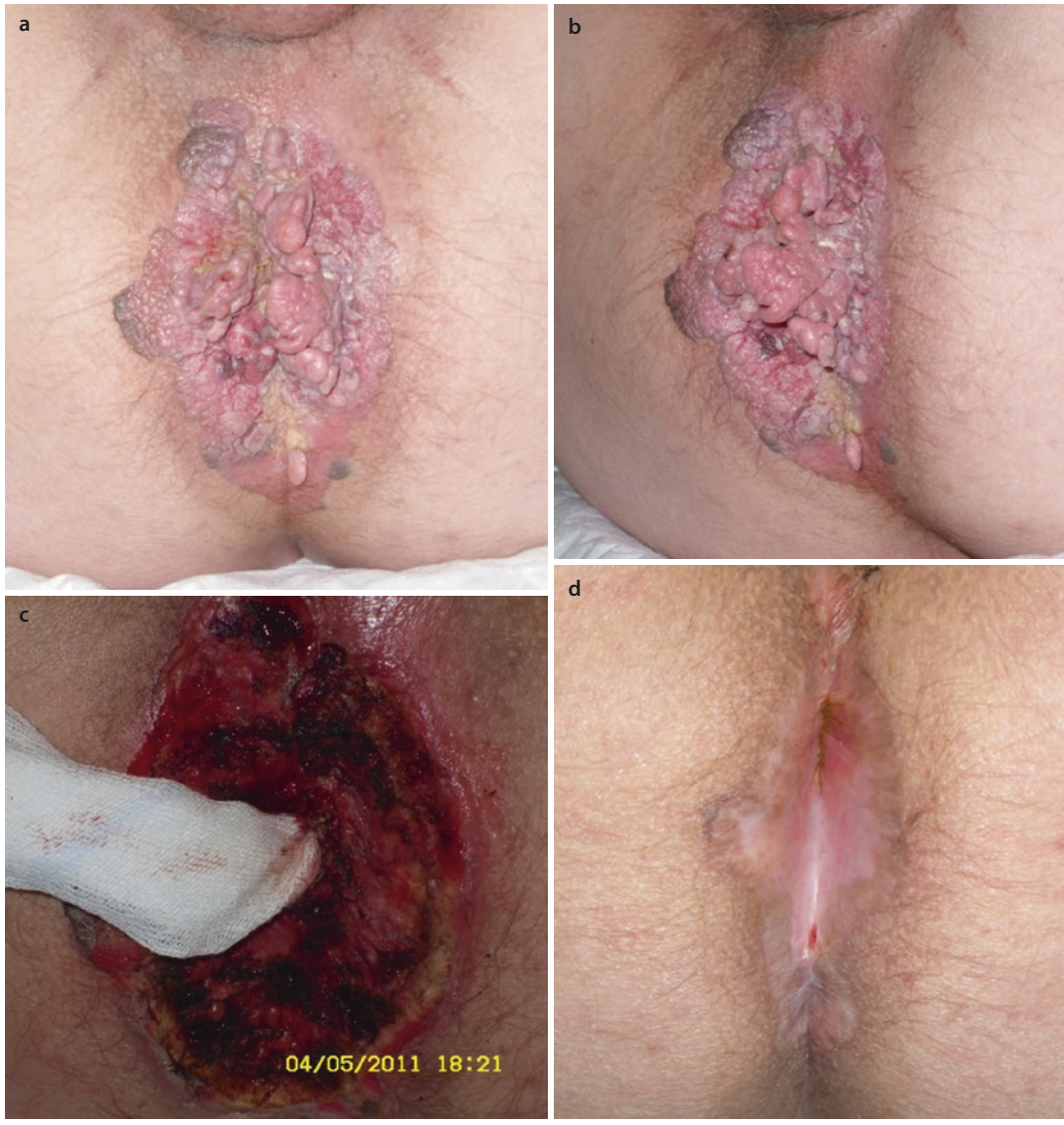


Fig. 9.28 Buschke–Loewenstein tumor. **a**, **b** Preoperatively. **c** Following radical excision (intra-anal compress). **d** After completed secondary healing

condylomata such as Buschke–Loewenstein tumors have a malignant potential and have therefore to be radically resected (Fig. 9.28).

Personnel Requirements In addition to the acting doctor, the presence of one assistant is useful to pass the necessary instruments, in order to reduce the required treatment time to a minimum.

Instrumental Requirements Instrumental requirements are:

- Local anesthetic
- Forceps and scissors
- HF loop or HF ball tip or bipolar forceps with HF generator
- Gel or saline or water
- Dressing material

Practical Execution Following local anesthesia and removal of some condylomata for histology and determination of the HPV type, the superficial thermo-destruction is carried out, while the area is constantly cooled by applying liquid or gel. Finally, the operative field is visually and haptically controlled for complete removal of all condylomata.

During thermo-destruction of condylomata, the vaporization process liberates viral particles into the room air. Therefore, a protection mask for the nose and mouth and protective goggles are required.

9.6.2 Anal Carcinoma (AWMF Anale Dysplasien und Analkarzinom bei HIV-Infizierten)

The anal carcinoma is a rare malignant epithelial tumor entity, in which two forms, the carcinoma of the anal edge (Fig. 9.29) and of the anal canal (Figs. 9.30 and 9.31), are differentiated.

Relevant risk factors for its development are HPV infection, immune deficit (HIV, posttransplant status), irradiation, or a chronic inflammatory bowel disease. Only very rarely do anal carcinomas originate de novo; most will develop from an anal intraepithelial neoplasia (AIN), e.g., condylomata, Bowen's disease, or Bowenoid papulosis. In addition, other premalignant anal diseases such as extramammary Paget's disease, basalioma, cutaneous T-cell lymphoma, and lichen sclerosus et atrophicus may be regarded as precursors.

The clinical sign is a hard or verrucous or exulcerating tumor with itching sensation, which may become symptomatic with wetting, pain, or bleeding.

Treatment of anal carcinomas is different between the carcinomas of the anal edge and of the anal canal: in tumor stages T1 and T2 and G1 or G2 of carcinomas of the anal edge, a primary surgical excision with adequate safety margin may be sufficient. Tumors of the anal edge that are more advanced or are in close relation to the sphincter apparatus are usually treated like tumors of the anal canal (except for Tis and some T1 tumors) by a combined radio-chemotherapy normally using 5-fluorouracil (5-FU) and mitomycin C.

Indication The task of the endoscopic or proctologic doctor in the case of anal carcinoma is restricted to taking biopsies to secure the histological diagnosis.

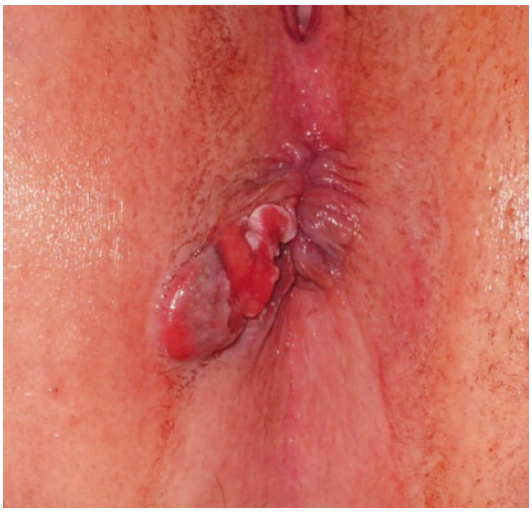


Fig. 9.29 Anal carcinoma

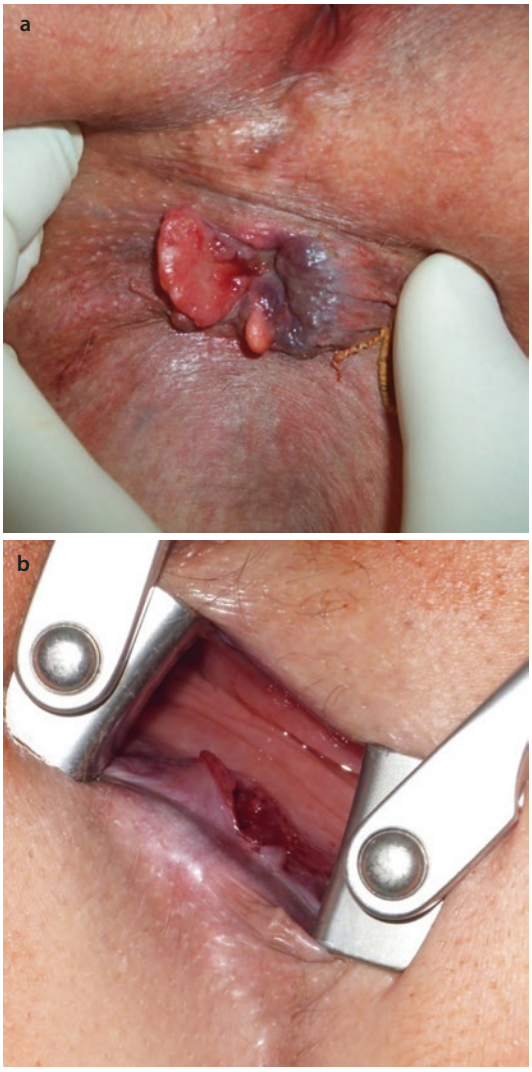


Fig. 9.30 **a**, **b** Anal carcinomas, originally misinterpreted as anal fissure

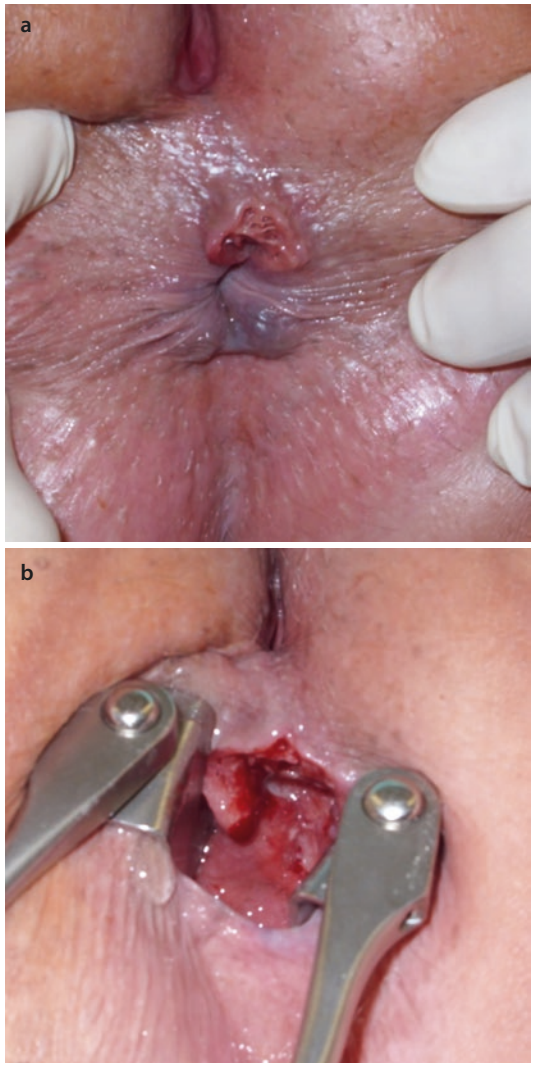


Fig. 9.31 **a, b** Rectal carcinoma with infiltration of anal canal and anal edge (adenocarcinoma, anal carcinoma usually are squamous cell carcinoma)

Personnel Requirements In addition to the acting doctor, the presence of one assistant is useful to pass the necessary instruments, in order to reduce the required treatment time to a minimum.

Instrumental Requirements Instrumental requirements are:

- Local anesthetic
- Forceps
- Biopsy clamps or forceps, scissors or scalpel
- Dressing material

Practical Execution In small carcinomas of the anal edge, an excisional biopsy under local anesthesia is feasible most of the time. In advanced carcinomas of the anal edge and in carcinomas of the anal canal, brief general anesthesia is advisable. Here, by means of the available instruments mentioned, several deep biopsies should be taken from different areas of the tumor.

In ulcerated tumors, the tissue biopsy should not be taken from the necrotic central ulcer ground but rather from the vital circumferential edge. A burning of the biopsy by HF coagulation must also be avoided.

9.7 Anal Fissure (Heitland 2012)

Anal fissure is a most painful anal disease where a longitudinal ulcer-like defect in the highly sensitive anodermal region is found. The cardinal symptom is defecation pain, which starts with stool passage and will last for several minutes up to hours. Eighty to ninety percent of anal fissures are localized at the posterior commissure at the 6 o'clock lithotomy position; 10–15% are ventral.

In all cases of a lateral position of a fissure, a malignant disease must be suspected.

The crucial factor for the onset of an anal fissure is a hard stool consistency causing a superficial disruption of the anoderm. In addition, a reflexive anal spasm may cause ischemia of the tissue, which then will aggravate the situation and lead to persistence or progression of the fissure.

If no healing is achieved, every acute anal fissure will become chronic within 2–3 months. Then a hypertrophic anal papilla or a («sentinel fold») is a constant finding.

▪ Conservative Treatment

As a causative treatment and basic therapy of a fissure, an adequate regulation of bowel consistency using fiber-rich diet and sufficient liquid intake should be the start. In addition, stool regulatory preparations such as psyllium (*Plantago ovata*) and macrogol are beneficial.

For analgesia, the intra-anal application of local anesthetic ointments or gauze-armed suppositories is helpful. The topical application of glyceryl trinitrate (GTN) ointment may reduce the sphincter tone. This can contribute to an improved subanodermal perfusion and thus help to heal the fissure.

Tip

GTN ointments may have the side effect of headaches. As an alternative to the commercially available GTN ointment, a specially and individually designed mixture preparation of calcium antagonistic drugs such as 2% diltiazem and 0.2% nifedipine ointment may be successfully used.

Operative Treatment

Indication The operative treatment is indicated after failure of the conservative attempts or if marked secondary sequelae of the fissure are making a conservative healing unlikely. The operative standard treatment of choice is fissurectomy (Fig. 9.32).

Personnel Requirements In addition to the acting doctor, the presence of one assistant is useful to pass the necessary instruments, in order to reduce the required treatment time to a minimum.

Instrumental Requirements Instrumental requirements are:

- Local anesthetic
- Forceps
- HF needle electrode with HF generator
- Dressing material

Practical Execution If the fissure is not too excessive and pain is tolerable, fissurectomy may be carried out under local anesthesia. However, in most cases, short general anesthesia is superior.

The first step is a gentle and slow manual sphincter dilatation for the reduction of the usually existing anal spasm. Then the fissure, together with all fissure edges and the fissure ground, is completely excised using the HF electrode, meticulously preserving the internal anal sphincter muscle (Fig. 9.33). The perianal drainage wound then helps with uneventful secondary wound healing.

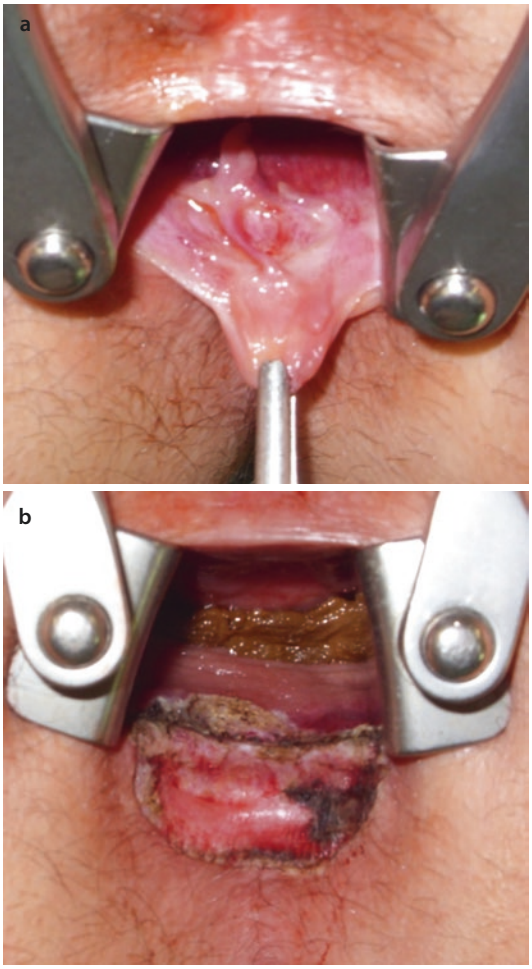


Fig. 9.32 Chronic anal fissure. **a** Preoperative finding with hypertrophic anal papilla. **b** Postoperative result following fissurectomy

A lateral or partial sphincterotomy, which used to previously be the treatment of choice, should be regarded as obsolete because of its irreversible impact on continence in the long term.

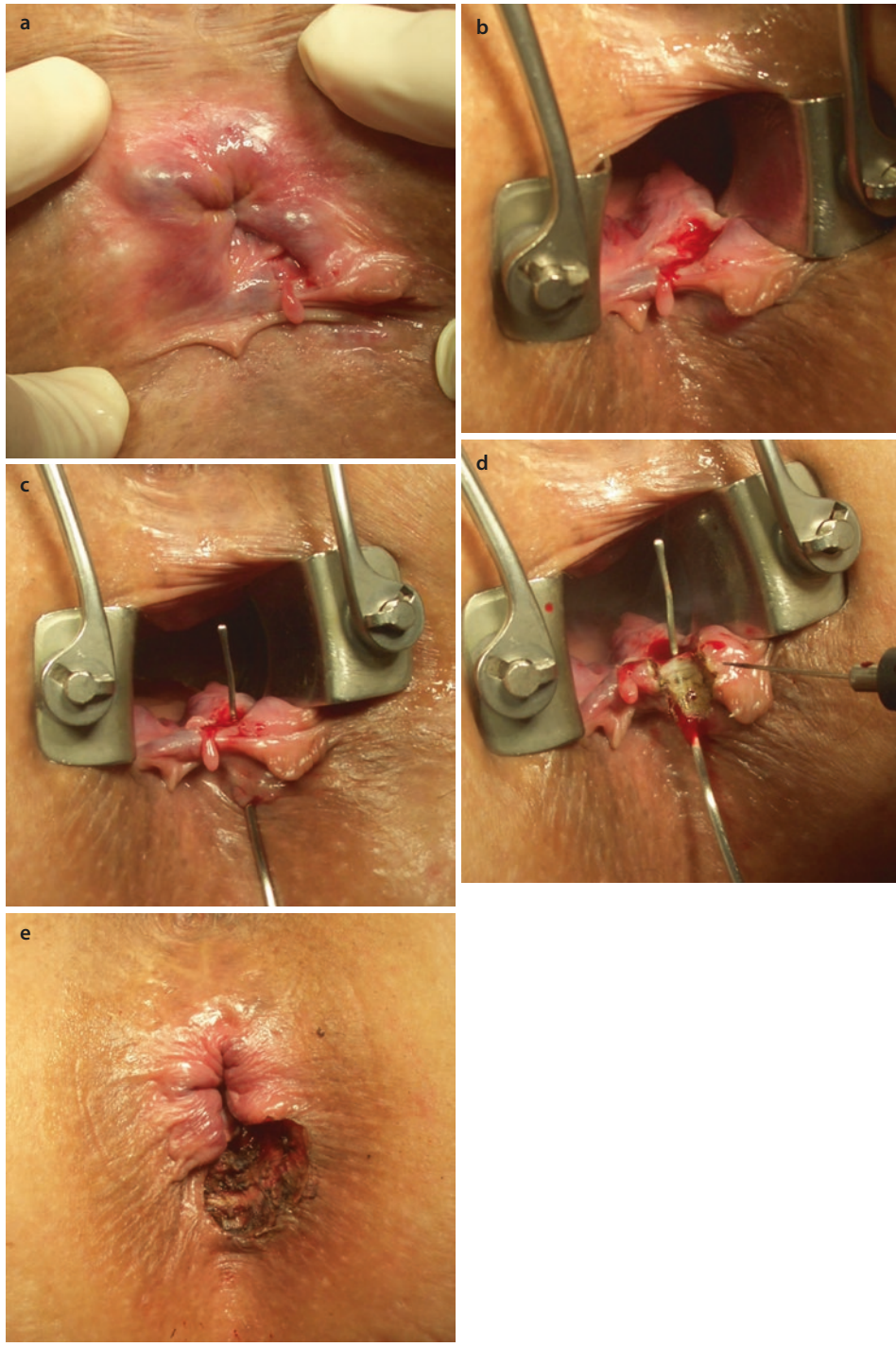


Fig. 9.33 Chronic anal fissure with intersphincteric anal fistula. **a**, **b** Preoperative finding. **c** Probe in fistula. **d** Fistulotomy by HF electrode with cutting of fibers of the internal sphincter muscle. **e** Postoperative result following fistulectomy and fissurectomy with external wound opening

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Combined Laparoscopic–Endoscopic Procedures

Dirk Wilhelm, Alexander Meining, and Hubertus Feussner

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Combining a (minimally invasive) surgical intervention with simultaneous flexible endoscopy is beneficial in different indications to increase safeness and efficiency. The respective contribution of both modalities to the intervention varies significantly, so one can terminologically distinguish different forms of combined (hybrid) procedures, ranging from simple endoscopic support (for localization of a lesion) via classical laparoscopic–endoscopic combined procedure to hybrid NOTES. As a basic aspect, hybrid interventions are characterized by simultaneous application of laparoscopy and flexible endoscopy and by less invasive tumor therapy where the lesion is approached from different sides (e.g., endoluminal and peritoneal).

10.1 Introduction

For what indications might combined laparoscopic–endoscopic procedures be useful? First of all, and despite the significant evolution of therapeutic flexible endoscopy in the therapy of benign and early malignant gastrointestinal tumors, is if they are not amenable to endoscopic resection (or if resection appears too risky). For example, an awkward localization (behind folds, inside bowel loops, etc.) of a tumor might prevent pure endoscopic therapy; this can be overcome by laparoscopic support (Church 2003). Identically, lesions located in the submucosal layer with a relevant extramurally protruding aspect (e.g., gastrointestinal stromal tumor) are better treated by means of combined extraluminal–intraluminal manipulation (Fig. 10.1) with the resection being done laparoscopically. From another aspect, the absolute size of a lesion might also limit flexible endoscopic resectability, although endoscopic submucosal dissection (ESD) and endoscopic mucosal resection (EMR) have significantly developed over the last years. However, large lesions can be too technically demanding and prone to iatrogenic perforation and thus are sometimes better treated surgically.

Nevertheless, even in these complex lesions, flexible endoscopy is of great value, as it has already been possible to show during conventional surgical interventions, for example, to ease precise tumor localization (Sakanoue 1993). While flexible endoscopy appears supportive but only «nice to have» in open surgery, it becomes a «conditio sine qua non» in laparoscopic surgery. This inalienability of flexible endoscopy, at least for the mentioned indications, is explained by procedural limitations of minimally invasive surgery that are brought about by reduced degrees of freedom (only a few but fixed trocar sites), by the small size of the instruments, and if nothing else by the loss of tactile sensation. Due to these limitations, local laparoscopic resection of benign and early malignant pathologies of the gastrointestinal tract is hindered significantly (Table 10.1). Even in the case of a large protrud-

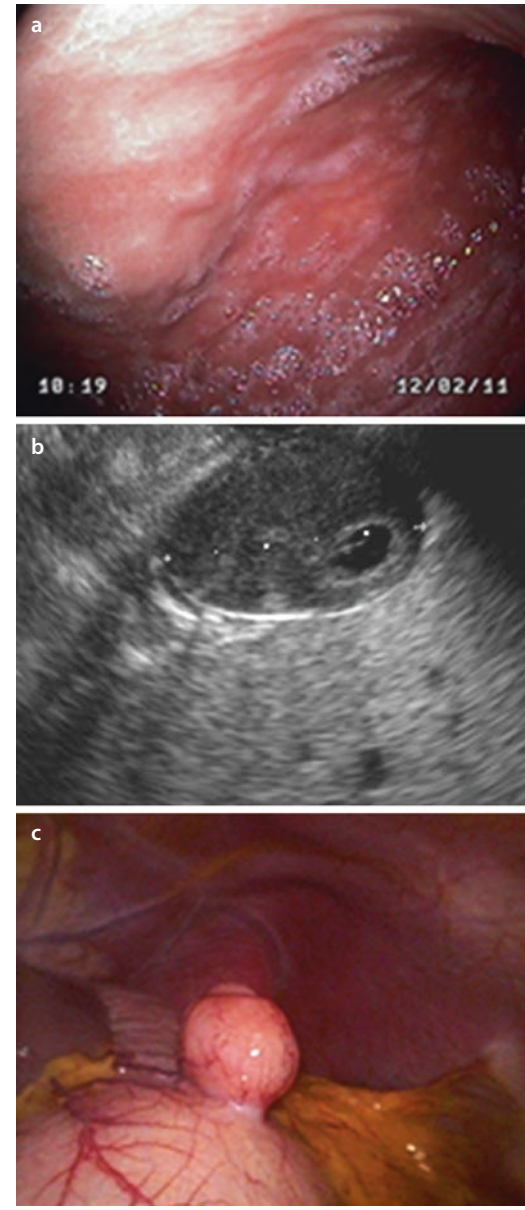

Fig. 10.1 **a** Hourglass-shaped gastrointestinal stromal tumor located in the gastric fundus that appears by endoscopic assessment to be endoluminally growing. **b** Endosonographic finding that obviously supports endoscopic assessment. **c** Intraoperative laparoscopic vision showing the large extraluminal aspect

ing mass, the precise extent of a tumor and its defined borders are estimated by laparoscopy only at a quality level that allows for an extended but not for a tissue-sparing local resection.

In most cases, preoperative marking of the tumor prior to laparoscopic resection seems indispensable. However, available techniques for preoperative tumor marking (endoscopic tattoo, clip, etc.) are evaluated as unreliable and too imprecise (Cho et al. 2007; D'Annibale et al. 2004) and, identically, allow only for gross tumor resection. In particular, adhesive pigments available do not remain at the site and show diffusion effects soon after injection, resulting in staining of a much larger area than intended and thus requiring extended surgery (Fig. 10.2). If at all, we recommend Indian ink for endoscopic tattoo.

The marking of a tumor by endoscopic clips might become even more critical. Although placement of clips can be achieved easily and with acceptable precision, identification of the clips turns out to be difficult and cumbersome even if intraoperative fluoroscopy is available (Fig. 10.3). In some rare cases, mislocalization

Table 10.1 Known limitations of laparoscopy and endoscopy. By combining both techniques these limitations can be overcome

Laparoscopy	Endoscopy
Imprecise localization of endoluminal lesions	Only amenable to superficial, circumscript lesions
Reduced degrees of freedom	Limited hemostasis
No evaluation of suture lines from outside	Highly limited viscerosynthesis, no suturing
Inferior and limited exposure techniques	Only applicable endoluminally
Difficulties in accessing subcardial and prepyloric lesions	Restricted maximum lesion size (2–3 cm)

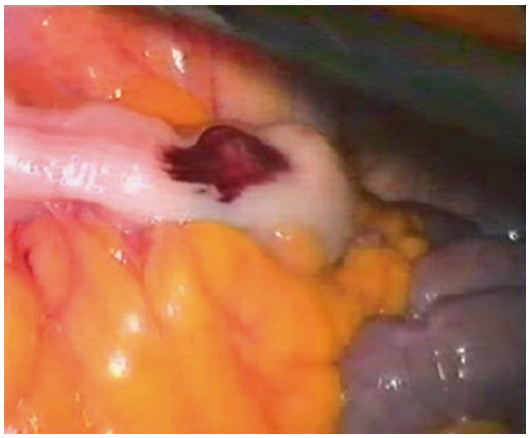

Fig. 10.2 Preoperative endoluminal–endoscopic color staining of a tumor. Already 3 h after injection, the pigment diffuses beyond the area of interest. Precise localization and demarcation of the tumor borders become impossible. In this specific case, unreliable marking of the tumor resulted in an unnecessarily gross and tubular resection

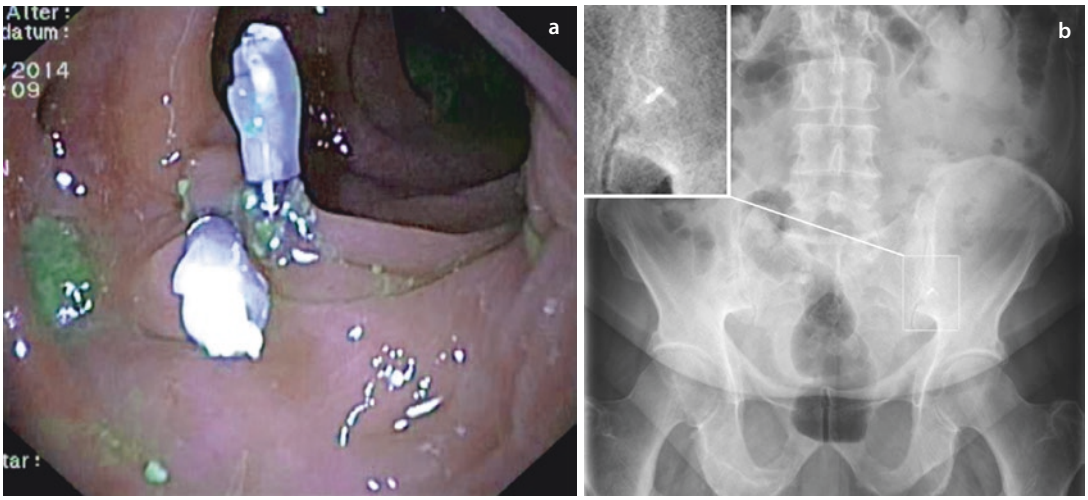

Fig. 10.3 **a** Marking of a lesion by endoscopic clip placement. **b** Intraoperative fluoroscopic visualization. Although identification of the clip seems easy and unequivocal, precise tumor resection without intraoperative endoscopic support becomes difficult in the majority of interventions

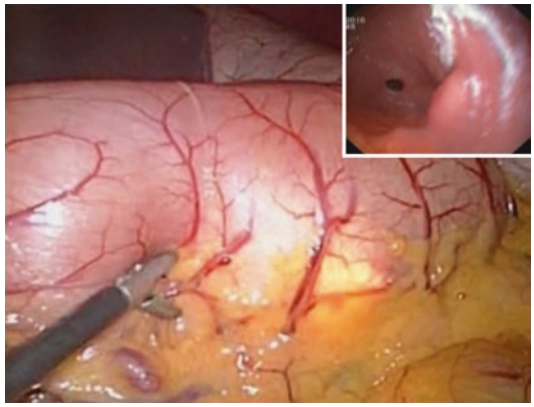

Fig. 10.4. Invagination of a small prepyloric lesion through external manipulation by a laparoscopic grasper. Although the stomach is extended to its maximum, the palpating instrument is easily identified from inside

of endoscopic clips during surgery has resulted in resection of the wrong colon segment and in medicolegal conflicts.

As compared to the insufficient marking by tattoo and clips, intraoperative endoscopy is capable of precisely describing the endoluminal aspect of a lesion that can be demonstrated to the surgeon and that finally facilitates true local resection. Demonstration of the tumor borders can be achieved by manipulating the intestinal wall from the outside while observing from the inside or via transillumination (diaphanoscopy), which means illustrating the endoluminal lesion by spot lighting (Fig. 10.4). Intraoperative endoscopy is second to none for the abovementioned marking techniques and, accordingly, the modality of choice for intraoperative tumor localization.

It is important to note that the contribution of intraoperative endoscopy is not only confined to localizing a lesion but is extended over the entire intervention with the idea of a combined laparoscopic–endoscopic intervention. This additional contribution is extremely valuable and was realized even several years ago.

Potential Advantages of Intraoperative Endoscopy

- Highly precise tumor localization
- Endoluminal tumor resection
- Prevention of stenosis
- Test for leakproofness after resection
- Endoluminal specimen extraction

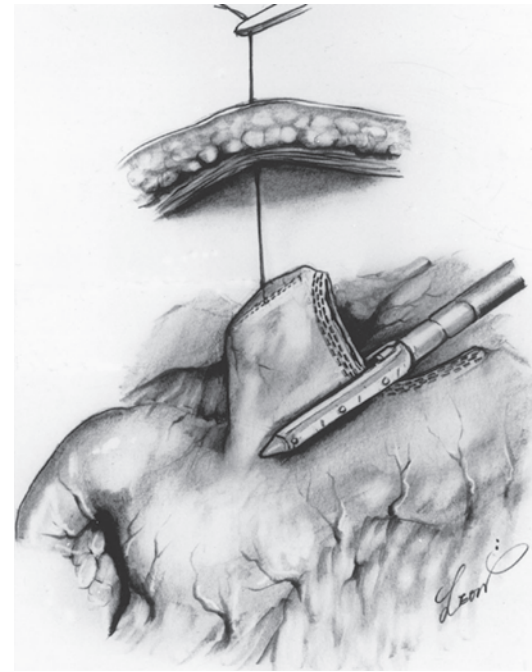

Fig. 10.5 The so-called lesion-lifting method was first published by Ohgami in 1992 for resection of a T1 cancer that was located at the anterior gastric aspect. Tumor resection was eased by exposure with anchors that helped to elevate the inflicted part of the stomach and was finally completed by stapler application (Ohgami et al. 1999)

The first reports on combined hybrid interventions date back to the early 1990s and deal with the therapy of benign and early malignant tumors of the stomach and the colon. In this context, Ohgami first reported on the «lesion-lifting method» that he applied in 1994 for the therapy of gastric leiomyosarcomas and T1 cancer (Fig. 10.5). For this technique, the tumor-bearing aspect of the anterior gastric wall was exposed by anchors that were inserted into the lumen under endoscopic vision. Tumor resection is then easily performed by stapler application and wedge resection of the affected gastric aspect. Intraoperative gastroscopy is maintained throughout the resection to assure correct exposure of the tumor and to verify complete and secure tumor resection (Ohgami et al. 1994, 1996). Alternatively, tumor resection is also possible by a transgastric approach, which was introduced by Ohashi et al. (1995). For a transgastric resection, laparoscopic trocars are advanced via the abdominal wall and under flexible endoscopic guidance into the gastric lumen; thus endoluminal tumor resection is performed

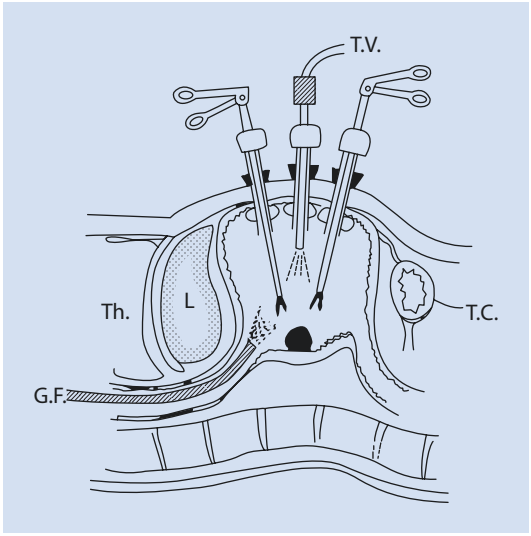

Fig. 10.6 Tumors located at the posterior side of the stomach that cannot be accessed by a lesion lift can be treated by a transgastric resection. Transgastric resection can be done both by performing an anterior gastrostomy and by inserting the trocars into the gastric lumen as described by Ohashi. The latter technique avoids spillage of gastric content and is less traumatic (Ohashi et al. 1995)

inside the gastric lumen with standard laparoscopic instruments (Fig. 10.6). Visualization during the intervention is possible without application of a laparoscopy only on the basis of the gastroscope.

As for gastric lesions, combined interventions are also applicable to colonic lesions. Depending on the exact localization of the tumor in respect to the colonic circumference, resection might be possible without opening of the lumen in form of a wedge resection (Shallman et al. 1993) or with a transluminal approach after incision (Champault 1994; Zuro et al. 1992). Identical to the technique which has been described for gastric pathologies, simultaneous endoscopy supports laparoscopic resection by tumor localization, endoluminal control during the resection, and reduction of the postoperative complication rate by testing the suture lines for leakproofness. In some favorable lesions, endoluminal endoscopic resection can be performed secondarily and by means of laparoscopic assistance and manipulation, even though it appeared impossible at initial endoscopic evaluation (Beck and Karulf 1993; Smedh et al. 1997). As compared to a combined transluminal or wedge resection as described above, laparoscopically assisted endoscopic resection further reduces the interventional trauma, as it avoids opening/resection of the intestinal wall. If the risk of secondary perforation is estimated as too high after endoscopic tumor resection, oversewing of the resection site from the outside by laparoscopy is easily achieved. Two approaches are conceivable: preemptive suturing before endoscopic resection as described by Back and Karulf in 1993 or according to Sarker in 2014, by prior application of a mega-clip (the so-called endoscopic full-thickness resection (EFTR)), and securing of the resection site secondary to endoscopic resection, if a local burn or pending perforation is visualized by laparoscopy.

The modality of «combined endoscopic–laparoscopic interventions» developed only slowly in the beginning, although this terminology was already used in 1995 by Payne et al. (1995). In the original phase, one did not refer to the consequent application of intraoperative endoscopy but to the simultaneous therapy of gastrointestinal lesions by accessing them via different routes and by different technologies. Subsequently, it was possible to show that combined interventions were not restricted only to colonic or gastric lesions but could also be applied for the treatment of tumors of different origin and location (Feussner et al. 2003). A systematic classification of the different forms of combined endoscopic–laparoscopic interventions is also part of this latter publication. According to this classification, one can distinguish laparoscopically assisted endoscopic resections from endoscopy-assisted laparoscopic resection—depending on which of the involved partners is resecting the tumor. For endoscopy-assisted laparoscopic interventions, further differentiation and subclassification are offered, and this distinguishes resection with intended opening of the gastrointestinal lumen to gain access to the tumor (endoscopy-assisted transluminal resection (EATR)) and resection without the need to open the intestinal integrity from tumor therapy by wedge resection (endoscopy-assisted wedge resection (EAWR)). Not to be forgotten and infrequently required for treatment of large tumors, the endoscopy-assisted segmental resection has to be mentioned (EASR) that is also part of this classification, although it is, due to the fact of extended resection, not in the primary focus of a combined tumor therapy. In EASR, the contribution of intraoperative endoscopy is reduced to a minimum and is

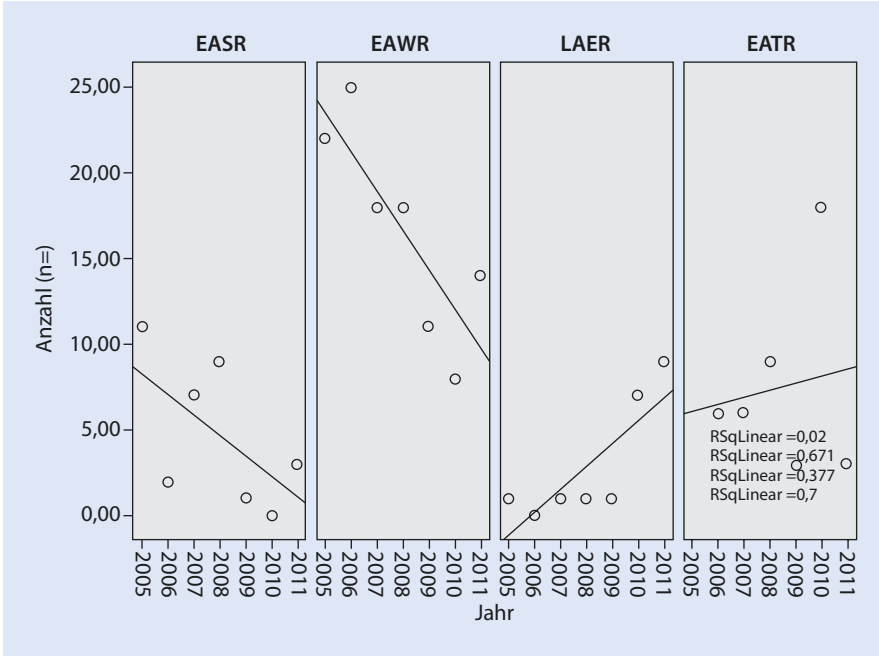

Fig. 10.7 Regression analysis of intervention frequencies of different types of combined interventions. It should be noted that while a reduction of EASR and less frequently of EAWR was observed, one could observe a slight increase in transluminal resections (*EATR*) and a strong increase in endoscopic resections (*LAER*)

more an intraoperative endoscopy than a hybrid intervention. Only in tumors that do not allow for local tumor resection (planned EASR) preoperative marking of the tumor site by tattoo is permissible.

Over the past decades, we were successful in optimizing the initially published techniques and further reducing the trauma, e.g., by using percutaneously placed suspension sutures to support exposure or by manipulation sutures that are inserted assisted by endoscopy close to the tumor to ease resection. But simultaneously, therapeutic flexible endoscopy also significantly evolved in the meantime, facilitating even resection of larger lesions and tumors located in the submucosa. For example, endoscopic submucosal dissection (ESD) techniques allow for resection of flat spreading adenomas that cannot be treated by snare polypectomy (Hotta et al. 2012). Obviously, these advanced endoscopic techniques can easily be incorporated to combined interventions and now can be applied to local endoluminal tumor therapy that is supported by laparoscopic assistance (e.g., exposure of a lesion by neutralization of bends and haustrations). Thanks to that, the rate of laparoscopically assisted endoscopic resections has dramatically increased in recent years, while we can identify a reduction of laparoscopic resection and especially of segmental resections (Fig. 10.7).

10.2 Technical Considerations

Combined laparoscopic–endoscopic interventions are performed in the operation theater and with the patient under general anesthesia. Obviously, for hybrid interventions, the operating room must be fully equipped with both state-of-the-art laparoscopic and endoscopic equipment, so the personnel must be trained in both techniques. To ease cooperative work at a high-quality standard, enough room must be given to the laparoscopic and the endoscopic team, and visualization must be optimized not only as far as one's own working monitor is concerned but must further include access to the visual field of the respective partner. Accordingly, placement of the working towers, the patient, and the monitors has to be adapted and optimized. Therefore and as the ideal solution, the hybrid intervention room should be equipped with double monitors for both actors to ergonomically visualize the operative field of both modalities simultaneously. Since flat screen

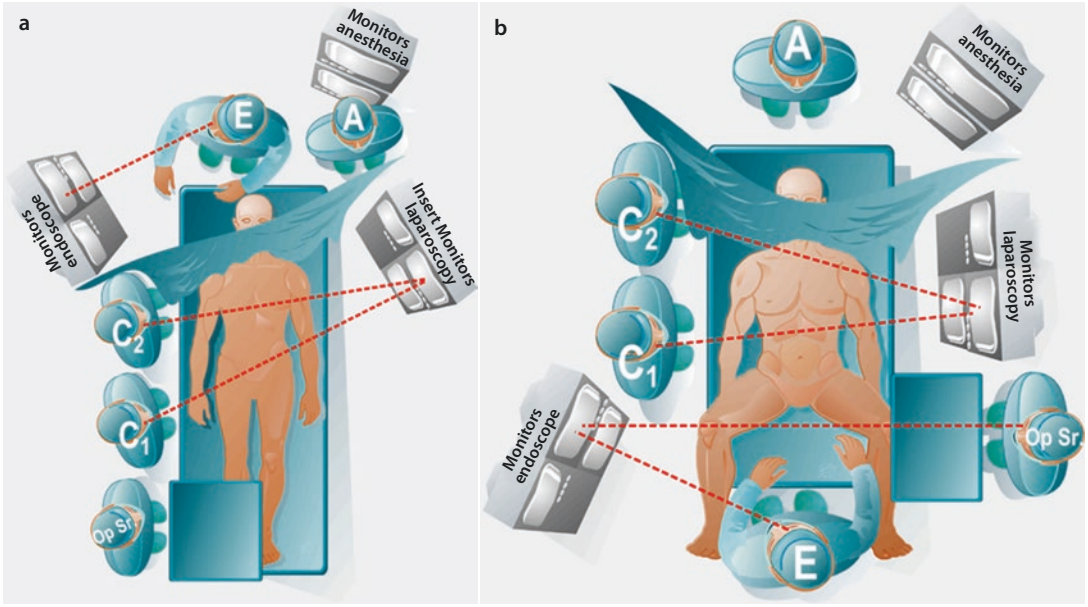

Fig. 10.8 **a** For interventions in the upper gastrointestinal tract, the endoscopist has to find his place alongside the anesthesiologist at the patient's head. In most cases, the surgeon and the camera assistant are positioned on the right side of the patient, with good vision to the monitors on the opposite side that visualize both the laparoscopic and the endoscopic field of view. **b** If a hybrid intervention deals with colonic lesions, the patient is placed in a lithotomy position. The endoscopist is asked to place himself in the confined region in between the legs for colonoscopy. Depending on the location of the lesion, the surgeon operates from the right (left hemicolon) or the left side (right hemicolon)

monitors have long been available, mounting of the panels on the ceiling is no longer a problem. If a double-screen solution is unachievable, picture-in-picture mode is used to integrate the different video sources into one monitor.

In Fig. 10.8, a typical OR configuration for hybrid interventions is shown. For interventions in the upper gastrointestinal tract, the endoscopist is situated beside the anesthesiologist at the head of the patient and outside the sterile operating field.

During hybrid colonic resections, the patient is positioned in a lithotomy position. It is inadvisable for the endoscopist to be positioned in close proximity to the sterile operative field. Only a sterile drape that is fixed to the patient's legs prevents from contamination. As the endoscopic tower has to be placed besides the patient, it is sometimes difficult (if ceiling-mounted monitors are not available) to obtain a direct view of the monitor. In these cases, wearing a head-mounted display (HMD) has proved beneficial (Fig. 10.9).

Colonoscopic examination turned out to be highly demanding inside the operating theater, when the patient cannot be maneuvered later-

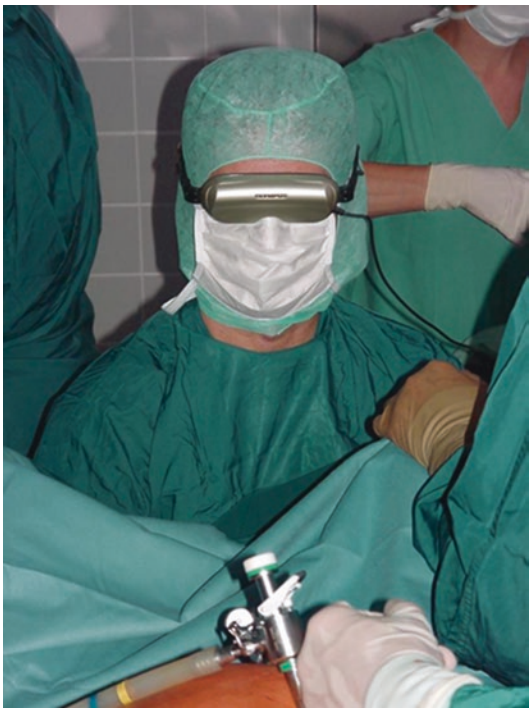

Fig. 10.9 Wearing a head-mounted display (HMD) was rated ergonomically superior if the endoscopic tower had to be placed in an unfavorable position

ally and when general anesthesia neutralizes abdominal guarding. Additionally, the endoscopist should avoid over-insufflation and distension of the bowel loops during endoscopy in order not to hinder later laparoscopy. For the same reason, we have the impression that it is better to use CO^2 instead of room air for insufflation, as it is absorbed much faster. However, even with CO^2, insufflation should be reduced to a minimum. If insufflation is unavoidable, bowel distension can be controlled by clamping the intestine outside the region of interest by application of a soft grasper.

Irrespective of the abovementioned aspects, some additional issues have to be considered. Intubation of the esophagus with the endoscope can be impossible due to the tracheal tube being air blocked. If so, reducing the cuff pressure or deblocking of the cuff is helpful, but this must be done in close cooperation with the anesthesiologist and with care. In addition, an inserted gastric tube can interfere with gastroscopy. However, we recommend removal of the tube anyway before commencing the intervention. It should be noted that any intraoperative manipulation at the patient's head, e.g., for placement of the bite-protecting ring, might lead to dislocation of the tube, airway problems, or some other severe dangers to the patient, so it must be done with the highest accuracy possible and always side-by-side with the anesthesiologist. This holds true even more if a hybrid procedure aims to resect an esophageal lesion with the need for single-lung ventilation and double-lumen intubation and with the patient in an awkward position.

Air insufflation during endoscopy in the course of hybrid interventions should always be kept to a minimum not to hinder laparoscopic vision by distended bowel loops.

As soon as the endoscope is advanced into the stomach, one should remove all fluids by suction to prevent spillage and peritoneal contamination during transluminal manipulation.

As already mentioned, if a hybrid procedure requires colonoscopy, special attention has to be paid to maintain hygienic requirements and to preserve the sterile operative field, as the endoscopist is situated close to the surgeon. Therefore, and as a basic prerequisite, the endoscopist is asked to wear sterile scrubs just like anybody else during a surgical intervention. A relevant problem for efficient colonoscopy arises from the confined space between the patient's legs, not only for manipulating the endoscope but also in order to be supported by any assistance, e.g., for scope stabilization or to navigate a snare. As hybrid interventions are done under general anesthesia and with the patient relaxed, a supportive effect from the tensed abdominal wall for guidance of the endoscope is not to be expected. This is not only problematic in terms of technical feasibility of intraoperative colonoscopy but can result in iatrogenic colon perforation, as in addition typical warning signs such as pain and abdominal overdistension will not be noticed. For this reason, assistance from the operating surgeon, either by transabdominal or laparoscopic guidance, is extremely helpful. Nevertheless, we prefer colonoscopy to be done with a desufflated abdomen and with no laparoscopic instruments introduced, as we suppose the risk of violation is minimal with this technique. In practice, we start the operation with a diagnostic laparoscopy to desufflate soon thereafter, to advance the colonoscope to the lesion of interest. Not until then is laparoscopy restarted, unless endoscopy is impossible due to anatomical alterations that require laparoscopic support. Finally, both partners can start the hybrid resection, as soon as the lesion is visible with the colonoscope.

Obviously, and not only for the mentioned reasons, an effective combined laparoscopic–endoscopic intervention is only successful when both actors work together closely and with adequate comprehension of the working process of the partner. Ideally, both partners are trained in both laparoscopic surgery and flexible endoscopy.

Laparoscopy is not only supportive to endoscopy but can also complicate colonoscopy by inadequate manipulation from the outside and because of the laparoscopic light that interferes with intraluminal vision. Accordingly, close cooperation and helpful coordination between the partners are of utmost importance.

In daily praxis, however, not only technical problems but even more organizational issues interfere with effective collaboration. In particular, timing of an intervention that takes place in the surgical OR is challenging when the endoscopist is work-

ing in another department and has to integrate the intervention into his timetable. Additional work arises if all instruments and the endoscopic tower have to be brought to the OR as well.

With the formation of viscero-medical centers and thanks to an improved interdisciplinary cooperation, we strongly believe these obstacles can be overcome.

10.3 Safety Laparoscopy

In risky and complex endoscopic interventions (e.g., full-thickness resections or interventions with a high risk for perforation), a priori laparoscopic support and surveillance might be reasonable.

Safety laparoscopy needs to be performed under general anesthesia but can be reduced to a minimum, thus a single trocar access with introduction of a needlescope only (2 mm optical system). Although the endoscope can only be identified indirectly and by its transluminating light, the laparoscopist can easily follow the endoscopic intervention. If a perforation occurs, it can immediately be identified by vision or secondarily by gas bubbles or spillage of intraluminal fluids. If full-thickness resection with immediate endoscopic closure of the intestinal defect is intended, the laparoscopist can test for a leakproof closure of the defect.

Sometimes, when the lesion is located averted from the laparoscope or toward the mesentery or the lesser sac, laparoscopic exposure requires the introduction of additional instruments and dissection of the dedicated resection site. Fortunately, even then mini-laparoscopic instruments can be used to keep the interventional trauma as low as possible.

10.4 Laparoscopy-Assisted Endoscopic Resection (LAER)

In some rare lesions, when primary endoscopic resection appears impossible due to disadvantageous aspects and after failure of typical facilitating measures such as repositioning of the patient, exposure by submucosal injection, or re-endoscopy, endoscopy treatment can succeed in some case if supported by laparoscopy laparoscopy-assisted endoscopic resection (LAER)). As opposed to the abovementioned «safety laparoscopy», in LAER, the laparoscopic assistance and extraluminal manipulation are planned from the beginning, or it turns out during intraoperative assessment that in spite of the tumor having been scheduled for laparoscopic resection, an endoluminal resection is feasible (Fig. 10.10). For example, this can be achieved by protruding the lesion to the luminal side by external manipulation, so it is amenable to snare resection or external dissection, and by stretching of the affected bowel segment to allow for endoscopic therapy (Fig. 10.11).

Moreover, laparoscopic hemostasis, irrespective of whether it is achieved by direct suturing or

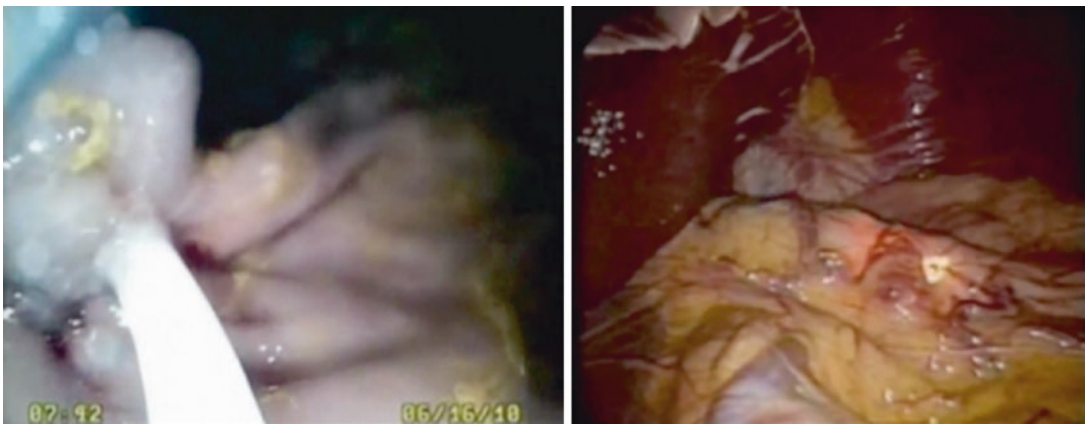

Fig. 10.10 Sole endoscopic interventions that appear risky are sometimes better performed under laparoscopic surveillance (safety laparoscopy). In cases of perforation or any other adverse event, laparoscopic support is immediately available either for oversewing of the intestine or for hemostasis. Due to advances in interventional endoscopy and the ability to perform full-thickness closure, safety laparoscopy is only rarely indicated

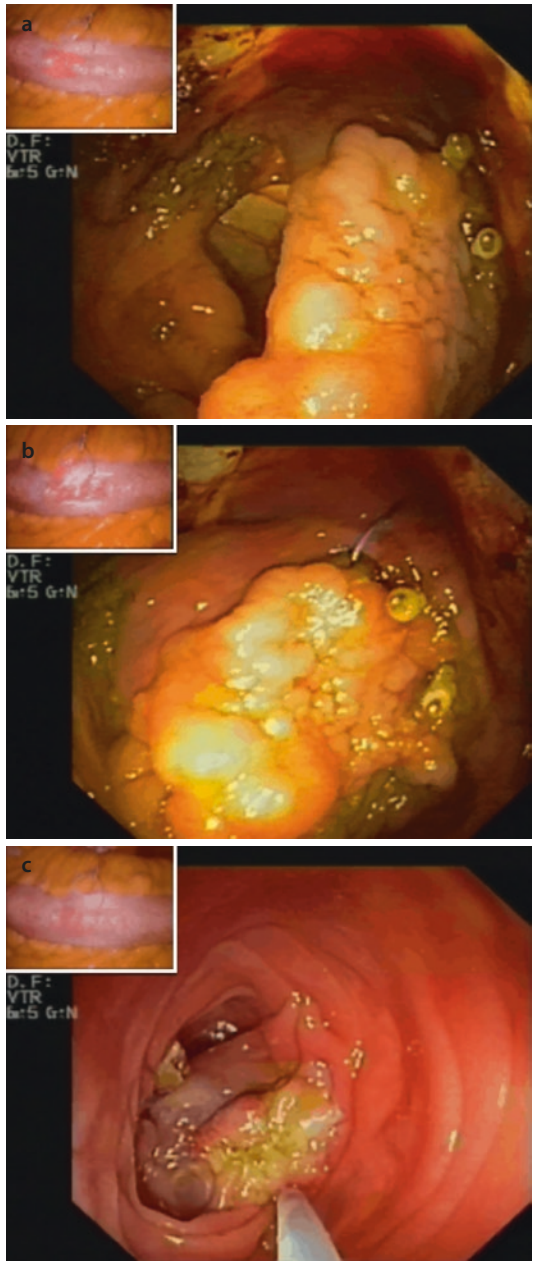

Fig. 10.11 **a** Complete exposure and sufficient evaluation were never given during preoperative colonoscopy. **b** Intraoperative view, with the inflicted bowel segment stretched by external manipulation. **c** Finally, safe endoscopic resection was easily conducted under laparoscopic support

by control of the feeding artery, is helpful in the case of iatrogenic bleeding after endoscopic resection. Fortunately, and because of laparoscopic «rear cover», endoscopic tumor resection can be performed regardless of potential side effects and with maximum thoroughness. Accordingly, LAER can ensure complete and oncologically adequate endoluminal therapy (Tsujimoto et al. 2010).

For LAER, we usually insert three 5-mm trocars. The insertion points are carefully chosen according to the position of the lesions (Fig. 10.12), as is done in all hybrid interventions.

10.5 Endoscopy-Assisted Wedge Resection (EAWR)

During EAWR, tumor resection is achieved without opening of the intestinal lumen and without direct vision of the laparoscope onto the lesion. Tumor resection is done as full-thickness stapler resection of the tumor-bearing intestinal region. Localization and marking of the tumor in these instances are provided solely from the endoluminal site by endoscopy, especially in the case of a flat-growing not protruding lesion, as is often seen in the colon. Accordingly, the endoluminal support is decisive and has to fulfill all requirements in EAWR (Fig. 10.13). Wedge resection can be eased by exposing sutures that are placed around the tumor site for elevation and that can be inserted transabdominally to avoid the need for additional trocars (Fig. 10.14). As in most hybrid interventions, the specimen is then transferred to a retrieval bag for extraction (Fig. 10.15).

Simultaneous endoscopy can also contribute to hybrid intervention by splinting the intestinal lumen during resection to avoid postoperative stenosis. We always recommend wedge resection being oriented rectangular to the intestinal direction, as this lowers the risk of postoperative intestinal obstruction (Fig. 10.16). Even if the lesion is amenable to wedge resection in large tumors or in narrow anatomical regions, a transluminal resection is sometimes superior, as it preserves tissue. The resulting defect is subsequently closed by stapler and oblique to the intestinal axis, again to avoid stenosis (loss of length to preserve the internal diameter) (Fig. 10.17). To prevent postoperative bleeding and insufficiency, we recommend oversewing of the stapler line. Beforehand, completeness of resection has to be evaluated by endoscopic examination and by reviewing the

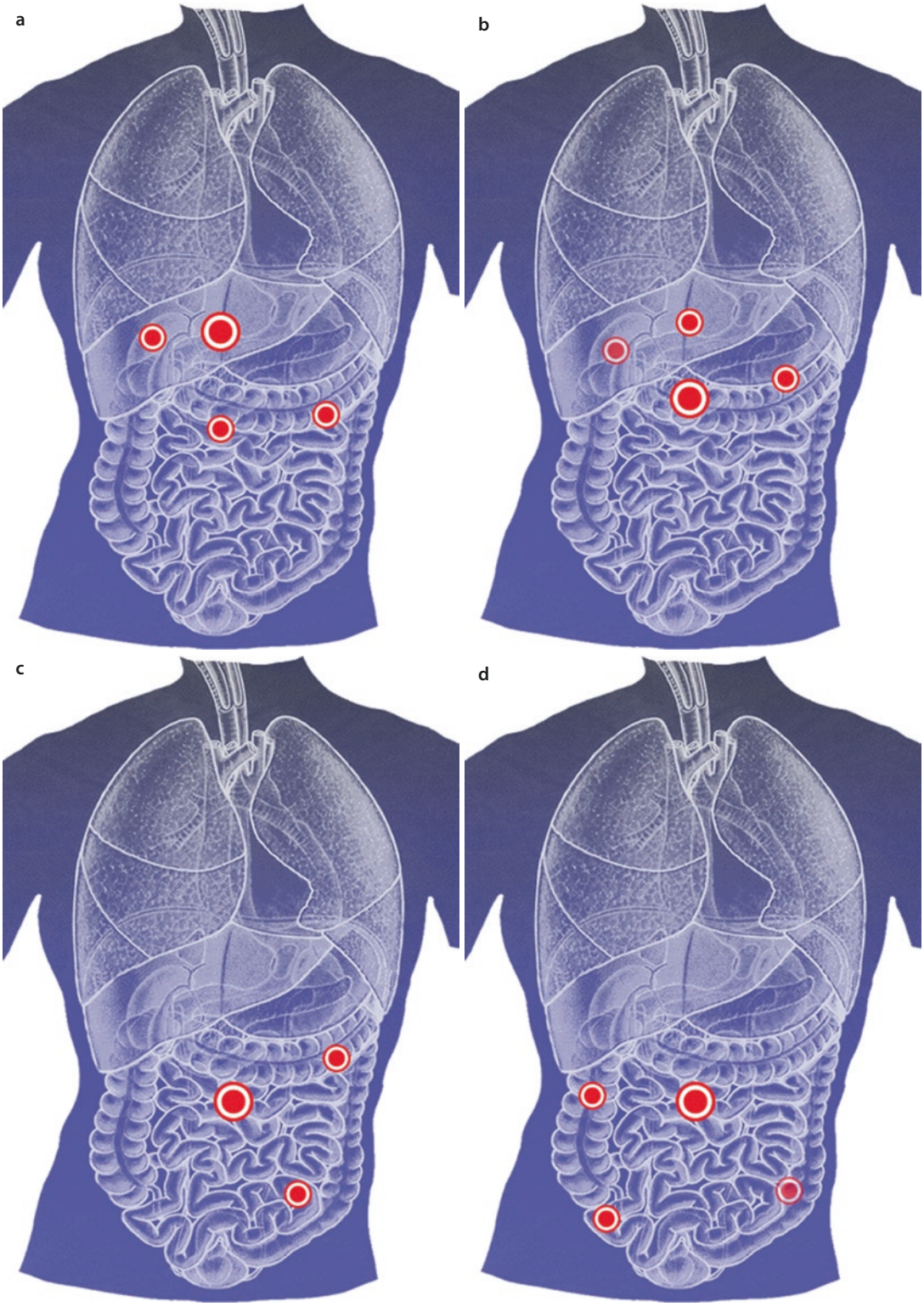

Fig. 10.12 Placement of trocars for different hybrid interventions. **a** Interventions on the distal esophagus, cardia, and proximal aspect of the stomach. **b** Gastric hybrid interventions on the distal aspect of the stomach and antrum. **c** Interventions on the right hemicolon. **d** Interventions on the left hemicolon

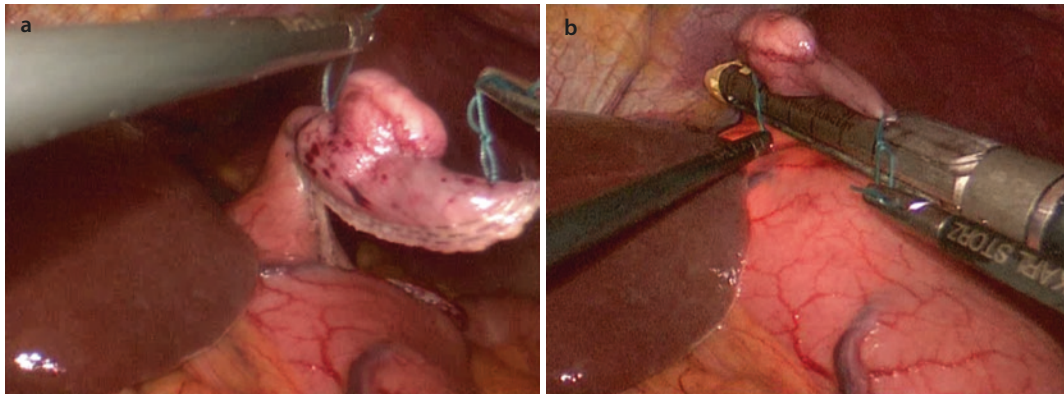

Fig. 10.13 **a** The tumor that was already visible from the outside view has been partly resected by linear stapler application (endoscopic assistance assured complete tumor resection by endoluminal control). **b** Completion of tumor resection with the second stapler magazine

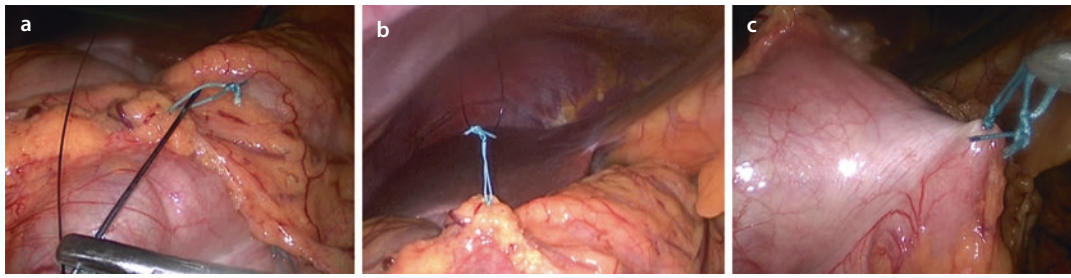

Fig. 10.14 **a**–**c** Exposing sutures support atraumatic resection of intestinal lesions. They are inserted transabdominally and do not require additional port sites. These sutures have proved themselves extremely helpful during all types of hybrid interventions and ease local tissue-sparing resection

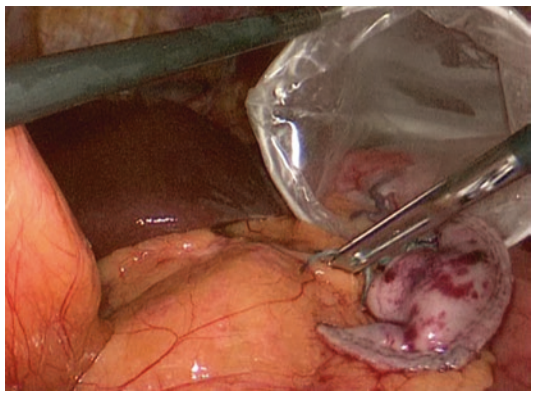

Fig. 10.15 Retraction of specimens is always achieved by means of a retrieval bag to avoid potential tumor cell spillage. Only in the case of endoluminal or transluminal resection is specimen retrieval sometimes possible from the endoscopic site

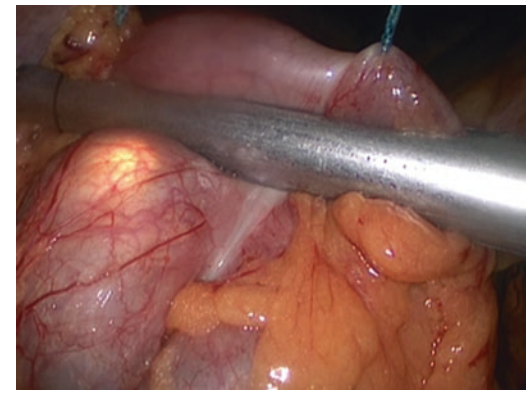

Fig. 10.16 Endoscopy-assisted wedge resection in the transverse colon. The tumor is resected by application of one stapler magazine, while the remaining intestinal lumen is splinted from the inside by the endoscope. Localization of the lesion and precise stapler placement take place on the basis of endoluminal endoscopic assessment

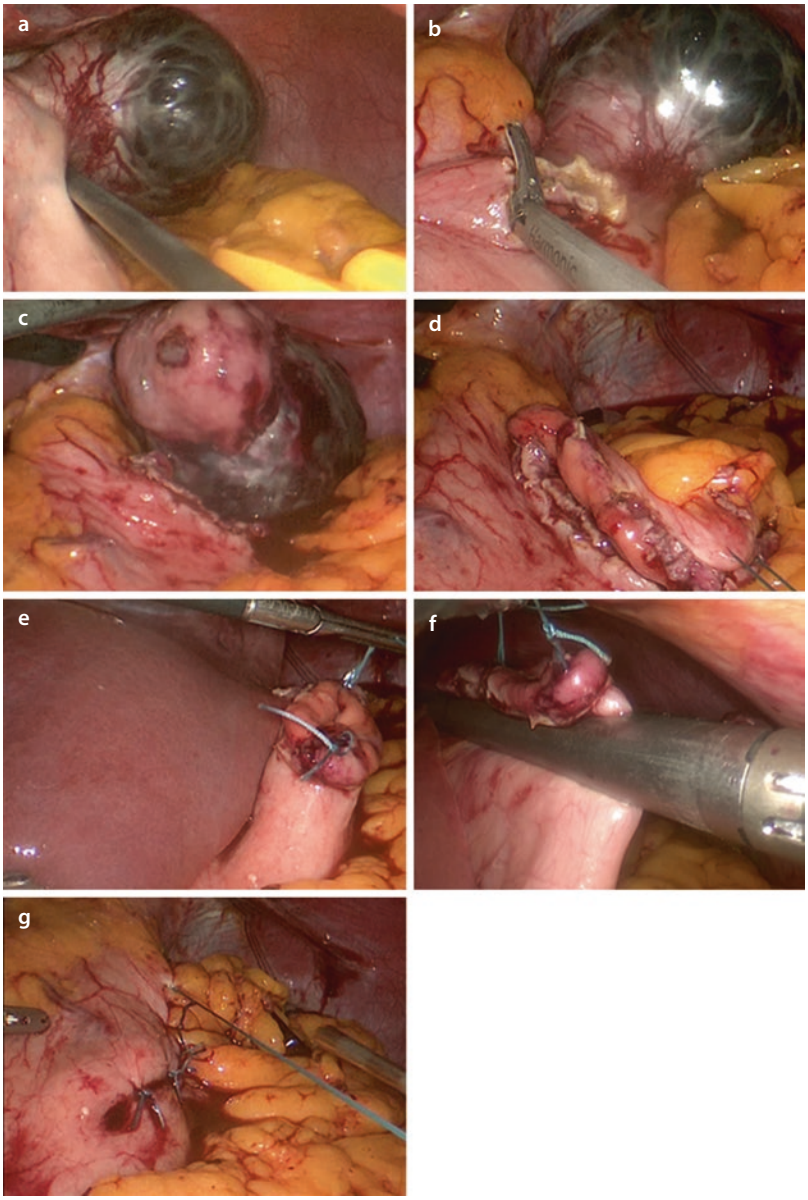

Fig. 10.17 **a** Even large tumors can be resected by endoscopy-assisted wedge resection subject to the condition that the remaining lumen is wide enough (e.g., gastric corpus). **b**–**e** Following resection, the resulting defect is closed provisionally by adaption. **f** Final closure of the resection site by stapler application. **g** Assessment of the resection site at the end of the hybrid intervention (low-risk GIST, 5 cm with hemorrhage, complete resection)

extracted specimen. Although some might argue that oversewing of the stapler line is superfluous and time-consuming, we always recommend this additional step as the clinical gold standard. This applies equally to a test for leakproofness that we link to endoscopic endoluminal assessment, and that is done by instillation of blue color water in a volume of 200–300 ml (we use methylene blue for staining of the watery solution).

10.6 Endoscopy-Assisted Laparoscopic Transluminal Resection (EATR)

Lesions that are located at the posterior side of the stomach or toward the mesentery cannot in general be treated by wedge resection but require a transluminal approach. We called this modality endoscopy-assisted laparoscopic transluminal

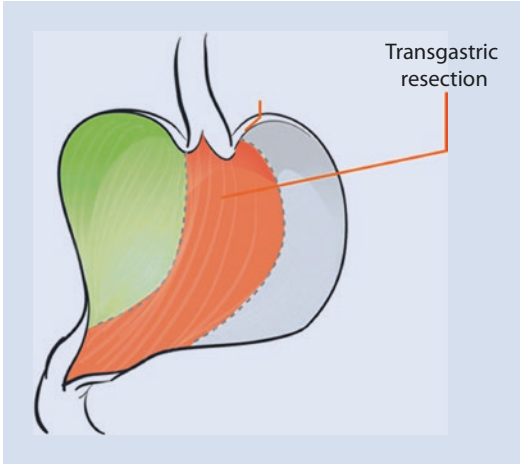

Fig. 10.18 Typical distribution of different hybrid resection techniques in the stomach. Regions that in general can be treated by EARW are colored *green*, whereas EATR is preferred in the *red* regions

resection (EATR) (Fig. 10.18). As compared to EAWR, transluminal resections start with opening of the intestinal lumen at the anterior side, typically just opposite the lesion. However, exact planning and decision-making with regard to the most suitable site for enterotomy must result from intraoperative assessment of both laparoscopist and endoscopist. If the enterotomy is placed favorably, the tumor can be grasped and exposed easily and be resected again by application of a stapler. As for EAWR, application of exposing sutures is helpful in some instances.

Unfortunately, air insufflation and endoscopic exposure become impossible as soon as the intestinal lumen is opened and the endoluminal air leaks into the abdomen. Because of this fact, endoscopic support in EATR is restricted to the localization of the lesion and planning of the enterotomy, as well as to the final assessment of the resection line and the intestinal closure.

After successful resection of the lesion, the enterotomy is closed by suture or again by stapler application, then resulting in a second anterior stapler line (one for the tumor resection and one for the enterotomy closure) (Fig. 10.19). As endoscopic evaluation of the former tumor site is impossible as long as the insufflated air leaks via the enterotomy, we prefer provisional closure of the latter for inspection. If endoluminal assessment shows complete tumor resection, the enterotomy is finally closed in a second step as mentioned before.

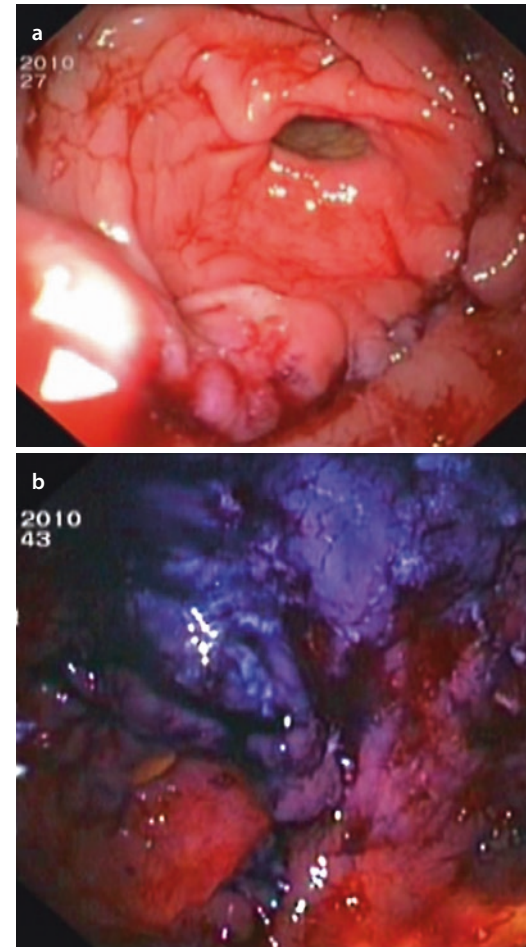

Fig. 10.19 **a** Intraoperative endoscopic support deems indispensable, especially for lesions located just before the pylorus or in the subcardial region, to avoid postoperative stenosis. **b** As already mentioned for EAWR, also in EATR, the endoscopic evaluation of the stapler line for hemostasis and airtightness helps to reduce postoperative complications

10.7 Endoscopy-Assisted Laparoscopic Segmental Resection (EASR)

Endoscopy-assisted laparoscopic segmental resection implies tubular removal of a confined intestinal segment and applies to colonic (or small-bowel) lesions only. As we strive to treat intestinal lesions in a local fashion whenever possible, EASR is the modality of choice for extending tumors only (tumor size more than half of the circumference). In EASR, intraoperative endoscopy is again helpful in identifying the precise localiza-

tion of the lesion and demonstrating this site to the laparoscopist. The respective bowel segment is then dissected and freed from the mesentery, to be resected subsequently.

Depending on the exact tumor position, the reconstruction of the intestinal continuity can follow different principles: after sigmoid resection, anastomosis is generally done with application of a circular stapler. In these cases, the endoscope can be used to advance the anvil plate proximate to the former resection site, which allows for reduction of the invasiveness and eventually for avoidance of a mini-laparotomy (Fig. 10.20). As we think formation of an anastomosis in proximal regions of the large bowel outside the range of a circular stapler is less reliable and cumbersome, we prefer hand-assisted anastomosis via a mini-laparotomy in these instances. This does not apply to the ileocolic region, where suitable techniques for minimally invasive re-anastomization are available (Fig. 10.21). After reconstruction of the intestinal continuity, the endoscope can again be used to evaluate the anastomosis from the inside for patency and hemostasis. If ever an anastomosis-related complication is recognized, this can be treated by the endoscope, e.g., by clip application in the case of bleeding at the stapler line.

As mentioned before, we finalize the intervention with endoluminal assessment of the resection site by air insufflation and instillation of stained water. Thanks to this and to the preserved blood supply after local hybrid resection, complication rates of combined interventions are extremely low. Decision-making with regard to the most suitable hybrid resection technique (EAWR, EATR, EASR, LAER) in general has to be made intraoperatively and in agreement between endoscopy and laparoscopy (Fig. 10.22).

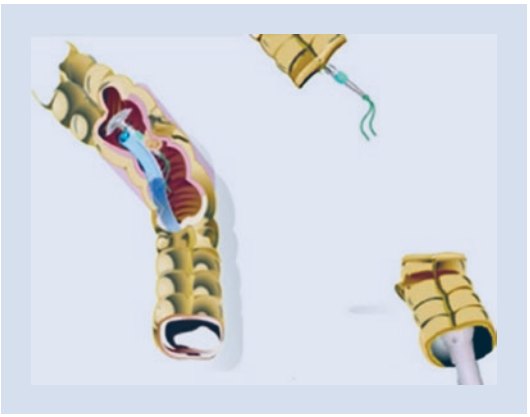

Fig. 10.20 Endoscopy-assisted laparoscopic segmental resection. Placement of the anvil plate of the circular stapler proximate to the former resection line. If retrieval of the specimen can be achieved by endoscopic extraction, a pure hybrid intervention is possible without the need for mini-laparotomy

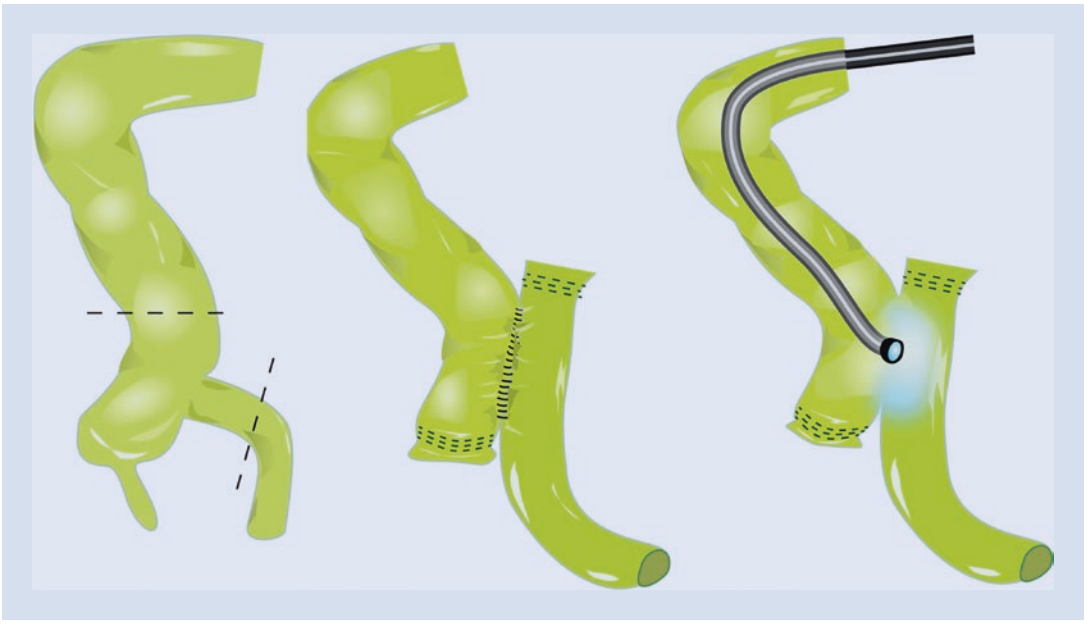

Fig. 10.21 Endoscopy-assisted laparoscopic ileocolic (segmental) resection

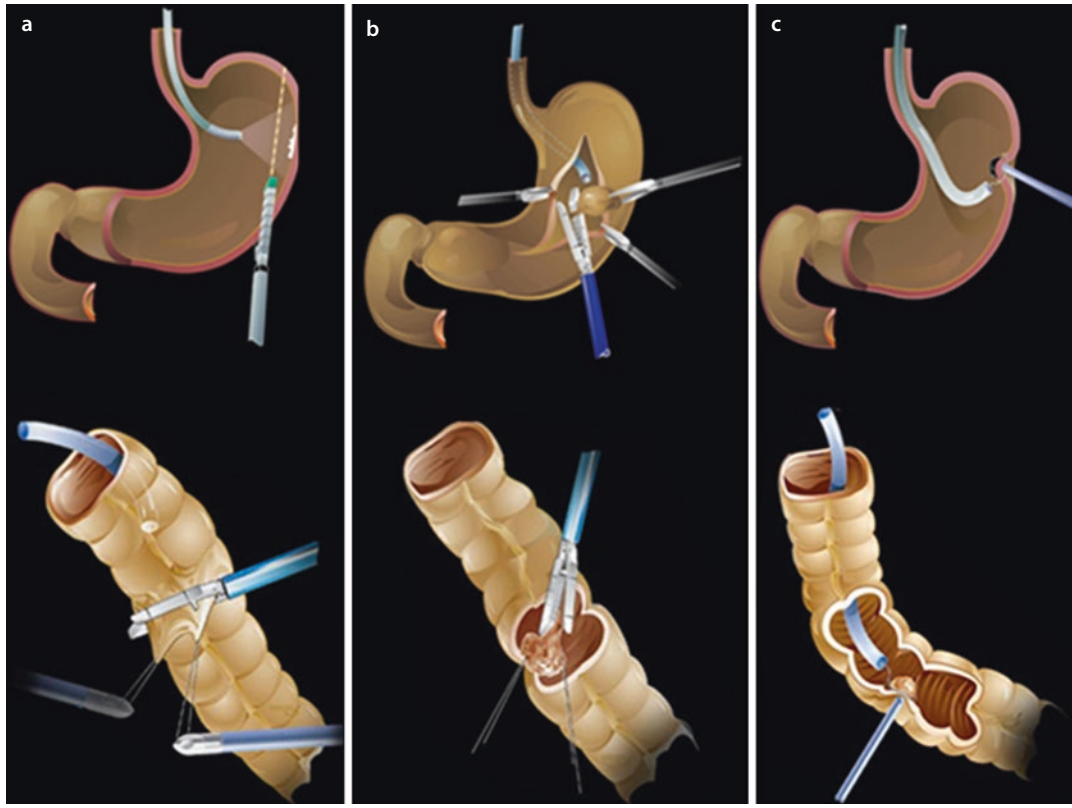

Fig. 10.22 Combined laparoscopic-endoscopic interventions include **a** endoscopically assisted laparoscopic wedge resection, **b** endoscopically assisted laparoscopic translumenal resection and **b** laparoscopically assisted endoscopic resection

10.8 Laparo-endoscopic Combined Therapy of Common Bile Duct Disorders

Visualization of the biliary system sometimes becomes necessary during laparoscopic cholecystectomy, as for:

- Unclear anatomic conditions and anatomical variation
- Suspicion of choledocholithiasis
- Suspicion of iatrogenic bile duct injury

Although intraoperative cholangiography is the method of choice in such situations, it can be unavailable or unfeasible from time to time. And even if laparoscopic cholangiography discovers a problem, it does not support a minimally invasive therapy but in general requires laparotomy and conventional surgical treatment (e.g., biliodigestive anastomosis). The same applies to the treatment of common bile duct injuries when suturing is technically demanding and thus has to be performed in an open fashion.

As a less invasive alternative to open common bile duct repair, again endoscopic support is of potential interest (La Greca et al. 2008). Intraoperative endoscopic retrograde cholangiography (ERC) might be superior to surgical cholangiography for examining the entire biliary system including the papilla Vateri. Moreover, it allows for immediate atraumatic therapy of encountered problems, for example, the extraction of stones in the case of a choledocholithiasis or placement of a biliary stent for treatment of leaks or stenosis (Iimuro et al. 2013). Interestingly, intraoperative ERC is considered less complex than it might seem (La Greca et al. 2008), especially when aided by biliary guidewire that was inserted via the cystic stump.

As compared to an open biliary repair or subsequent postoperative application of ERC, intraoperative endoscopic cholangiography reduces both the trauma and the postoperative stay.

10.9 Results

Following an initial hype for combined laparoscopic–endoscopic interventions in the early 1990s, this interventional technique was for years only applied in dedicated centers and at a low frequency. This fact is difficult to explain; however, we suppose that on the one hand, hybrid interventions require a high expertise for both laparoscopy and endoscopy, which interferes with its broad application. However, and due to the impressive development of laparoscopic surgery and the evolution of therapeutic endoscopy, this limitation is no longer present.

On the other hand, and maybe of much higher impact, we think the strict separation of laparoscopy and flexible endoscopy, or the corresponding departments, might have played a relevant role and brought hybrid interventions down to a niche procedure. In particular, restriction in the interdisciplinary dialogue and the need to schedule a hybrid procedure with respect to the timetables of two independent organizational units prevented the ubiquitous establishment of this technique.

However, just recently, combined interventions have gained popularity and have been rediscovered as an attractive modality by many (Kennedy et al. 2011). The active cooperation between gastroenterologists and surgeons is furthermore stimulated by the formation of viscero-medical centers that integrate both fields in one department and that support collaborative work such as hybrid procedures.

But the hype with regard to natural orifice transluminal endoscopic surgery (NOTES) also fathers this development, and when looking at the literature, one will notice that most NOTES interventions today are rather more a hybrid intervention or similar to «safety laparoscopy» than being a «pure NOTES» procedure.

Combined interventions in the lower gastrointestinal tract mainly focus on the handling of adenomas which can't be treated by endoscopy, thus benign lesions of large size or with an unsuitable position (up to 10% of lesions according to literature) (Table 10.2) (Cheung et al. 2012; Lee et al. 2013). As explained above, all resected adenomas have to be confirmed as «endoscopically unresectable» because of the size or localization and after repeated endoscopy. By combining endoscopy with laparoscopy, one is able to close the therapeutic gap between the respective modalities and to facilitate local atraumatic therapy for large endoluminal pathologies.

Although the complication rate of 5–10% of enlisted publications might appear relatively high, it has to be pointed out that most complications are minor wound abscesses or local infections. True complications such as insufficiency of the stapler row are extremely low and reported in literature in single cases only. The most serious complication to be found in literature is bowel perforation during intraoperative endoscopy and accounts for 1–2%. Accordingly, the increased risk for this complication has always to be addressed during preoperative patient information. As already mentioned, the higher risk for iatrogenic bowel perforation is due to a missing guidance of the abdominal wall during general anesthesia and due to the confined and awkward conditions for simultaneous colonoscopy. Also to be mentioned is the high rate of missed carcinomas to be found in resected specimens, with more than half of them requiring radical oncologic surgery. This high rate is explained by the size of resected tumors with a mean diameter of 3.7 cm but can also result from the fact that some of the lesions were not adequately accessible for reliable assessment. As an alternative to local hybrid resection, some institutions prefer primary radical resection of endoscopically unresectable adenomas by citing the high carcinoma rate (Hauenschild et al. 2009). In our opinion, however, extended surgery on the other hand results in overtreatment in almost 90% of patients and in an avoidable high complication rate. In addition, we could not find any report in literature on an adverse oncologic outcome after local resection of a carcinoma that had to be completed by oncologic resection in a second step. In conclusion, a local hybrid resection should be accomplished in all adenomas that are endoscopically unresectable. Obviously, the patient has to be informed with regard to the higher risk of malignancy and the need for additional surgery beforehand. For this reason, pathologists are asked to proceed the workup of specimens after hybrid resections with priority. To conclude, and with respect to the discussed conditions, combined interventions should be regarded as an attractive and atraumatic interventional technique that has a low complication rate and that can be easily implemented in most clinics.

Lesions of the submucosal layer and predominantly gastrointestinal stromal tumors are an ideal indication for upper GI hybrid interventions

Table 10.2 Combined laparoscopic–endoscopic colon resections

Author	Year	No. of patients	Hospitalization (days)	Complication rate (%)	No. of successfully treated pts.	Operation time	Mean tumor diameter (cm)	No. of pts. with HIEN	No. of pts. with carcinoma
Franklin	2009	176	1.1	9	150	97	3.7	n.a.	18
Wilhelm	2009	146	8	25	139	100	k. A.	n.a.	17
Grünhagen	2011	11	1	18	9	45	2.0	1	1
Wood	2011	13	2	15	10	n.a	n.a.	n.a.	1
Cruz	2011	25	1.5	8	19	93	2.4	n.a.	3
Lee	2011	65	1–5	4.4	48	145	3	n.a.	1
Goh	2013	30	2	13.3	22	105	1.4	8	2

n.a. not available

Table 10.3 List of published upper GI hybrid interventions

Author	Year	No. of patients	Hospitalization (days)	Complication rate (%)	No. of successfully treated pts. (*n*)	Operation time (min)	Mean tumor size (cm)	No. of resected GIST (*n*)	No. of NET/ Heterotop. pancreas
Schubert	2005	26	5.6	7,7	23	53–83	1.7–3.6	16	7
Mochizuki	2006	12	7	17	12	100	2.7	10	2
Novitsky	2006	50	3,8	8	50	135	4.4	50	0
Hiki	2007	7	7.4	0	7	169	4.6	6	1
Wilhelm	2008	93	7,4	7,5	87	90	3.7	62	31
Abe	2009	4	7	0	4	201	3.7	3	1
Tsujimoto	2010	20	11.6	0	20	157	3.8	16	4
Vecchio	2013	1	4	0	1	n.a.	2.0	1	0
Heo	2013	7	7.4	0	7	169	4.6	6	1
Schlag	2013	20		0	20	44	1.6	6	14

n.a. not available

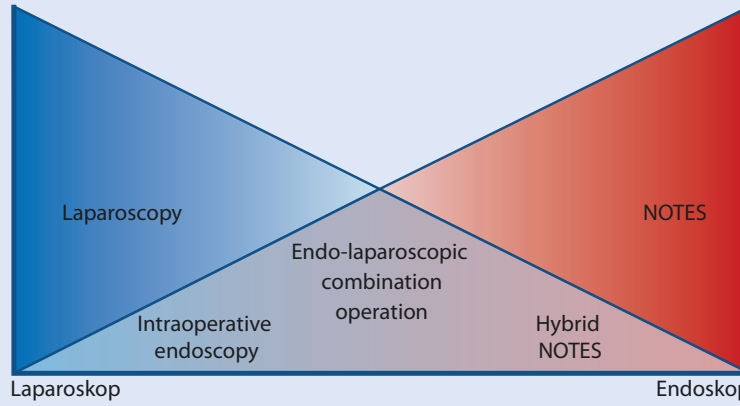

Fig. 10.23 In contrast to related interventional techniques such as NOTES and the so-called hybrid NOTES procedures, hybrid interventions are characterized by an equal contribution of endoscopy and laparoscopy. They have to be seen as a unique modality at the interface between conventional laparoscopy and the future of surgery or maybe NOTES

(Kosmidis et al. 2013). Thus, most publications in literature report on the therapy of this subtype of tumor (Table 10.3). Thanks to simultaneous intraoperative endoscopy, local tissue-sparing resection is feasible in the majority of cases after precise localization. If the tumor size does not exceed 2 cm, even endoscopic resection with full-thickness gastric wall closure can be achieved by highly expert endoscopists (Schlag 2013, Sarker et al. 2014). Endoscopic resection can also be applied to larger lesions; however, this then demands laparoscopic wall defect closure by suture. As has been shown by several studies in literature, local hybrid resection of GIST is followed up with low recurrence rates (<5%) and acceptably low complication rates (5%). The most frequent complication, postoperative bleeding from the stapler line, could be overcome by oversuturing in our series. Hybrid tumor resection is easily applicable to tumor sizes of up to 3–4 cm (7 cm) and avoids extended resection. In particular, lesions located in the pylorus and in the subcardial region benefit from combined endoscopic–laparoscopic tumor resection and can be treated without the need for extensive intestinal reconstruction.

The consequent application of endoscopic techniques during laparoscopic interventions has significantly reduced interventional trauma, and individualized therapy has emerged for a distinct group of patients (Fig. 10.23). When revising the development of hybrid interventions over the recent years, one can identify an increasing importance of flexible endoscopy and an increasing percentage of hybrid interventions that are conducted as «laparoscopy-assisted endoscopic resections.» If this development continues, we may anticipate a further evolution of hybrid interventions toward «pure NOTES» procedures. That is, to say, hybrid interventions can be regarded as the pioneers for flexible endoscopic surgery. And when reviewing the literature, one can find corresponding publications, for example, the combination of a local endoscopic full-thickness resection of an early gastric cancer that was complemented by laparoscopic lymphadenectomy (Cho et al. 2011). Accompanied by improved staging modalities and tumor biology assessment, we can anticipate the development of a new field for local tumor therapy.

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Supplementary Information

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Appendix A: Analgosedation

The question of analgosedation should be considered independently from the individual types of endoscopic examination. Due to the use of natural routes into the body, endoscopies are not very painful. Nevertheless, endoscopic examination is uncomfortable and anxiety provoking. In particular for patients who need regular endoscopic controls, it is important to maintain compliance; and for the examiner to ensure optimal conditions, analgosedation is to be recommended. Of course risks and benefits of analgosedation must be balanced in the light of individual patient requirements.

In Europe there exists an interdisciplinary S3 guideline for sedation in gastrointestinal endoscopy which was published in 2010 and revised in 2015 (Non-anesthesiologist administration of propofol for gastrointestinal endoscopy: European Society of Gastrointestinal Endoscopy, European Society of Gastroenterology and Endoscopy Nurses and Associates Guideline—Updated June 2015.

Dumonceau JM, et al. *Endoscopy*. 2015;47(12): 1175–89. doi: 10.1055/s-0034-1393414. German Guideline Update S3-guideline: «sedation for gastrointestinal endoscopy» 2014 (AWMF-Register-No. 021/014, publ. In: Z Gastroenterol. 2016;54(1):58–95. doi: 10.1055/s-0041-109680. Epub 2016 Jan 11).

The US guidelines of ASGE and SAGES were published in 2008 (► http://www.asge.org/uploadedFiles/Publications_and_Products/Practice_Guidelines/Sedation%20and%20Anesthesia%20in%20GI%20Endoscopy%202008.pdf).

These guidelines have the merit of describing an interdisciplinary consensus about analgosedation in endoscopy patients.

The reader is asked to study these guidelines. This short description does not cover all aspects of the guidelines. Of course every practical regime has to reflect the national medicolegal situation and traditions.

To provide a practical overview, the authors give some recommendations based on their personal experience and examples for common clinical situations.

1. Informed consent
   - An intended analgosedation has to be a part of the informed consent. Complications from this are more common than complications from endoscopy itself.
   - Information including possible complications but also about the time after leaving the hospital/medical office (barring from driving a car, avoidance of dangerous situations and decisions) are essential.
2. Logistic requirements for analgosedation
   - With regard to safety aspects, the logistic requirements should reflect not the standard treatment execution but the management of possible complications. With regard to this, the extent of precautions depends on the patient's condition and the intended procedures.
   - Standard requirements during the examination are:
     - Registration of minimally three vital parameters: pulse, oxygen saturation, blood pressure, and ECG where applicable
     - Safe i.v. route
     - Permanent oxygen insufflation
     - Holding ready of emergency drugs, instruments for tracheal intubation, ventilation devices, and devices for CPR
     - Option to alert a second doctor
   - Post-examination:
     - Permanent control of vital parameters till sedation has subsided completely
     - Release management with enduring driving ban
3. Patient-related precautions
   - The ASA classification provides a rough overview reflecting the ability for anesthesia. Furthermore, there are some aspects which have to be respected:
     - In patients with BMI >40, due to the lipophilicity of propofol, hard-to-anticipate problems with its pharmacodynamics can occur. That's why in these cases the standby of an anaesthetist is needed.
     - The same holds true for patients with obstacles for tracheal intubation.

- In patients for whom the use of a HF generator is planned, cardiac defibrillators and old types of pacemakers have to be inactivated before the procedure. ECG monitoring is required. If in doubt, contact the cardiologist.
- With regard to the possible consequent hypotension and bradycardia, the use of propofol in patients with coronary heart disease should be very critically examined.

4. Personal requirements

- All persons who take part in the analgosedation have to be prepared for their tasks. For nurses and physician assistants, there are special courses. Surprisingly, for doctors, there are few clear qualifications. Professional experience in intensive care and emergency is a good basis. The participation in special courses is also recommended.
- Some interpretations of the guidelines mention the requirement for a «third person.» The guideline text focuses on a «second» person with a specific qualified person who is dedicated to the surveillance of the patient. Because the attention of the endoscopist (and of his assistant if there is one) is occupied by the endoscopic procedure itself, they are not able to give the necessary attention to the analgosedation of the patient.
- In simple procedures and patients with a low-risk profile, a qualified physician can administer the initial medication and then hand over the surveillance to a qualified person. This qualified and experienced person should take no other responsibilities within the procedure.
- This means that the number of necessary persons depends from the complexity of the procedure. If the endoscopic procedure doesn't need an assistant (e.g., in diagnostic EUS), two persons are enough. Nearly all other procedures require three persons; surveillance and endoscopic assistance have to be carried out by different persons.

5. Recommended medications

- With regard to the choice of sedatives, the guidelines offer different solutions. Due to the atraumatic character of endoluminal endoscopy, analgesics are generally unnecessary. The most usual substance is propofol, which can be administered exclusively or in combination with a short-acting benzodiazepine.
- Proposals for practical use:
  - Examinations of short duration: If the expected examination time is lower than the half-life period of propofol (8 min), it will suffice as a single medication (e.g., in diagnostic EGD).
  - For longer examinations, first a single dose of benzodiazepine (1–5 mg) can be administered and then subsequent doses of propofol for continuation of the analgosedation.
  - The reference value for propofol is 0.5–1.0 mg/kg body weight for the first dose. Depending on the effect, further doses of 20–30 mg may be administered with attention to the delayed effect.
  - The provision of doses according to the need is to be recommended rather than continuous dosage, because in this way control of consciousness is better managed.
  - A continuous running fluid infusion ensures the permanent circulation of administered medications.

6. Care after analgosedation

- The responsibility of the endoscopy team extends to post-sedation management. This includes not only the time until full recovery from all effects of medication but also the whereabouts of the patient including driving ban.

Appendix B: Blood Coagulation and Anticoagulatory Therapy

General points:

- Preset limits of blood coagulation parameters (thrombocytes, INR, PTT) cannot be given for all patients and all types of endoscopic interventions. Such limits will not be sufficiently comprehensive for the biologic variability in medicine.
- Coagulation parameter limits should be adapted to the anticipated intervention. Coagulation requirements show great variability and differ significantly between diagnostic EGD and large-scale area mucosectomy or sphincterotomy.
- In our endoscopic clinic, we accept as a lower limit for smaller interventions thrombocytes 40,000/µl, Quick 40% (INR 1.9), and adapt these limits according to the invasiveness of the planned intervention. Some experts prefer 50,000/µl thrombocytes and Quick's of 50%.

Patients on anticoagulatory therapy (Table A.1):

- The lower limits and time frames given in the table are for orientation and should be adapted to the specific patient's situation and where necessary exceeded.
- Continuation vs discontinuation of anticoagulatory therapy is always a trade-off between the risk of a hemorrhagic and a thromboembolic event. In many cases, we accept a higher bleeding risk in favor of a lower thromboembolic risk, such as after recent myocardial infarction: clinical management of episodes of recurrent gastrointestinal bleeding is often easier and a lower burden for the patient than for recurrent thromboembolic events, e.g., reinfarction.
- Close collaboration of the endoscopist with the attending cardiologist, neurologist, or vascular surgeon is strongly advised.
- It should be considered whether an elective endoscopic intervention may be postponed to a time when there is less intensive anticoagulatory therapy (e.g., 6–12 months after placement of a drug-eluting coronary stent).
- Generally, we do not pause ASS, if clearly indicated, for most endoscopic interventions, as studies have not shown an increased bleeding risk under ASS (e.g., after polypectomies during colonoscopy; Manocha et al. 2012), but have demonstrated an increased cardiovascular event rate after pausing ASS (e.g., in GI bleeding; Sung et al. 2010). Attention should be paid to the increased risk of delayed bleeding.
- New anticoagulants are being actively introduced while this book is being edited. Please check for updated recommendations on a regular basis.

Table A.1 Summary of anticoagulatory medication of different classes, antidotes, and time frames for pausing prior to endoscopic interventions, if full restoration of blood coagulation is sought

Mechanism of action	Active component	Registered trade name	Half-life[a] [h]	Antidote	Delay before intervention
Vitamin K antagonists	Phenprocoumon	Marcumar	20–60	Vitamin K FFP PPSB	Appr. 5–7 days (guided by INR)
Factor Xa inhibitors	Rivaroxaban	Xarelto	5–13	No specific antidote available Consider PPSB, aPCC, r-FVIIa	24 h (to 48 h in patients with creatinine clearance <50 ml/h and in elderly patients)
	Apixaban	Eliquis	8–13		24 h
Direct thrombin inhibitors	Dabigatran	Pradaxa	12–14	No specific antidote available Consider PPSB, aPCC, r-FVIIa, HD	24 h (prolonged in impaired renal clearance)
Platelet inhibitors ADP antagonists (thienopyridine)	Acetylsalicylic acid (ASS)		2–3	No specific antidote available Consider PC, FFP	5–7 days
	Clopidogrel Ticlopidin Prasugrel Ticagrelor	Plavix Ticlid Effient Brilinta	7–8 12 2–15 7–8.5	No specific antidote available Consider PC, FFP	5–7 days 5 days 7 days 5 days
GPIIb/IIIa inhibitors	Abciximab Eptifibatide Tirofiban	ReoPro Integrilin Aggrastat	0.5 2.5 2	No specific antidote available Consider PC Consider HD for Tirofiban	(12–)24 h 2–4 h At start of intervention
Low molecular heparins	Dalteparin Tinzaparin Fondaparinux	Fragmin Innohep Arixtra	2 4 17–21	Protamine sulfate FVIIa	12(−24) h (prolonged in impaired renal clearance)

Modified from Parekh et al. (2014) and Rote Liste (2014)
aPCC activated prothrombin C complex, *FFP* fresh frozen plasma, *HD* hemodialysis, *INR* international normalized ratio, *PPSB* prothrombin concentrate, *r-FVIIa* recombinant activated factor VII, *PC* platelet concentrate
[a]The half-life is given for patients with normal renal clearance. Action of anticoagulants may surpass half-life significantly, such as in irreversible platelet aggregation inhibition by ADP antagonists

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