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Editors

Imaging in Bariatric Surgery

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Preface

Obesity represents an important public health issue worldwide. In European Union countries, overweight and obesity affect respectively 30–70% and 10–30% of adult population. In the USA 70% of the population is currently affected by excess weight or obesity.

The etiology of obesity is multifactorial, involving a complex interaction among genetics, hormones, and environmental factors. More importantly, it is associated with chronic comorbidities, physical or psychological symptoms, and/or functional limitations, which can have a substantial, negative impact on quality of life and mortality.

Unfortunately, diet therapy, with and without support organizations, is relatively ineffective in treating obesity in the long term, and there are currently no effective pharmaceutical drugs. At present, surgery represents the only effective therapeutic modality for morbid obesity.

The efficacy of surgery on weight reduction has been widely confirmed by a large literature. In addition to the effective weight loss achieved by patients undergoing bariatric surgical procedures, a substantial majority of patients with diabetes, hyperlipidemia, hypertension, and obstructive sleep apnea experience complete resolution or improvement of their comorbid conditions.

All therapeutic interventions need to have efficacy balanced against risk. In such an assessment, bariatric surgery does well, with operative 30-day mortality rate of 0.08% (0.31% in the long term).

Mortality is also significantly influenced by the surgical technique with laparoscopic procedures being safer than open surgery.

Because bariatric surgery is an effective and safe therapy, the number of procedures as well as the number of specialized surgeons is dramatically increasing and consequently the request for imaging. Imaging has a key role in assessing patients referred to bariatric surgery, both in preoperative and in postoperative settings.

The aim of this book is to address most of the issues that both radiologists and surgeons involved in bariatric imaging might encounter in clinical practice. Surgeons will find information about indications to imaging both in pre- and postoperative periods, considering imaging evolution and the potentials of new cross-sectional imaging techniques. Radiologists will learn about the best modality to choose to answer different clinical questions and the best technical approach. A detailed review of surgical procedures and consequent "new" postoperative anatomy is available. This is mandatory to interpret imaging and to understand promptly possible complications.

In the hope that the book will respond to your expectations, we hope you have a good read.

Latina, Italy Andrea Laghi
Latina, Italy Marco Rengo

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What's Behind the Obesity Epidemic

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Carlotta Pozza and Andrea M. Isidori

1.1 Introduction

Obesity is defined as an abnormal or excessive accumulation of fat that may impair health, and it is a chronic disease that is increasing in prevalence [1].

Global obesity rates have tripled in many countries of the World Health Organization (WHO) European Region since the 1980s, and the numbers of those affected continue to rise at an alarming rate [2].

Based on the latest estimates in European Union countries, overweight affects 30–70%, and obesity affects 10–30% of adults. In the USA 70% of the population are now affected by excess weight or obesity [3, 4].

It is now no exaggeration to state that obesity is an international epidemic. Moreover, it is no longer a disorder of the adult since obesity prevalence in children has accelerated rapidly affecting 21.1% of girls and 18.6% of European boys (Ahrens et al. 2014).

1.2 Definition and Diagnosis

Clinically, obesity is defined on the basis of the body mass index (BMI), calculated as weight in kilograms divided by height in meter squared. The WHO states that for adults, the healthy range for BMI is between 18.5 and 24.9. Overweight is defined as a body mass index of 25 to 29.9, and obesity is defined as a body mass index of 30 or higher (Table 1.1) [2].

These BMI cut points in adults are the same for men and women, regardless of their age.

For clinical and research purpose, obesity is classified into three categories: class I (30–34.9), class II (35–39.9), and class III (>40) [5]. With the growth of extreme obesity, researchers and clinicians have further divided class III into super obesity (BMI 50–59) and super-super obesity (BMI > 60).

The current used BMI cutoff values are based on morbidity and mortality studies in Caucasian population [6]. Several studies observed that some obese patients do not show expected metabolic abnormalities despite their substantial excess of body fat, demonstrating that while obesity increases the possibility of having complications, not every obese patient will develop them [7]. Although BMI is the

Table 1.1 Classification of obesity

Classification	Body mass index category
Underweight	<18.5
Normal weight	18.5–24.9
Overweight	25.0–29.9
Obese	>30.0
Class I	30.0–34.9
Class II	35.0–39.9
Class III	>40.0

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accepted method to classify obesity and it can be used to predict and evaluate disease risk in epidemiological studies, it does not differentiate the composition of lean versus fat tissue and therefore may lead to erroneous interpretations (Kushner et al. 2009).

Moreover, obese individuals differ not only in respect to the excess fat mass but also in its regional distribution in different body sites. It is important to distinguish between android obesity and gynoid fat distribution, in which fat is allocated peripherally around the body [6].

Indeed, central or visceral abdominal obesity is associated with substantially different metabolic profiles and cardiovascular risk factors than gluteal-femoral obesity. To assess these differences, it is useful to measure waist circumference (WC). Population studies have shown that people with larger WC have impaired health and increased cardiovascular risk compared with those with normal WC within the healthful, overweight, and class I obesity BMI categories. Abdominal fat is clinically defined as a WC of 102 cm or more in men and 88 cm or more in women (Kushner et al. 2009).

In addition to BMI and WC, there are other markers for excess body fat evaluation used for clinical practice, as the skinfold thickness and the waist-to-hip ratio [6].

Next to these descriptive classifications, the presence of obesity-related comorbidities is gaining importance as a discriminating factor, as captured by the Edmonton Obesity Staging System (EOSS) [8] and the Cardiometabolic Disease Staging (CMDS) system [9]. The current trend is to consider two types of obesity, the so-called eumetabolic obesity (not associated with comorbidities) and dysmetabolic obesity (associated with inflammation, insulin resistance, dyslipidemia, hypertension).

Finally, direct measure of body mass fat, through magnetic resonance imaging (MRI), computed tomography (CT), dual-energy X-ray absorptiometry (DXA), bioimpedance analysis, and total body water, is gaining interest to assess the obese phenotype, but more studies are needed before either can be routinely recommended for office use.

1.3 Pathogenesis and Etiology

The etiology of obesity is multifactorial, involving a complex interaction among genetics, hormones, and the environment [10]. Body weight is regulated by a multifaceted system, including both peripheral and central factors. *Ghrelin* is a circulating peptide hormone, originally isolated from the stomach, but it has also been identified in other peripheral tissues, such as the gastrointestinal tract, pancreas, ovary, and adrenal cortex. It is the only known peripherally acting orexigenic hormone and is responsible for stimulating appetite [11]. *Leptin*, another product of adipocytes, is also a central mediator of inflammation in obesity [12]. Leptin acts as a dominant long-term signal responsible for informing the brain of adipose energy reserves. In addition to adipose tissue, leptin is also produced in small amounts in the stomach, mammary epithelium, placenta, and heart. Leptin binds to specific receptors on appetite-modulating neurons and the arcuate nucleus in the hypothalamus, giving information about the status of the body energy stores, and it inhibits appetite. Leptin-deficient mice that lack leptin receptors have been shown to be hyperphagic and obese. True leptin deficiency in humans is rare; however, obese humans are, in part, leptin resistant.

Other factors involved in the regulation of body weight are *peptide YY* (PYY), secreted by the L cells of the distal small bowel and colon and released after a meal, by its signals to the hypothalamus cause delayed gastric emptying, thus reducing gastric secretion [13]; *cholecystokinin* (CCK), produced in the gallbladder, pancreas, and stomach and concentrated in the small intestine, released in response to dietary fat, regulates gallbladder contraction, pancreatic exocrine secretion, gastric emptying, and gut motility, which acts centrally by increasing satiety and decreasing appetite; and *glucagon-like peptide-1* (GLP-1), whose biological activities comprehend stimulation of glucose-dependent insulin secretion and insulin biosynthesis, inhibition of glucagon secretion and gastric emptying, and inhibition of food intake. Several other hormones, collectively indicated as adipokines, are produced by the adipocytes. The key secretory products are tumor necrosis factor-alpha (TNF-α), whose role in obesity has been linked to insulin resistance; interleukin 6 (IL-6), a pleiotropic circulating cytokine linked to inflammation, impairment of host defenses, and tissue injury; and adiponectin, an adipokine derived from plasma protein, which is insulin sensitizing, anti-inflammatory, and antiatherogenic.

Secondary pathologic causes of obesity include drugs and neuroendocrine diseases (hypothalamic, pituitary, thyroid and adrenal) (Table 1.2)

Table 1.2 Etiology of obesity

Environmental causes
Dietary factors
Lack of physical activity
Lifestyle factors
Neuroendocrine obesity
Hypothalamic obesity Trauma Tumors Inflammation Surgery Increased intracranial pressure
Cushing's syndrome
Hypothyroidism
PCOS
Growth hormone deficiency – Hypogonadism – insulinoma and hyperinsulinaemia – pseudohypoparathyroidism
Drugs
Antipsychotics
Antidepressants
Anticonvulsants
Steroids
Adrenergic antagonists
Serotonin antagonists
Oral hypoglycemic agents
Genetic and congenital disorders
Prader-Willi syndrome
Bardet-Biedl syndrome
Leptin deficiency
Albright hereditary dystrophy
Alstrom-Hallgren syndrome
Cohen syndrome
Carpenter syndrome
Beckwith-Wiedemann syndrome
Pseudohypoparathyroidism type 1a
Pregnancy and menopause
Eating disorders and psychological causes
Bulimia nervosa
Stress
Anomalous eating habits
Depression, lack of confidence, and self-esteem
Social factors

that should be excluded by the endocrinologist before other treatments are commenced.

1.4 Associated Comorbidities

Obesity is associated with chronic comorbidities [14, 15], physical or psychological symptoms, and/or functional limitations, which can have a substantial, negative impact on quality of life (stages 2–4 EOSS) [16] and mortality (stages 2–4 CMDS system) [3].

The most well-established weight-related comorbidities are insulin resistance, type 2 diabetes (T2D), and cardiovascular disease, the risks of which are proportional to BMI. Other recognized complications associated with overweight and obesity include obstructive sleep apnea, nonalcoholic fatty liver disease, osteoarthritis, polycystic ovary syndrome, and increased mortality [16, 17]. Hereafter are discussed the most frequent complications of overweight/obesity.

1.4.1 Insulin Resistance, Type 2 Diabetes, and Metabolic Syndrome

Obesity is often associated with the development of adipose tissue (AT) inflammation. Obesity-induced inflammation is a chronic, low-grade inflammation that produces much lower levels of circulating cytokines compared to classical immunity inflammation. It particularly resembles the inflammation observed in atherosclerosis, which is one of the complications of metabolic syndrome along with insulin resistance and lipid dysregulation [18]. Thus, obesity-induced inflammation may be a different kind of inflammation, namely, one that is the result of overnutrition and stress pathways that drive abnormal metabolic homeostasis (e.g., high levels of lipid, free fatty acids (FFA), glucose, or ROS). There is increasing evidence showing that inflammation is an important pathogenic mediator of the development of obesity-induced insulin resistance [19]. Adipose tissue (AT) contains immune cells, and obesity increases their numbers and activation levels, particularly in AT macrophages (ATMs). Other pro-inflammatory cells found in AT include neutrophils, Th1 CD4 T cells, CD8 T cells, B cells, dendritic cells (DCs), and mast cells.

AT in obesity acts as an endocrine organ that regulates the production of various hormones and cytokines, which include TNF-α and IL-6. More recently identified adipokines that promote inflammation include resistin, retinol-binding protein 4 (RbP4), lipocalin 2, IL-18, angiopoietin-like protein 2 (ANGPTL2), CC chemokine ligand 2 (CCL2), CXC chemokine ligand 5 (CXCL5), and nicotinamide phosphoribosyltransferase (NAmPT) [20]. Systemic metabolic inflammation can affect pancreatic islets through distinct mechanisms, contributing to beta cell failure in type 2 diabetes (T2D).

Obesity associated to hypothalamic inflammation is accompanied by the loss of the first phase of insulin secretion.

The risk of developing T2DM proportionately doubles with every 5–7.9 kg gain in weight. Conversely, T2DM impairs other weight-related problems, particularly heart failure, obstructive sleep apnea (OSA), and hypogonadism. The marked increase in the prevalence of obesity has played a major role in the 25% increase in diabetes. According to data from NHANESIII, two-thirds of the men and women in the USA with diagnosed type 2 diabetes have a BMI of 27 kg/m^2 or greater. The risk of developing diabetes increases linearly with BMI [21].

1.4.2 Hypertension

Hypertension is about six times more frequent in obese than in lean individuals [22]. Among men, the prevalence of high blood pressure increased progressively with increasing BMI, from 15% at a BMI of <25 kg/m^2 to 42% at a BMI of ≥30 kg/m^2. Women showed a pattern similar to that of men; the prevalence of hypertension being 15% at a BMI of <25 kg/m^2 to 38% at a BMI of ≥30 kg/m^2 [23]. Obesity is associated with increased blood flow and vasodilatation. Although cardiac index (cardiac output divided by body weight) does not increase, cardiac output and glomerular filtration rate do [24].

Increased renal sodium retention also contributes. Other factors considered responsible for obesity-related alterations include enhanced sympathetic tone, activation of the renin-angiotensin system (RAS), with elevations of circulating renin, angiotensinogen, and angiotensin II, despite the increased renal sodium retention, hyperinsulinemia, structural changes in the kidney, and elaboration of adipokines [24].

1.4.3 Dyslipidemia

The typical dyslipidemia of obesity consists of increased triglycerides (TG) and FFA, decreased HDL-C with HDL dysfunction and normal, or slightly increased LDL-C with increased small dense LDL [25].

The development of small dense LDL in obesity is mainly due to increased TG concentrations and does not depend on total body fat mass [26]. The concentrations of plasma apolipoprotein (apo) B are also often increased, partially because of hepatic overproduction of apo B-containing lipoproteins [27, 28].

1.4.4 Cardiovascular Disease

The incremental increases in left ventricular filling pressure and volume throughout time may produce chamber dilation. This leads to increased wall stress, which predisposes to an increase in myocardial mass and eventually to left ventricular hypertrophy, typically of the eccentric type. Left atrial enlargement may also occur, due to left ventricular hypertrophy (LVH) in long-standing obesity and/or the effects of concomitant hypertension, and as a consequence may mediate the risk of atrial fibrillation associated with obesity. Age and cardiac hypertrophy predispose to left ventricular systolic dysfunction. Moreover, lipid deposition can impair tissue and organ function because the size of fat around key organs may increase organs modifying their function. Also, lipid accumulation can occur in ectopic sites, within nonadipose cells, and contribute to cell dysfunction or death (lipotoxicity).

Thus, through different mechanisms (increased total blood volume, increased cardiac output, LVH, left ventricular diastolic dysfunction, lipotoxicity), obesity may predispose to heart failure. [29].

1.4.5 Female Dysfunctions

Age of menarche generally occurs at a younger age in obese than in normal-weight girls, and there is evidence that in adolescent and young women, the age of onset of obesity and menstrual irregularities are significantly correlated.

Fertility seems to decline in women with increasing obesity, whether they have or do not have polycystic ovarian syndrome (PCOS). Mechanisms by which obesity influences the pathophysiology and clinical expression of PCOS are complex and not completely understood [30]. However, obesity is believed to play a distinct pathophysiological role in the development of hyperandrogenism in women with PCOS. Insulin acts as a true gonadotropic hormone [31]. At ovarian level, by acting through its own receptors and the insulin growth factor (IGF) receptor type I, insulin synergizes LH action and stimulates ovarian steroidogenesis both in granulosa and thecal cells. Moreover, insulin seems to increase pituitary sensitivity to gonadotropin-releasing hormone (GnRH) action, overstimulating ovarian androgen production. The GH/IGF-1 system has a role in favoring altered ovarian androgen secretion and granulosa cell function in PCOS [31]. IGF-1 bioavailability appears to be reduced in obese than in normal-weight PCOS women, as a consequence of the combined low GH and high insulin levels, which depends on obesity per se [32].

The association between obesity and infertility in women has long been recognized. Epidemiological studies have demonstrated that in the fertile period of their life, obese women frequently present with menstrual cycle alterations and chronic or intermittent anovulation [32, 33].

Obesity may affect fertility and reproduction in women by disturbing spontaneous ovulation, by interfering with the efficiency and outcomes of assisted reproductive technology, and by worsening the physiological process and delivery in pregnancy [34].

1.4.6 Male Dysfunctions

There is a well-known link between obesity and testosterone deficiency (hypogonadism), and although there appears to be a complex interplay between body composition, obesity, androgen levels, vascular disease, and T2DM, the exact mechanisms, which lead to hypogonadism in obese men, have yet to be determined. Male obesity is commonly associated with testosterone levels within the hypogonadal range. An increased aromatase activity within adipocytes results in the peripheral conversion of testosterone into estradiol and a subsequent rise in serum estradiol levels. Estradiol exerts a negative feedback effect on LH secretion and suppresses the hypothalamic-pituitary-testicular (HPT) axis, thus leading to a reduction in plasma testosterone levels and secondary hypogonadism. Inflammatory mediators associated with obesity may also contribute to the suppression of the HPT axis. Inflammatory mediators may exert a direct inhibitory effect on the HPT axis or may contribute to secondary hypogonadism through indirect mechanisms such as worsening of insulin resistance [35]. Hypogonadism can itself worsen obesity and promote increased fat mass that in turn may worsen the hypogonadal state.

Erectile dysfunction and reduced male fertility are associated with obesity and are thought to be mediated by low testosterone levels and by the elevated levels of several pro-inflammatory cytokines, such as interleukin 6 (IL-6), interleukin 8 (IL-8), and C-reactive protein (CRP) [36]. Obesity has been linked to reduced sperm count, increased DNA fragmentation in sperm, and reduced sperm motility in proportion to the degree of obesity [32].

1.4.7 Osteoarthritis

Osteoarthritis (OA) is the most common rheumatic disease in the world and represents the first cause of disability in the world after 40 years old [37]. The primary etiology of OA in obesity tends to be persistent loading during joint movement and locomotion, but inflammatory and metabolic characteristics of obesity affect joint health as well [38]. The risk of knee osteoarthritis is strongly and proportionally associated with BMI. Obese individuals are at increased risk of distal extremity injuries and tendinopathies.

1.4.8 Obstructive Sleep Apnea

Several respiratory complications are associated with obesity. Obese patients have an increased demand for ventilation and breathing workload, respiratory muscle inefficiency, decreased functional reserve capacity, and expiratory reserve volume. These often result in a ventilation-perfusion discrepancy, especially in the supine position. Sleep apnea is defined as repeated episodes of obstructive apnea and hypopnea during sleep, together with daytime sleepiness or altered cardiopulmonary function. The prevalence of sleep-disordered breathing and sleep disturbances rises dramatically in obese subjects, and obesity is by far the most important modifiable risk factor for sleep-disordered breathing.

Obesity increases the prevalence of sleep-disordered breathing tenfold. This rise in incidence is proportional to weight gain [12, 29].

1.4.9 Cancer

There is a strong association between elevated BMI and cancer risk and between BMI and cancer mortality related to esophageal, colon, rectum, liver, gallbladder, pancreas, kidney, non-Hodgkin lymphoma, multiple myeloma, and prostate cancer. Obesity leads to 20–35% of all the cancers. The major candidates relating obesity to cancer are those cytokines that cause insulin resistance: leptin, IL-6, TNF-a, adiponectin, and FFAs [39, 40]. Insulin resistance and hyperinsulinemia promote the production of insulin-like growth factor-1 (IGF-1). Many cancer cell lines, including prostate and colon, have IGF-1 receptors. Visceral adipocytes, by way of lipolysis, increase the circulating level of FFAs that may have cancer potential both directly, by causing cellular proliferation, by directly stimulating IGF-1, and indirectly, through insulin resistance [12].

1.4.10 Psychological Disorders

Obesity may also have psychological effects: obese individuals have a greater likelihood of experiencing depressive symptoms than non-obese individuals [odds ratio 1.26, 95% confidence interval (CI) 1.17–1.36] ($p \leq 0.001$), so it is important to consider both diseases and their possible association due to major health cost and involvement in life quality [3, 41].

Conclusions

Obesity is a heterogeneous disease, and individualizing therapy is mandatory. Treatment approaches should take into account the underlying causes of obesity. If a complication from obesity exists, targeting both the excess weight and the comorbid disease would be desirable to improve benefit.

The American Association of Clinical Endocrinologists (AACE), the American Medical Association, the Obesity Society (TOS), and the Endocrine Society all classify obesity as a disease and recognize that it requires treatment [3, 42].

Modest weight loss with lifestyle modification programs can have long-term health benefits, including improved lipid and glycemic control and reduced risk of T2DM. However, low adherence can severely prejudice their long-term weight loss efficacy. Bariatric procedures seem to be more effective than nonsurgical interventions in terms of weight loss and may decrease the long-term risk of comorbidities, as well as overall mortality. However, bariatric surgery is not suitable or feasible for all people with obesity. Pharmacological options have the potential to connect the treatment gap between lifestyle modifications and bariatric surgical procedures [3], but target individual complications may result in problematic polypharmacy [3]. An appropriate therapeutic approach aimed primarily at treating the causes of obesity and to achieve a reduction in body weight is needed in order to reduce obesity comorbidities.

The case for a preventive approach to the obesity epidemic is compelling. Obesity poses one of the most significant threats to population health that is currently faced.

Key Points

1. Obesity is defined on the basis of the body mass index (BMI) based on morbidity and mortality studies in the Caucasian population.
2. The etiology of obesity is multifactorial, involving a complex interaction among genetics, hormones, and the environment.
3. The most well-established weight-related comorbidities are insulin resistance, type 2 diabetes (T2D), and cardiovascular disease, the risks of which are proportional to BMI.

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2 Surgical Approaches to the Treatment of Obesity

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Laparoscopic adjustable silicone gastric banding (LAGB) was the first bariatric procedure to be performed by a laparoscopic approach. Introduction of LAGB into clinical practice was an immediate success in Europe as well as in Australia. Although sleeve gastrectomy, standard Roux-en-Y gastric bypass (RYGBP), and biliopancreatic diversion with duodenal switch (BPD-DS) currently represent the majority of laparoscopic bariatric/metabolic procedures in the United States and Canada, laparoscopic gastric banding during the last 10 years has been growing acceptance by physicians as well as by patients. The idea behind the operation is to "create" a small pouch in the upper part of the stomach with a controlled and adjustable stoma, without stapling, thus limiting the daily food intake (restrictive procedure). The silicone prosthesis is placed around the stomach just below the gastroesophageal junction, creating a 15–20 mL pouch (virtual pouch) (Fig. 2.1). This operation does not involve neither rerouting of food through the upper gastrointestinal tract nor exclusion of intestinal segments. The weight loss process in the short and long term is due to the food intake restriction and early satiety. In the highest quality study, excess body weight loss at 1 year after LAGB is 48%. At this time the hypertension, diabetes, dyslipidemia, and sleep apnea resolution rate were about 55%, 58%, 42%, and 45%, respectively [1]. The LAGB represents the bariatric procedure with the lower reported incidence of short- and mid-term adverse events [2–4]; however, long-term data show a higher incidence of postoperative acute complications leading to band repositioning or removal and eventually conversion to other procedures [5–7].

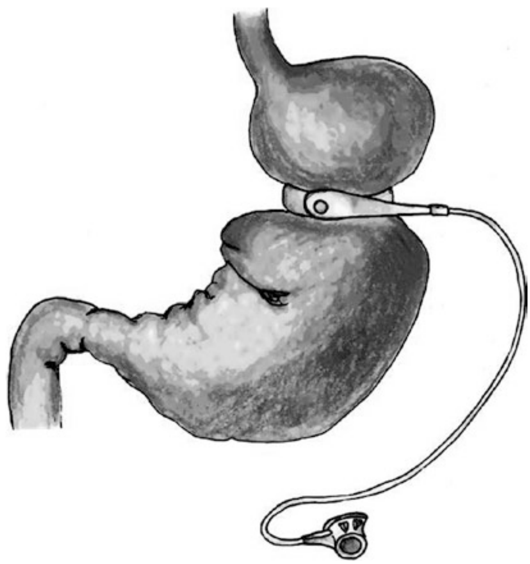

Fig. 2.1 Gastric banding

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2.1 Pouch Dilation

The major complications are pouch dilation (acute or chronic) often referred to as "slippage," erosion, and permanent or recurrent outlet obstruction. Slippage is the most common LAGB complication and the leading cause of reoperation. It can develop early or late during the postoperative course. It reported incidence of 1–20%, in the published series [5–12], dropped (event 0.9%) after the surgical technique, and the prosthesis evolved during the years [5, 9, 13]. It consists in the dilatation of the gastric pouch, above the band, in three different modalities: anterior, posterior, or symmetrical. Chronic pouch dilation presents with a gradual onset of symptoms as food intolerance, dysphagia, decrease in satiety, and sense of restriction. Its diagnosis and treatment are usually managed by the bariatric surgeon. An acute slippage is characterized by persistent abdominal pain, vomiting, and eventually obstructive symptoms. The incidence of acute slippage dropped to about 2–10% after the positioning technique of the band through the pars flaccida has been generally adopted (24% with the initial peri-gastric technique) [5]. The radiological diagnosis is based on the modified orientation of the band on plain abdominal X-ray, associated with an enlarged gastric pouch at the upper GI series [14]. Band position, connection tube location, and continuity with the access port should be always checked both on plain and contrast X-ray. Emergency treatment consists in complete band deflation through the subcutaneous port system, nasogastric tube positioning in the pouch (possibly under radiographic control), and intravenous administration of fluids, antiemetics, and proton pump inhibitors [5, 8, 9]. This should determine a significant improvement of the condition and allow time to refer the patient to the bariatric center. Complete deflation should be done under strict aseptic conditions. After having determined the port location either by palpation or fluoroscopy, a non-coring Huber needle is smoothly introduced percutaneously through the dome of the port until the metallic bottom is reached, and then the saline solution can be aspirated. Good results can be achieved with conservative treatment, especially in the symmetrical dilation, but if symptoms persist for more than 3–5 days, surgical treatment is needed to prevent gastric pouch ischemia. Laparoscopic approach in case of acute slippage is effective in over 95% of the cases and is the standard choice, provided that no gastric necrosis is found [5, 8, 9, 13].

2.2 Gastric Obstruction

Food bolus obstruction can be the cause of an acute, persistent dysphagia. It should be conservatively managed in the same manner as acute slippage. If band slippage is not confirmed by gastrografin swallow, band deflation, intravenous fluids, and even endoscopic removal of the bolus should be done. If the treatment is successful, the patient should be encouraged to obtain nutritional counseling and bariatric surgeon's reevaluation [9].

2.3 Complicated Intragastric Band Migration

Intragastric band migration (incidence 0.8–4%) is usually diagnosed at the radiological or endoscopic follow-up and usually is not a surgical emergency [8, 10, 12, 15, 16]. Intraoperative gastric wall trauma and tight band placement may account for early erosion; high band pressure, band overinflation, and dietary noncompliance can cause late band erosion. Band removal is mandatory because of the risk of complications as hemorrhage or perforation but is part of a standard approach in a bariatric center, which includes serial upper GI endoscopies. Most cases do not require emergency surgery. Chronic melena, with chronic anemia, in the absence of abdominal symptoms and with a stop of weight loss or even weight regain, is a sign of latent band erosion and possible intragastric migration [6–10, 12]. Hemorrhage from an eroded band has been reported [17]. Port site infection might be a sign of band erosion into the gastric wall [8, 9]. Acute port infection, with evident local signs, like port site inflammation, abscess, or cutaneous fistulas, requires urgent surgical drainage and referral to the bariatric center for further investigations.

2.3.1 Roux-en-Y Gastric Bypass

Laparoscopic Roux-en-Y gastric bypass with isolated gastric pouch was described in1993 by Wittgrove et al. For a long time, the RYGBP has been the most largely performed bariatric/metabolic procedure in the USA (Fig. 2.2). The standard gastric bypass procedure consists in (I) creation of a small, (15–30 mL) isolated gastric pouch using an endoscopic surgical stapler, accompanied by a bypass of the remaining stomach, duodenum, and first tract of jejunum, and (II) reconstruction of the GI tract with the Roux limb with a biliary loop length of 30–75 cm and alimentary limb length of 100–150 cm. In the variant "long limb," the length of the alimentary limb is 150–250 cm; in the "distal" RYGB, the common channel length is 150 cm, measured from ileocecal valve. The latter variant is more similar to the BPD inducing more intestinal malabsorption than standard LRYGB, which produces a limited malabsorption of around 30% of lipid. In a high-quality study, excess body weight loss at 1 year was 76% after standard RYGB. Blood pressure decreases significantly after this procedure, and it has been shown that at 1 year of follow-up, 46% of patients achieved complete resolution of hypertension, while 19% showed an improvement. The RYGB prevents diabetes in 99–100% of patients with impaired glucose tolerance and leads to clinical resolution of 80–90% of newly diagnosed cases of T2DM. Moreover, after RYGBP, a rapid improvement in insulin resistance with in few days has been described. After 8 years, RYGBP was associated with an EWL of 69%, hypertension, diabetes, dyslipidemia resolution rate of 66%, 82%, and 40%, respectively [18].

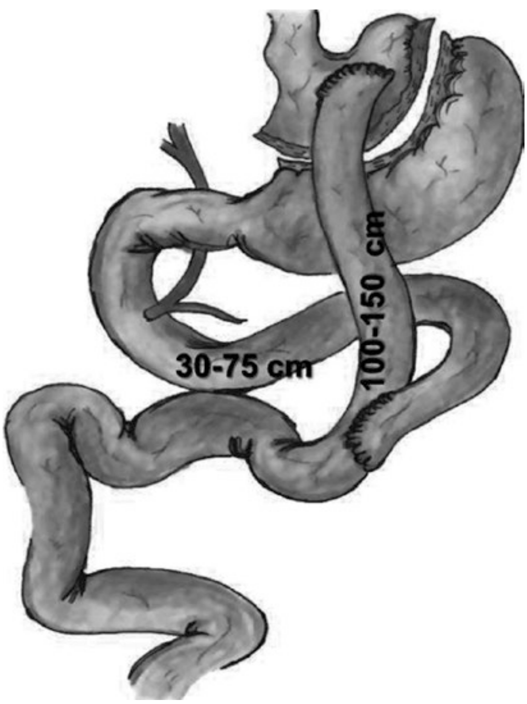

Fig. 2.2 Gastric bypass

Laparoscopic mini- (or single-anastomosis) gastric bypass is a new alternative to standard RYGB. Developed by Dr. Robert Rutledge in 1997, this procedure is becoming popular because of its simple surgical technique (single, gastrojejunal anastomosis) and preliminary results that reported a lower complication rate, a similar efficacy, including weight reduction and control of DM, compared to standard RYGBP.

2.4 Anastomotic Leak

Anastomotic leak after GBP is a life-threatening complication (incidence 0–6.1%) [9, 19]. It presents some problems: timing (early or late), clinical presentation (from subclinical to sepsis), diagnosis (gastrografin swallows, CT scan, and blood counts), and treatment (conservative, including fluid resuscitation, antibiotics, analgesia, endoscopic stent, and transfer to the bariatric unit when possible). Surgical emergency treatment should be considered in a hemodynamically unstable patient with severe, persistent symptoms: intense washout of the abdominal cavity and multiple drain placement should be considered. Laparoscopic approach is the best option if experience is present [9]. Final surgical treatment should be referred to the bariatric center.

2.5 Complicated Marginal Ulcer

Marginal ulcer is a peptic ulcer on the mucosa near the site of the gastrojejunal anastomosis. It can occur early (1–3 months) or late after a GBP. It is located either on the anastomosis (50%) or the jejunum (40%); its reported incidence ranges between 0.3 and 16%, and several risk factors are involved (operative technique, type of absorbable/nonabsorbable sutures used, patient age, history of previous gastric surgery, preoperative diabetes, coronary artery disease or peptic ulcer disease, and the use of nonsteroidal anti-inflammatory medications or tobacco) [20–22]. In a large cohort study, prior or current tobacco use remained the only independent risk factor for ulcer persistence after treatment [22]. The most common presenting symptom is pain (63%) followed by bleeding (24%), but perforation can occur. Perforated marginal ulcer incidence after GBP is ≤1%. The clinical picture is similar to any other visceral perforation: severe epigastric pain, tachycardia, fever, and leukocytosis, with free air on plain radiographs or CT scan. Surgical management is required; it can be performed by laparoscopy or laparotomy. It may require surgical revision of the anastomosis, with significant morbidity, but successful management with omental patch has been also reported [23, 24]. A gastrostomy tube in the excluded stomach should be considered for enteral nutrition, and high doses of PPI are always associated [9, 20, 25].

Stricture of the gastrojejunostomy after a Roux-en-Y gastric bypass is reported in 3 to 27% of cases. Quite often, however, the presence of a marginal ulcer can narrow the anastomosis or the efferent limb, causing symptoms of obstruction that can be mistaken for the result of a stricture of the anastomosis due to scarring [20, 24, 25].

2.5.1 Biliopancreatic Diversion

Scopinaro first performed the biliopancreatic diversion (BPD) in 1976 in Genova (Italy). This operation induces controlled malabsorption without many of the potential side effects caused by bacterial overgrowth and indiscriminate malabsorption associated with the jejunoileal bypass, which is now completely abandoned. This operation combines removal of two thirds of the stomach (distal gastrectomy) with a long intestinal bypass (common channel 50 cm, alimentary limb 250 cm). The operation includes cholecystectomy and liver biopsy.

The procedure was later modified by Hess with a variant that he called "duodenal switch" in 1986 that was first performed laparoscopically by Gagner in 1999. Instead of performing a distal gastrectomy, a "sleeve gastrectomy" along the vertical axis of the stomach (volume of remnant 70–150 mL) was proposed, preserving the pylorus and initial segment of the duodenum, which is then anastomosed to a segment of the ileum, similarly to the BPD, to create the alimentary segment (common channel 100 cm). Preservation of the pyloric sphincter is designed to be more physiological. The sleeve gastrectomy decreases the volume of the stomach and also decreases the parietal cell mass, with the intent of decreasing the incidence of ulcers at the duodeno-ileal anastomosis. These procedures produce selective malabsorption by limiting food digestion and absorption to a short, common ileal segment. The potential for nutritional complications exists. Patients undergoing the biliopancreatic diversion or duodenal switch procedure require close long-term medical follow-up and regular monitoring of fat-soluble vitamins, vitamin B12, iron, and calcium. Scopinaro et al. report the long-term outcome of BPD in a series of 312 obese patients with T2DM. Fasting serum glucose concentration fell to within normal values in all but two of the patients and remained in the physiological range in all but six, for a mean follow-up of 10 years [26]. Inabnet reported recently a hypertension and dyslipidemia resolution rate of 52.9 and 64%, respectively, after BPD-DS. In order to reduce operative morbidity and mortality in high-risk superobese patients, BPD-DS was divided in two stages: laparoscopic sleeve gastrectomy (LSG) as first stage followed after 6–12 months and by second stage consisting in duodeno-ileostomy and ileo-ileostomy.

Biliopancreatic diversion along with its variations is the bariatric/metabolic procedure with the higher reported estimated weight loss. Patients require particular attention, especially in the emergency room setting, for the changes in their gastrointestinal (GI) anatomy and physiology following surgery [27, 28]. Early or late complications of BPD or DS are rare and often require the experience of a bariatric surgery team for their prompt resolution. Many complications that might necessitate a general surgeon's emergency attention are complicated marginal ulcer (hemorrhage or perforation), bleeding, small bowel obstruction (SBO) due to internal hernia (biliopancreatic limb, alimentary limb, or the common channel) or incisional hernia, small bowel or gastric perforation, leak from staple line or anastomoses, intra-abdominal abscess, and anastomotic stenosis [28–30]. Specific late complications, even if not surgical, might be observed in an emergency setting: protein malnutrition (often not properly treated in a nonspecialized center), severe anemia, and Wernicke's encephalopathy [27–29]. Stabilization of the patient is usually possible in order to transfer the patient to a specialized bariatric center. Particular attention should be addressed to appendicitis or cholelithiasis after BPD or DS. Initial BPD included cholecystectomy, appendectomy, and hepatic biopsy [31], but after the introduction of laparoscopy and technical evolution to DS, these procedures are no longer routinely performed.

2.6 Sleeve Gastrectomy

Results obtained in terms of weight loss and resolution of comorbidities after LSG encouraged and stimulated the diffusion of this operation inducing several authors to propose this procedure as a primary bariatric procedure. In fact, LSG is a technically simple surgical procedure with a low complication rate and negligible long-term nutritional deficiencies. The effect on weight loss and resolution of comorbidities have been attributed to the reduction of the gastric capacity

Fig. 2.3 Sleeve gastrectomy

(restrictive effect) and/or to the orexigenic and anorexigenic intestinal hormone modification (hormonal effect).

Laparoscopic sleeve gastrectomy (LSG) (Fig. 2.3) is today recognized as a stand-alone procedure that originates from the two-stage approach of the biliopancreatic diversion with duodenal switch (BPD-DS). Early staple line complications are rare but most feared; bleeding and/or leaks are usually managed by the bariatric center in the immediate postoperative days. Depending on the local regional circumstances, more and more bariatric procedures, including sleeve gastrectomy, are performed nowadays on a very short hospitalization, with early discharge as standard of care. Therefore, the general surgeon can be confronted even with early complications like bleeding or acute leaks.

2.7 Suture Line Leakage

Suture line leakage rate after LSG ranges between 0.7 and 7%, depending on the series and the patient characteristics [32], with a risk ranging between 1.5 and 2.4% in recent systematic reviews and meta-analysis [33, 34]. Revisional surgery after initial bariatric procedure (conversion of gastric banding or vertical gastroplasty to LSG or gastric bypass) can increase the fistula rate up to 20% [32]. The critical areas for leakage are the top of the suture line, near the gastroesophageal junction (89%), and the transition point between sequential cartridges. Postoperative leaks may be classified into acute, late, very late, and chronic [32, 35, 36]. In a large retrospective study including 2834 patients, the leaks were diagnosed at a median of 7 days postoperatively, with 73% of the cases at 3–14 days after discharge [37]. Symptoms and signs suggestive of a localized or generalized peritonitis (pain, fever, tachycardia, tachypnea, often left pleural effusion, and pain in the left shoulder) in a patient who recently had bariatric surgery are likely due to a late fistula. Abdominal plain X-rays and contrast X-ray studies may assist in the diagnosis, but in all suspected cases, a CT scan with oral gastrografin is essential. Misdiagnosis will worsen the patient's future evolution.

The CT scan usually shows three possible pictures:

1. High staple line fistula (esophagogastric junction) along with a left subdiaphragmatic collection.
2. "Bubbles" in the peri-gastric fat near the staple line and a peri-gastric fluid collection without evidence of contrast medium leak.
3. Multiple leaks and diffuse fluid collection in the latter case; an emergency laparoscopy/laparotomy (according to the local skill) may be indicated to carry out a lavage of the upper abdominal cavity and drainage as a first emergency surgical step. Conservative treatment including bowel rest, fluid resuscitation, antibiotics, aspiration of esophageal and gastric secretions, nutritional support, analgesia, endoscopic stent, and transfer to the bariatric unit is appropriate, but experienced intensive care, endoscopy, and radiology units may be required. Surgical emergency treatment should be considered in a hemodynamically unstable patient with severe, persistent symptoms and an acute fistula or a late fistula with diffuse fluid collection. Laparoscopic approach is the best option if experience is available [9] and can accomplish extensive peritoneal washout, identification of the fistula site (check first the esophagogastric junction), and multiple drainage.

No attempt of correction of the staple line defect is usually indicated. Three main objectives are pursued: sepsis control, prevention of abdominal recontamination, and nutritional (parenteral and enteral) support [35, 38–40]. All other cases of late staple line fistula, if stable, should be referred to the bariatric center where the best management strategy can be adopted. Their treatment is based on percutaneous drainage plus parenteral/enteral nutrition and antibiotics. An endoscopic prosthesis can be positioned in selected cases and/or endoscopic fibrin glue applied [32, 41–44].

2.8 Mid-Gastric Stenosis

Persistent vomiting and food intolerance can be caused by a mid-gastric stenosis (incidence 0.7–4%, usually less than 1%) as a result of a sleeve gastrectomy calibrated on a too narrow tube or due to the oversewing of the staple line [14, 41]. After conservative treatment of dehydration, the patient should be referred to the bariatric center for endoscopic or radiological dilation (usually the patient requires three to four endoscopic/radiological outpatient sessions) [45]. Unsuccessful treatment might rarely determine an elective conversion to gastric bypass or seromyotomy for a long stenosis [14].

2.9 Gastric Plication

Gastric plication is an emergent bariatric operation that was re-proposed a few years ago, after its initial description three to four decades ago [46], and improved by the laparoscopic approach and recent experimental studies [47, 48]. Laparoscopic greater curvature gastric plication (LGP) is still an investigational procedure, popular in the Middle East and Central America [49].

In the LGP the dissection of the greater gastric curvature started 5 cm from the pylorus up to the angle of His, left undisturbed. A bougie was inserted into the stomach. Gastric plication was performed starting at the His angle. A running, extra-mucosal, nonabsorbable suture was performed as a first row. A second row of extra-mucosal, nonabsorbable, interrupted sutures was then added in order to tighten the plication.

Experience with management of complications is limited: the two systematic reviews, available to date, include only 307 and 521 patients [49, 50]; their data have to be interpreted with caution; the low follow-up rate of several published series may imply a selection bias, and complications may be underreported [49]. Average complication rate is 8 and 15.1%; reoperation rate is 4.6 and 3%. Prolonged nausea, vomiting, and sialorrhea are common and may require readmission for intravenous administration of antiemetics, prokinetics, and hydration [50, 51]. Reported major complications are gastric obstruction, bleeding (intraluminal upper GI bleeding or intraperitoneal), leaks, and perforations.

Gastric obstruction is the most common reason for reoperation. It is often due to adhesions and fold prolapse or edema, followed by serous fluid collection within the virtual cavity between the folds. It can occur either in the early postoperative period or several weeks after the operation [51], and it may require treatment by a non-bariatric team. Initial conservative treatment (anti-inflammatory and PPIs) can be attempted. If vomiting does not improve, gastroscopy could resolve the obstruction by fold manipulation, but laparoscopic partial or complete reversion of the plication will become necessary in case of refractory obstructive symptoms [52], and a referral to the bariatric center is recommended whenever possible. Acute gastric herniation through the sutures has also been described [49, 51]. Leaks after LGP are documented in 1.6% of patients [50]; they range from minor leaks to gastric perforation, determined either by the manipulation of the electrosurgery devices or inadequate technique, causing ischemia or stenosis of the gastric tube [48, 49]. Prolonged postoperative nausea and forceful vomiting may also be involved in a leak development. Treatment of peritonitis is indicated, with copious lavage of the abdominal cavity; suture invagination of a perforation within the stomach wall or partial or total reduction of the plication may be indicated.

2.10 Non-procedure-Specific Acute Complications

2.10.1 Bleeding

Bleeding can be a consequence of the staple line or other sources [10, 12, 17, 41]. Trocar site bleeding, splenic injury, or liver lacerations from retractor injury are rare but possible hemorrhage sources. Usually these complications appear in the first 48 h after surgery, when the patient is still under bariatric specialist surveillance, but routine early discharge policies can bring an early postoperative bleeding to the attention of a general surgeon or an emergency physician. Although the clinical picture of bleeding often leaves no room for doubts (anemia, hypotension, tachycardia, hematemesis, and melena), the site of bleeding and the corresponding control can be a challenge. Early bleeding from a staple or suture line can be extra- or intraluminal. Most early upper gastrointestinal, intraluminal hemorrhage will manifest with hematemesis and melena, and their treatment does not differ from any other upper GI bleeding in a non-bariatric patient. In all cases, management includes serial blood counts, good intravenous access, fluids administration, stop of anticoagulants, monitoring of vital signs, and upper GI endoscopy. If the endoscopist is familiar with the anatomic changes related to the bariatric procedure, endoscopy may reveal the bleeding point from the inner side of the staple line and control it by adrenaline injection, electrocoagulation, or endoclips if good visualization is obtained. The endoscopic examination for perforation at the bleeding site should be not omitted. Late bleeding in a gastric bypass can present relevant peculiarities. Heneghan et al. reported an incidence of 0.94% of 4466 patients who underwent GBP during a 10-year period [53]. Bleeding occurred within 30 days in 71% of the patients, and the etiology included staple lines, iatrogenic visceral injury, or mesenteric vessel bleeding. The authors report that 43% of the cases required operative intervention to achieve hemostasis. A significant amount of later hemorrhage in a gastric bypass is related to a marginal ulcer. Severe hemorrhage or perforation can be faced by a general surgeon as reported [9, 20]. Endoscopic management is essential, and only its failure can indicate an angiography (selected cases) or surgical exploration. The jejuno-jejunal anastomosis of a gastric bypass or the ileoileal anastomosis in a biliopancreatic diversion can also be responsible for bleeding. Spiral angio-CT scan [28] or selective angiography can assess bleeding at these sites. Bleeding in a GBP can originate also from erosion or ulcerations of the gastric remnant [54] or even from duodenal or jejunal ulceration [55]. Refractory bleeding from the gastric remnant or other sites with no access for endoscopy can entail surgical revision [9, 20, 25]. Upper gastrointestinal bleeding can occur anytime after LAGB positioning due to erosions or ulcers. Peptic ulcer, Mallory-Weiss tear, erosive gastritis, and esophagitis can also be sources of bleeding in patients with LAGB. Acute upper GI bleeding, occurring in late follow-up, could be the result of an active ulcer, and careful endoscopy should recognize and even treat it [8–10, 12]. An extremely rare cause is bleeding from a peptic ulcer during pregnancy [8, 9] due to severe eclampsia or preeclampsia and stress that may lead to acute gastric or duodenal ulceration, even complicated with perforation. Severe vomiting in pregnant patients with a gastric band could induce peptic ulcer; band deflation at the beginning of pregnancy in anticipation of pregnancy-induced vomiting seems advisable, even if there is a risk of excess weight regain; however, most series report a selective deflation policy [56]. The initial treatment of upper GI bleeding after LAGB, as of any other gastrointestinal bleeding, is conservative (adequate resuscitation, close monitoring, assessment of the severity of bleeding, blood transfusions, and emergency endoscopy when necessary). When surgery becomes necessary, the patient should be referred to the bariatric center, when the clinical situation permits it. Extraluminal bleeding could be shown by the drain when present and still functional; otherwise, an acute drop of hematocrit, with hypotension and tachycardia, would indicate unstable hemodynamic condition that may require reoperation for lavage, identification of the source, and hemostasis. At surgery, the bleeding source (staple line, retrogastric vessels, short gastric vessels, omentum dissection line, splenic or liver injury, trocar site, etc.) will be often no longer active; intense abdominal washout, multiple drainage, and supportive intensive care will suffice. Laparoscopic approach is recommended, but only where experience is available.

2.10.2 SBO After Bariatric Procedures

Evaluation and treatment of SBO is one of the most common tasks that a general surgeon or an emergency physician has to face. About 16% of surgical admissions and more than 300,000 operations annually in the USA are related to SBO [57].

The standard management algorithm, commonly practiced for SBO, includes an initial trial of non-operative treatment using nasogastric decompression, bowel rest, fluid resuscitation, and close monitoring. A substantial number of cases are treated only with such conservative measures in the absence of signs suggesting impending or ongoing bowel ischemia [57, 58]. In patients with history of bariatric surgery, the outcome of commonly adopted protocols could be affected by several factors related to the new anatomy and physiology of the gastrointestinal tract. Physicians that are not adequately familiar with these alterations may be misled in their evaluation. The nasogastric decompression may be ineffective on a substantial portion of the gastrointestinal tract (gastric remnant, biliopancreatic limb), and prolonged non-operative management may be futile and dangerous. If a Roux reconstruction is present, a portion of the bowel is excluded from the alimentary flow; the evaluating physician must consider that obstipation may then be absent even in a complete obstruction and that the risk of a closed-loop bowel obstruction is higher than in non-bariatric patients. Finally, it may be difficult to identify small incisional hernias (trocar site hernias) in an obese patient, and the incidence of internal hernia is higher. The worldwide increasing diffusion of bariatric surgery makes it crucial that any physician involved in emergency care becomes familiar with the peculiarity of SBO in the bariatric patient and achieves a complete understanding of the bariatric procedures. The incidence of SBO after open bariatric surgery has been reported to be in the range of 1–5% [59]. Smith et al. [60] reported an incidence of 2.7% after laparoscopic gastric bypass. A recent review of nearly 10,000 laparoscopic gastric bypass reported an overall incidence of 3.6%. Martin et al., analyzing the Nationwide Inpatient Samples (2006–2007), reported 9505 admissions for SBO in bariatric patients vs. 54,342 in the non-bariatric population. Surgery was performed in 62% of the patients versus only 28% of the non-bariatric group. Bariatric patients were also taken to the operating room earlier (1 vs. 3.3 days). These data emphasize the necessity of earlier emergency surgery to avoid severe intestinal complication and related mortality in this cohort of patients. It appeared also that bariatric patients are approached more often by laparoscopy with good outcomes and significantly less complication and mortality [61]. Small bowel obstruction has been anecdotically reported after LAGB due to adhesions in patients with history of multiple surgical interventions and also due to the connection tube or to the abnormal migration of an eroded band [8, 15, 62, 63]. Diagnosis is not always easy because patients with LAGB may be unable to vomit; liquid accumulation within the closed loop determines severe gastric dilation that can cause gastric wall necrosis [15]. Early diagnosis of small bowel obstruction and early intervention, which can be as straightforward as fluid removal from the LAGB and nasogastric tube insertion, are of utmost importance. Failure of accomplishing these basic steps can determine an unfavorable prognosis, with evolution toward stomach or bowel necrosis. The most common cause of SBO in the bariatric population is an abdominal wall or internal hernia [61]. Port site hernia could be determined by the ≥10 mm trocar abdominal fascial defects left unclosed at the end of the laparoscopic bariatric procedures [9, 10, 12]. A trocar site hernia is an uncommon complication of laparoscopic surgery; however, it is necessary to take into consideration this possibility in the bariatric patient: a recent review showed that higher BMI is a significant risk factor for its development [64] even if its incidence after bariatric surgery does not seem to be higher [65]. The identification of small incisional hernia can be exceedingly difficult in obese patients. Emergency treatment for partial or complete bowel obstruction allows rapid reduction of the herniated content. A laparoscopic approach is recommended if adequate experience is available; bowel resection might be necessary in case of perforation or bowel ischemia. The closure of the abdominal wall defect completes the operation. Internal hernia is widely recognized as the most frequent cause of SBO (>50%) in bariatric patients [66]. SBO after GBP or BPD is determined mainly by internal hernia [27, 28, 67, 68]. There are three classic locations where SBO can occur after GBP: Petersen space (between Roux limb's mesentery and transverse mesocolon), at the transverse mesocolon defect (for retrocolic bypasses), and at the jejuno-jejunostomy [67]. Obstruction can involve the alimentary limb, the biliopancreatic limb, or the common channel, with incidence between 0.4 and 7.5% [68, 69]. Symptoms can suggest the site of obstruction: heartburn and vomiting are associated with the common channel or alimentary limb's obstruction; bilious vomiting originates from the common channel obstruction; distension of the gastric remnant or biliopancreatic limb suggests common channel and biliopancreatic limb obstruction. Diagnosis is based on clinical presentation, plain abdominal X-ray, and upper gastrointestinal studies. CT scan is a standard diagnostic tool and can demonstrate the dilatation of the Roux limb, of the gastric remnant, or of the biliopancreatic limb, depending on localization [70–73] . Even sophisticated imaging (multislice CT spiral scan), however, will fail to disclose internal hernia in up to two of three cases [74, 75]. This has led to an increasing acceptance for immediate laparoscopic/laparotomic exploration in bariatric patients with subtle symptoms of SBO [67, 76, 77]. Symptom persistence, acidosis, lactate rise, or signs of an acute abdomen should prompt exploration. Laparoscopy is the best choice (if previous bariatric surgery was also laparoscopic) where expertise is available. Small bowel assessment and handling are not easy, regardless the access. As in any laparoscopic exploration for SBO, a retrograde examination of the bowel starting from the ileocecal valve is easier and less risky. In case of positive identification of an internal hernia, a gentle reduction should be done, followed by the closure of the mesenteric defect. Patients with history of bariatric procedures, who also had other abdominal surgery (cholecystectomy, incisional hernia repair, gynecological operation, etc.), should always be checked for potential mesenteric defects in other areas. Symptoms can also evolve chronically, with intermittent and recurrent abdominal pain associated with nausea and vomiting but without a clear obstructive picture. This can be misinterpreted as food intolerance, marginal ulcer, or gastroesophageal reflux disease (GERD). Quite often, the intermittent pinching of a loop of bowel in an internal hernia defect can induce chronic, intermittent abdominal pain; the mechanism underlying the symptom may remain unknown, not discovered even by the most sophisticated imaging techniques, unless a very high degree of suspicion is maintained. Any patient with previous GBP or BPD who presents with chronic, intermittent abdominal pain or recurrent signs of a SBO should be suspected of having an internal hernia, and a referral to a bariatric center for a laparoscopic exploration may be warranted. Early diagnosis and intervention are imperative in order to reduce morbidity and mortality associated with intestinal necrosis [31, 67, 73].

Acute SBO can be life-threatening in the post-bariatric patients who have undergone a Roux-en-Y reconstruction. In fact, an obstruction point along the biliary limb or at the small bowel anastomosis will result in a closed-loop obstruction that can be rapidly fatal if not recognized and decompressed. An invasive procedure (emergency surgery or percutaneous CT-guided gastrostomy) is the only option to achieve decompression because nasogastric suctioning is precluded by the anatomical changes. A closed-loop obstruction can also result from an obstruction distal to the jejuno-jejunostomy if an effective decompression is not obtained through the alimentary channel [9, 68]. The closed-loop obstruction of the biliopancreatic channel has been defined "bypass obstruction" by Mason. He maintained that a universally recognized denomination of this dangerous nosologic entity could facilitate recognition, study, prevention, and early treatment. In gastric bypass, the syndrome may include "gastric remnant dilatation," with potential gastric necrosis, or gastric obstruction with perforation. When presenting as an acute, rapidly evolving complication, a complete bypass obstruction has one of the shortest "time to treat" (TTT) [31]. This is due to the large volume of digestive fluids accumulated in the upper digestive tract, with possible evolution to gastric wall necrosis and/or perforation. Hypovolemic shock (evidenced by tachycardia) is thus complicated by peritonitis and sepsis due to perforation. A chronic presentation is also described, with symptoms including abdominal pain, nausea, hiccup, vomiting, and tachycardia. Elevated hepatic functional markers and pancreatic enzymes can be related to the increased duodenal pressure. CT scan may show the dilatation of the gastric remnant. The evaluation of the stomach remnant after GBP is attainable also by virtual gastroduodenoscopy [78]. Revision of the jejunostomy may be needed. In the emergency setting, when an interventional radiologist is not available, it is imperative to decompress the stomach, and subsequently, through the gastric access, it is possible to obtain X-ray contrast studies or endoscopy.

2.10.3 Biliary Tract Lithiasis After Bariatric Surgery

After bariatric surgery, the risk of gallstone formation increases if weight loss rate exceeds 1.5 kg/week or when there has been excess weight loss of more than 24% [79]. Most gallstones form in the first 6 months after surgery, with a symptomatic onset after a mean period of 10.2 months. A study by Kiewiet et al. reported a gallstone incidence of 30% after LAGB [80]. Miller reported an incidence of 22% at 1 year after vertical banded gastroplasty or LAGB and of 30% at 2 years after surgery [81]. Shiffman et al. described an incidence of gallstone formation of 38% within 6 months after Roux-en-Y GBP [82]. Scopinaro in 1980 reported 40% incidence of gallstones at 1 year after BPD [31]. Sugerman and Gagner showed that the incidence of gallstones after bariatric surgery can be reduced by prophylactic medical therapy [83, 84]. A recent meta-analysis confirmed the effectiveness of ursodeoxycholic acid prophylaxis [85].

Symptomatic gallstones, including acute cholecystitis in a patient with history of bariatric surgery, should not constitute a problem for the general surgeon. The presence of choledocholithiasis can be difficult to diagnose and treat after gastric or intestinal bypass due to the anatomical changes and the lack of endoscopic access using endoscopic retrograde cholangiopancreatography (ERCP) [78]. Diagnosis can be based on ultrasound, computed tomography, or magnetic resonance cholangiopancreatography. Before cholecystectomy for symptomatic gallstones, a careful evaluation of the common bile duct with noninvasive imaging techniques should be obtained, and a larger use of intraoperative cholangiogram is warranted [86]. Once common bile duct obstruction is diagnosed, the endoscopic/surgical treatment depends on the surgeon's experience and the patient's status. The problem of approaching bypassed structures is not new, and different access techniques have been de- scribed. The options include laparoscopic or open CBD exploration, percutaneous transhepatic instrumentation of the biliary tree, transgastric ERCP, transenteric endoscopic cholangiopancreatography, and ERCP using specialized endoscopes [87, 88]. The success rate reported using a retrograde approach is 65% in standard RYGBP [84] but nearly impossible in a long-limb RYGBP or BPD. In a GBP, it is possible to reach the biliary tree by advancing the endoscope through the stomach remnant, but the inability to distend the gastric remnant with air makes an imaging-guided access challenging [89]. The use of double balloon enteroscopy to perform an endoscopic-assisted placement of a trocar into the remnant stomach was recently reported [90]. An open gastrotomy is the easiest approach to access the residual stomach. Some studies describe a minimally invasive technique to access the bypassed stomach after RYGBP: a laparoscopic gastrotomy is obtained after induction of carbon dioxide pneumoperitoneum, and a 15 mm trocar is placed into the stomach to allow the insertion of the endoscope [91, 92]. When the endoscopic procedure is completed, the gastrotomy is closed with a running suture or a linear stapler. The procedure can be performed at the same time of the laparoscopic cholecystectomy. The possibility to reach the papilla after BPD through a surgical jejunostomy has been reported [93]. Mutignani recently published a case of laparoscopic-assisted ERCP [94].

2.10.4 Gastroesophageal Reflux Disease After Bariatric Surgery

Patients with history of bariatric surgery can access an emergency department with severe epigastric pain, burning pain, or chest pain. Severe gastroesophageal heartburn, described as de novo GERD, is frequent (up to 47%) [14, 17, 41, 95, 96]. Often this is related to an omitted diagnosis before the initial bariatric procedure. A concomitant hiatal hernia can be implied; its presence can remain unnoticed at surgery if the dissection of the fundus from the left diaphragmatic pillar is not carried out entirely. Several studies, including a systematic review, have reported an improvement of GERD following LAGB, stressing the potential short-term protective effect of the procedure toward acid reflux [97, 98]. A longer follow-up, however, shows a new onset of reflux symptoms in 15% of patients who underwent a LAGB and even 22.9% of newly developed esophagitis. New reflux symptoms after LAGB may either represent a band that is simply too tight or a band complication (slippage, outlet obstruction). Symptoms of GERD after LAGB might also be related to a "pseudoachalasia," caused by the progressive reduction of esophageal clearance, leading to stasis of ingested food and reflux of acid material. Esophageal dysmotility is often due to a band positioned too high or overfilled. Heartburn, regurgitation, vomiting, and dysphagia, especially when the proximal pouch is dilated, can be so severe to seek an emergency evaluation [99–101]. Pseudoachalasia and esophageal dysmotility are usually reversed after removal of the gastric band, and simple band deflation can determine rapid improvement of the symptoms [101, 102].

Gastrointestinal physiology is more dramatically changed after LSG: the removal of gastric fundus and body affects both gastric accommodation and acid secretion. These anatomic and physiologic modifications create a new balance between exacerbating and protective factors for GERD [99, 103–105]; aggressive intraoperative identification of hiatal hernia is appropriate, and diaphragmatic defect should be closed after the sleeve procedure is completed [41]. GERD symptoms after LSG usually appear during the first postoperative year [106, 107]. A second peak of GERD can be seen later (6 years postoperatively) and might be linked with the appearance of a neo-fundus [95], likely caused by incomplete resection at the time of the first operation. In patients with new-onset gastroesophageal reflux disease after LSG, proton pump inhibitors should be the first line of treatment [41], and referral to the bariatric center is usually possible. GBP has been considered the best bariatric operation in patients who present GERD symptoms preoperative workup [99]. However, bile reflux has been reported as an important cause of chronic epigastric pain after GBP [108, 109], but dysphagia in these patients is more commonly related to an impaired emptying of the gastric pouch [10, 12]. Some patients can complain transient dumping symptoms after RYNGB due to the rapid transit of the bolus in the alimentary limb, as observed in gastric surgery with different alimentary tract reconstructions. Dumping-like symptoms and dysphagia are sometimes associated.

2.10.5 Algorithm for the Surgical Approach to a Bariatric Patient Referred for Emergency

The approach to the bariatric patients with an emergency condition can be extremely challenging, and the issues to be taken into account are numerous and varied. After initial resuscitation, if needed, a systematic stepwise approach should be based both on the clinical picture assessment and on the knowledge of the specific procedure that the patient had. Consultation with the bariatric surgeon should be obtained early, and referral to a bariatric center should be taken into consideration at any time if permitted by the patient's conditions. The first overview is aimed at defining the clinical problem and its severity; then, a procedure-specific approach can be useful to get oriented in the differential diagnosis and plan the emergency treatment. Bariatric surgery has a low rate of postoperative complications, but some of them can evolve as surgical emergencies; they should be promptly recognized and appropriately managed. The surgeon must understand if problems arise from the specific bariatric procedures that the patient received and must be aware of the procedures' potential impact on the diagnosis and treatment of other abdominal diseases. Simple measures, like band deflation and hydration, can be critical and often will suffice to treat the patient's condition. When surgery is required, and transfer to a specialized center is not quickly possible, the treatment should take into consideration the specific aspects of these surgical operations in order to achieve the best results. Laparoscopic evaluation and treatment should be achievable in most of the cases, but the approach depends on the operator experience. Every general surgeon should have a basic knowledge of the most common surgical procedures adopted for the care of obesity and be able to cope with their possible consequences; bariatric surgeons should make any effort to share their know-how with non-bariatric colleagues.

2.10.6 New Procedures

The "ileal interposition" consists in the transposition and interposition of an isolated segment of ileum to the jejunum. The first technique described by DePaula et al. started with division of the jejunum 30 cm from the ligament of Treitz using a linear stapler. An ileal segment of 150 cm was created 50 cm proximal to the ileocecal valve, interposed peristaltically into the proximal jejunum. Ileal interposition was associated to a sleeve gastrectomy. The second technique was an ileal interposition associated with a diverted LSG. LSG was performed and the duodenum was transected using a 60 mm linear stapler. An ileal segment of 150 cm was created 50 cm proximal to the ileocecal valve, interposed and anastomosed peristaltically to the proximal duodenum. A point in the jejunum 50 cm from the ligament of Treitz was measured and anastomosed to the distal part of the interposed ileum. These procedures were performed by laparoscopy.

The potential use of endoluminal techniques in the field of bariatrics has prompted investigation into several promising applications. The technology currently under development can be divided roughly into four categories: suturing and stapling devices, endoluminally delivered prostheses, ablation-based devices, and electrical stimulation-based devices. In particular, the placement in duodenum of a prosthetic tube to prevent the contact of nutrients with the duodenal-jejunal mucosa may reproduce the same effect of RYGB/BPD in diabetes resolution.

Key Points

1. Major complications of laparoscopic adjustable gastric banding (LAGB) are represented by pouch dilation, gastric obstruction, and intragastric band migration.
2. Major complications of Roux-en-Y gastric bypass (RYGB) are represented by anastomotic leaks and marginal ulcers.
3. Major complications of laparoscopic sleeve gastrectomy (LSG) are represented by suture line leakage and mid-gastric stenosis.
4. Bleeding, small bowel obstruction, biliary tract lithiasis, and gastroesophageal reflux disease (GERD) are common complications of most of the bariatric procedures.

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3 The Role of Imaging Before and After Surgery

Marco Rengo, Simona Picchia, and Andrea Laghi

3.1 Before Surgery

In the preoperative phase, a multidisciplinary approach is recommended to evaluate obesity-related comorbidities.

As regards the radiological exams usually performed before bariatric surgery, they consist of chest X-ray, ultrasonography study (US) of the upper abdomen, and US of the thyroid. The US of the right upper quadrant is mainly performed to find cholelithiasis. The incidence of cholelithiasis is about 15–25% in obese patients [1], and, moreover, the risk of occurrence of cholelithiasis increases with rapid weight loss of more than 25% [2]. By detecting it before procedure, the surgeon might decide to perform cholecystectomy at the same time of bariatric surgery [3]. The US of thyroid is performed because the thyroid endocrine diseases are the most common endocrine diseases in obese patient after diabetes mellitus and, if not properly identified and treated, may represent a limit for the success rate of the bariatric surgery [4].

Actually there is no consensus on performing routine UGI radiography. Most of the surgeons considered it unnecessary. However, some studies demonstrate that it can provide important additional information influencing the operative procedure [5]. The UGI radiography with the use of oral barium contrast allows to assess patient's anatomy abnormalities such as malrotation (because these procedures are most of the times laparoscopic and anatomic, orientation may be misunderstood), esophageal motility disorders, gastric emptying, and hiatal hernia. In particular, the detection of hiatal hernia is important because its surgical correction during bariatric surgery improves patient outcomes and decreases reoperation rate. UGI radiography is more sensitive than endoscopy to detect hiatal hernia, especially by utilizing right anterior oblique technique instead of the commonly used upright technique [6]. Some institutes perform UGI radiography also to rule out occult peptic ulcer, that is, an absolute contraindication for bariatric surgery; however, recently, for this purpose endoscopic evaluation and screening for *Helicobacter pylori* are often preferred [1].

3.2 After Surgery

The most commonly imaging modalities used after bariatric surgery are the upper gastrointestinal (UGI) radiography and the computer tomography (CT).

The incidence of postoperative complications (both leak and stenosis, which are the most common) is low, and it decreased with the

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advancement of surgical techniques. For this reason, some recent studies consider unnecessary to perform routine UGI after bariatric surgery in asymptomatic patients because the potential benefit seems low compared with the costs and recommend to reserve the exam only for patients with clinical evidence of complications evaluable with radiography (e.g., leak, obstruction, and perforation) [7–14]. However, other studies prefer to perform routine UGI to assess the surgery and to diagnose possible complications because of clinical difficulties found in some cases [15, 16]. Among these last studies, the timing of the exam is also debated. In some cases the exam is routinely performed within the first and second postoperative days in order to obtain early diagnosis and prompt treatment, in other cases in the third postoperative day because UGI has considerable number of false-negative results in the early postoperative period, especially in case of leak [17]. It is generally recommended to perform CT in case of negative result at the UGI and persistence of clinical suspicion of complications, because it has more sensitivity and specificity and it is less operator dependent than UGI radiography [18]. CT is also performed in addition to the UGI radiography in case of diagnosis of leak to confirm the finding and exclude abscess formation [17]. CT is the first choice when patient is not able to stand in the upright position; when there is clinical suspicion of abscess, small bowel obstruction, internal hernia, and intussusception; and when other diagnoses are considered [19]. Familiarity with the surgical procedures and postoperative anatomy is essential for correct image interpretation.

3.3 Procedures

UGI radiography consists of an initial scout film of the abdomen to detect possible free extraluminal air and to facilitate the differentiation of surgical findings from contrast during fluoroscopic exam. The patient is then positioned in a semiupright position on the fluoroscopic table and swallows the oral contrast. The fluoroscope is activated by the radiologist for a few seconds prior to and then following the administration of the contrast. Images of the esophagus, stomach, and jejunum were obtained. The contrast can be water-soluble iodinated or barium contrast given orally or through the nasogastric tube; the first one is preferred in case of suspicion of leak (if patient is not allergic to iodine), the second one when there is no suspicion of leak or significant aspiration and in the preoperative period. Although small amounts of aspirated barium as well as of extraluminal barium from leakage can be well tolerated, this approach is recommended to minimize harm [20]. For this reason, after surgery, water-soluble contrast is usually used in the early postoperative period (because of increased risk of asymptomatic leak) and barium contrast in the late postoperative period. It must consider that not always leaks were seen with iodinated contrast, because it is not as dense as barium. For this reason, dual-phase exams can be done when leakage is suspected, first with iodinated contrast and then with small amounts of barium if no leak is seen with the first one [20].

The amount and the concentration of water-soluble iodinated contrast are usually 60 ml and 350 mgI/mL. The consistency (thin liquid, nectar-thick liquid, honey-thick liquid, pudding or cookie) and the volume of barium contrast are not well standardized [21].

Abdominal CT is performed with water-soluble iodinated contrast given orally or through the nasogastric tube with thin sectional acquisitions (approximately 3.0-mm section thickness) and reconstruction in axial, sagittal, and coronal planes. As the UGI radiography, the exam consists of a first scan without oral contrast and then a second scan with oral contrast to differentiate surgical findings from probable leak. The acquisition comes shortly after ingestion of oral contrast because the opacification of the stomach occurs immediately if there are no esophageal diseases and the opacification of the entire small bowel is not necessary. Since all of the common bariatric surgeries cause a reduction of gastric volume, a reduced amount of oral contrast agent (approximately 60 mL) is generally used [19]. The additional use of intravenous contrast media is recommended in case of suspicion of vascular complications and abscess. In these cases, arterial and venous phases or only venous phase is obtained. The amount of intravenous contrast media is based on patient's weight as non-bariatric surgery patients.

3.4 Radiation Dose

Since the main radiological techniques in the postoperative phase (routine exams or in case of complications) require the administration of X-rays and obese patients generally need more dose than normal-size patients to obtain similar quality of the images [22], the discussion about radiation exposure and ways to reduce it is extremely important in these patients. Moreover, bariatric surgery patients are often young, and it is known that the susceptibility to radiation-induced malignancies increases with decreasing age. Training in radiological protection for patients and medical and paramedical staff should be routinely done. Patients should be informed of the possibility of radiation effects.

As regards the fluoroscopy, the effective doses associated to bariatric procedures are approximately between 0.5 and 2.7 mSv, and the organs receiving the highest doses are the breast, stomach, pancreas, liver, and also lungs [23]. It is strongly recommended that the radiologist achieve any measure to reduce the radiation dose, especially in younger patients, by limiting the number of exams and by performing the exams with the appropriate position, as rapidly as possible, with the collimation of X-ray beam on the region of interest and with the use of pulsed-dose mode or low-dose mode rather than conventional mode if they are available [24].

Computed tomography (CT) is the imaging modality which contributes most of the radiation exposure. Dose ranged approximately between 4 and 156 mSv [25]. Strategies to minimize radiation, primarily by limiting the number of exams, should be pursued. When CT is essential, appropriate technique factors should be applied, including exam protocol that needs to be optimized according to the specific case, limitation of scan on the region required, accurate patient centering, tube current modulation, tube voltage modulation based on patient size (especially when weight loss starts), and iterative reconstruction algorithm software to reduce image noise [26].

Key Points

1. Actually, there is no consensus on performing routine upper gastrointestinal (UGI) radiography in the preoperative period.
2. UGI is considered unnecessary after surgery in asymptomatic patients.
3. CT is recommended in case of negative result at the UGI and persistence of clinical suspicion of complications.
4. The use of oral contrast agent is recommended for both UGI and CT.
5. The additional use of intravenous contrast media in CT is recommended in case of suspicion of vascular complications and abscess.
6. Strategies to minimize radiation, primarily by limiting the number of exams, should be pursued.

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Normal Imaging Findings After Surgery

4

Claire Smith and Damian Tolan

4.1 Introduction

The majority of patients who undergo bariatric surgery will have a smooth postoperative course not requiring any follow-up imaging. As with any procedure, the recovery rate varies between patients. Clinical symptoms or signs of a postoperative complication will often result in a visit to the radiology department. It is important that radiologists can recognize the normal postoperative appearances after bariatric surgery in order to be able to reassure the clinical team and the patient.

Patients may present years after the procedure with abdominal pain unrelated to their bariatric surgery. In these patients it is important to recognize the normal postsurgical anatomy to exclude this as a cause of their symptoms. There are older more complex surgical techniques, such as the Magenstrasse and Mill procedure, which are no longer routinely performed. Familiarity with the normal appearances of the various bariatric surgical techniques may prevent an incorrect attribution of the surgery as a cause of symptoms.

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As with clinical examination and surgical treatment, obesity poses additional technical and logistical challenges for obtaining and interpreting diagnostic images. In this chapter we will deal with some of the practical difficulties faced by radiologists in dealing with these cases, particularly around the choice of imaging modality and the imaging signs to look for when trying to diagnose 'normality' in a postoperative bariatric patient.

4.2 Choice of Imaging Modality

4.2.1 Logistical Considerations

The choice of imaging modality will depend upon the patient's symptoms and likely diagnosis, the time since surgery, the type of surgical procedure, the availability of resources (in particular the support staff and the available radiological expertise) and also the physical limitations due to the patient's weight and size. The clinical urgency, familiarity with the radiological technique and interpretation and limited out of hours imaging modality options will also influence the modality selected by a radiologist.

Prior to arranging for the patient to attend the radiology department, the physical logistics of imaging the patient must be planned carefully. Essential information to obtain before arranging a bariatric radiological examination includes (1) weight of the patient, (2) maximum body

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diameter (AP and lateral dimensions) and (3) patient mobility and ability to stay in the scanning position for the required length of time. These details must be gathered before the patient leaves a ward or high dependency unit, as the process of transferring the patient is a risk in itself and should only be undertaken if the patient is likely to be able to have the proposed imaging test.

Machine table weight limits and gantry size specifications vary between models and need to be checked to ensure the patients do not exceed this. The specifications of each machine in the department should be readily available for radiology department staff to refer to before accepting a referral. In general, newer-generation scanners tend to have increased bore size and weight limits to cope with the trend of increasing obesity and mitigate against claustrophobia. While older CT scanners have gantry diameters around 70 cm, newer CT scanners reach up to 80 cm. MR machines have gantry diameters between 60 and 70 cm. However in practice the working vertical diameter for all scanners is less than the lateral maximum due to table and mattress thickness [1]. In some cases central fat can be redistributed to a degree by wrapping or using straps to reduce girth.

The maximum table weight limit for CT and MRI scanners usually varies between 200 and 220 kg with some offering upgrade to a maximum limit of 300 kg. The engineering limitations are particularly stringent for CT scanners, which require calibrated movement with the rotation of the scanner. In some cases additional adjustments for the scanner table are needed, such as insertion of a table support, and the scan range may be reduced because of the forces exerted on the table at the limit of the scan range. Fluoroscopy machine table limits range between 200 and 250 kg but can go up to 320 kg in newer models. An important benefit of fluoroscopy is that the step can be removed and the patients imaged standing on the floor if the patient exceeds the limit and is mobile enough to bear their own weight [2]. A further advantage of fluoroscopy is that the maximum diameter between the patient and image intensifier can exceed 80 cm depending on the system that is available. Exceeding the table weight limit must be avoided as it can potentially damage the equipment, disrupt services for other patients in need and invalidate service warranty. Where there is a doubt about the precise patient weight, then an accurate weight should be obtained before agreeing to perform the examination.

As well as the physical constraints, the clinical team should understand the other patient factors required for successful examinations. In particular they must assess whether the patient can successfully lie flat for CT and MRI. This can be particularly problematic in superobese patients who can develop rapid respiratory compromise in a supine position from airway compression in the neck and diaphragmatic splinting from the abdomen, which is very distressing. Scanning the patient in a decubitus position can reduce pressure on the upper airway and diaphragm in this situation, but it is prudent to have support from an anaesthetic specialist who may decide if it is safer to perform the procedure under general anaesthesia. The team should also determine if the patient can weight bear and for how long this is possible as it may be necessary to perform a fluoroscopic assessment in an erect position as an alternative to supine cross-sectional imaging.

Depending on the patients' mobility, they are likely to require additional staff, slide sheets and boards and possibly hoists for transferring them to the scanner table. The risk of injury to patient and staff is high unless good moving and handling techniques are adhered to. It can be particularly difficult to safely roll patients to place transfer boards when the patient is as wide as the trolley or bed or when they are on an air mattress to prevent decubitus ulcers.

When setting up or upgrading a radiology service for the care of bariatric patients, these equipment specifications need to be considered to ensure new machines can accommodate the obese and super obese patient cohort.

4.2.2 Image Quality Considerations

Diagnostic image quality is also a key consideration for each modality.

4.2.2.1 Ultrasound

The deeper layer of subcutaneous and intraperitoneal fat causes beam attenuation and therefore impairs ultrasound image quality. Altering the settings of the machine will optimize images, and it is still possible to use ultrasound to obtain diagnostic quality images with attention to technique. Lower-frequency probe settings reduce beam attenuation, and there are additional functional settings that can improve image quality, with better edge definition from tissue harmonic imaging, the most commonly employed [3]. Reducing the sector width and using minimal depth will improve image resolution, while post-processing of images can also improve edge definition and reduce image noise. Presets can be added to scanners to automatically incorporate these optimization factors for ultrasound examinations in obese patients.

Further practical techniques that may also improve image quality are scanning through the minimum depth of tissue. This may require repositioning the patient or retraction of abdominal fat by an assistant as well as physical compression of tissues by increasing the scanning pressure. It is possible to obtain diagnostic quality images in many obese patients (Fig. 4.1) but in general the deeper the fat layer, the more attenuated the beam, and in some patients it may not be possible to answer the clinical question with this modality. Ultrasound may be useful to assess for superficial wound collections, but it is less useful to exclude deep postoperative collections.

A common ultrasound indication is to assess for gallstones. Obese patients are at higher risk of cholelithiasis, and there is also an increased frequency of stone formation following bariatric surgery, particularly Roux-en-Y gastric bypass. Ultrasound remains the best first test for the assessment for gallstone disease [4].

4.2.2.2 Radiography and Fluoroscopy

In radiography, image quality is reduced by photon scatter due to the greater depth of tissue beams that will pass through in obese patients. This effect increases noise in the image and reduces contrast resolution. Using a higher tube voltage reduces scatter but further reduces the contrast resolution. Digital radiography equipment has automated exposure control that may increase exposure time, thereby making images more susceptible to motion artefact. Image quality can be improved by using a smaller field of view to reduce scatter or grids to reduce scatter reaching the image intensifier, but the latter will increase radiation dose.

Fluoroscopy has similar issues, and a higher dose is typically needed to obtain diagnostic quality images. Depending on the quality and age of the equipment, low-dose pulsed fluoroscopy

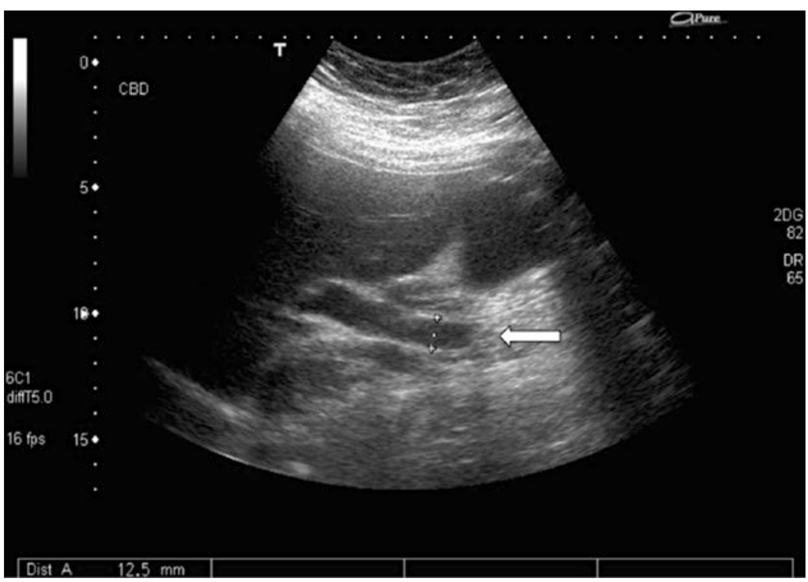

Fig. 4.1 A 5 cm layer of fat does not prevent diagnosis of 12 mm CBD dilatation due to an obstructing 10 mm calculus with posterior acoustic shadowing (*white arrow*). Note that the detail in the liver parenchyma is poor

may be unable to provide the clarity of imaging required to make a diagnosis, and full exposures are usually needed to detect complications such as anastomotic leak, particularly where a subtle abnormality is present.

4.2.2.3 CT

CT image quality is also degraded by photon scatter and will potentially result in a decreased signal-to-noise ratio in obese patients resulting in noisier images. However it is usually possible to obtain diagnostic quality images in patients that fit on the scanner. Modern scanners have image acquisition techniques and post-processing which can mitigate the impact of photon starvation. These include maximizing the tube mA and kV settings to increase tube output, with dual source CT scanners providing an obvious additional advantage over single source scanners in this situation, assuming that they have sufficient generator power capacity. Tubes can be allowed to cool completely before scanning the patient to prevent overloading in older machines. Decreased pitch and increased tube rotation time increase the radiation reaching the CT detectors at the expense of higher radiation dose to the patient while increasing reconstructed slice thickness, and the use of post-processing techniques such as iterative reconstruction can reduce noise in the image and improve image quality.

Automated exposure settings applied at image acquisition to reduce image noise can result in a very increased dose to the patient, and the average organ dose to an obese patient is approximately three to four times that of nonobese patients [5]. This can also dramatically increase the acquisition time of the scan because of the lower tube rotation times that are needed, which can lead to image degradation from motion artefact from breathing for example. Dose and image acquisition time can be reduced in this situation by overriding automatic exposure controls and to accept that images may be noisier while still of diagnostic quality. Where automated exposure settings are used, it is essential that the patient is correctly centred within the scanner, since CT exposure and dose reduction techniques can be very dependent on correct patient positioning prior to scanning.

Truncation artefact results from an area being scanned outside the field of view. This leads to incorrect imaging reconstruction calculation producing an imaging artefact, seen as a bright halo around the periphery of the patient obscuring the edge of the images. While reconstruction algorithms can reduce this artefact, it is most important that the region of greatest interest is in the centre of the field of view to reduce the impact of truncation artefact on image quality (Fig. 4.2 a, b). While this usually has little consequence in diagnostic abdominal imaging, it can cause

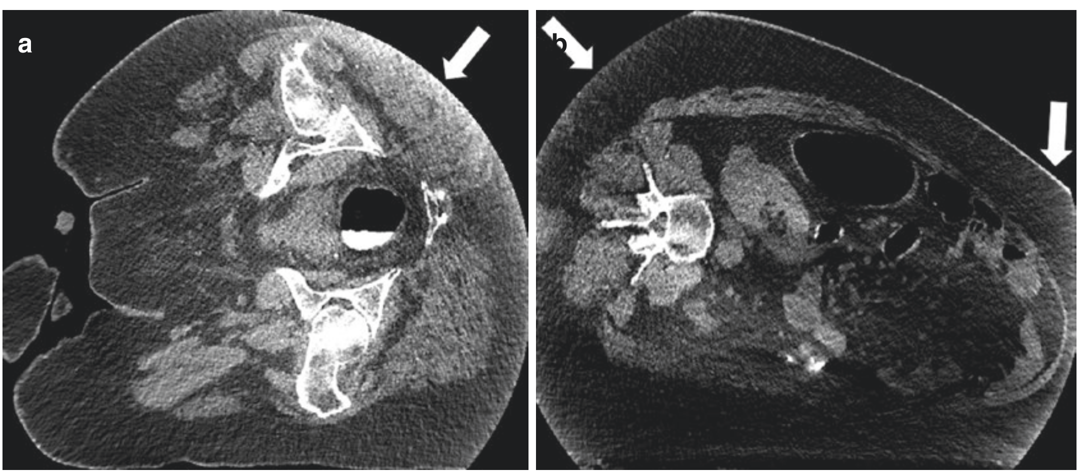

Fig. 4.2 (**a**) *Right* and (**b**) *left* decubitus positions for CT colonography examination in a 220 kg male. The area of interest is in the centre of the field of view. On the edge of the scan field a high attenuation truncation artifact is seen (*arrows*) which is worse where the gantry is in direct contact with the patient

problems when assessing the edge of the patients with stomas and hernias or when performing CT-guided intervention requiring skin markers. In this situation patient repositioning or use of straps to centre the region of interest within the field of view may be beneficial.

The optimal CT protocol depends on the clinical question, but in general using intravenous iodinated contrast medium to improve soft tissue contrast will optimize most studies. The dose of contrast medium is ideally calculated by patient weight, but in obese patients this leads to an overestimation of the required dose, since fat is poorly vascularized and hence does not significantly increase the overall blood pool. Estimations of lean body weight provide a better guide to dose, but a standard maximum fixed dose will negate the need for adjustments and may be a better approach [1]. The rate of injection and timing to trigger scans for each phase is the same as non-obese patients and depends on having secured venous access. Renal function assessment with eGFR should also be reviewed before administering iodinated contrast medium to reduce the risk of acute kidney injury.

4.2.2.4 Nuclear Medicine

Radionuclide imaging quality can be reduced in obese patients due to scatter and reduced signal-to-noise ratio. Doses are limited by legislation, but image quality can be improved by lengthening acquisition time. PET-CT is subject to the same limitations as both nuclear medicine and CT with truncation artefacts and reduced signal-to-noise ratio affecting image quality.

4.2.2.5 Magnetic Resonance Imaging

MR image quality is least affected directly by the volume of fat, as soft tissues do not attenuate radiofrequency energy (Fig. 4.3). Image quality will be affected by a reduced signal-to-noise ratio that, due to the larger scanning volume, reduces the radiofrequency signal per voxel of the image. Improved quality of the body surface coils containing an increased number of elements reduces this affect. Decreasing the field of view to increase the signal-to-noise ratio is limited by problems with phase wrapping artefact due to patient size. The key limitation of MRI is the length of acquisition and the need for good patient cooperation to reduce motion artefact when the patient is in a confined space. While open MRI systems are becoming more available, which potentially increases access to obese patients for MRI, these scanners usually operate at lower field strengths (0.5–0.6 T), which limit the imaging that can be performed.

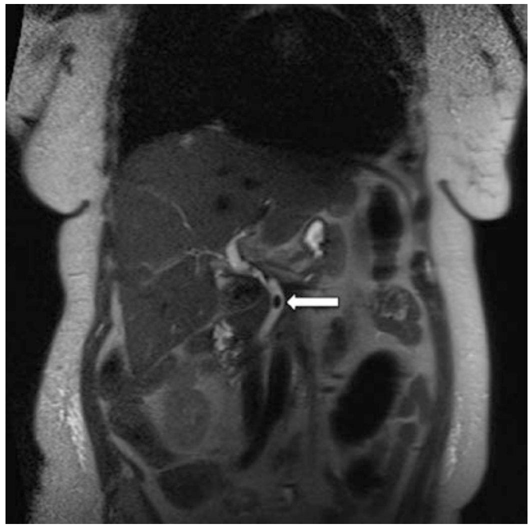

Fig. 4.3 Diagnostic MRI quality with 1.5 T MRI coronal T2 weighted HASTE in a 120 kg patient. A calculus in the common bile duct is clearly demonstrated (*arrow*)

4.3 The Immediate and Early Postoperative Phase

Imaging in this period usually results from concerns for an early postoperative complication such as anastomotic leak or functional obstruction, to detect a source of infection or bleeding. There is a growing consensus that routine postoperative fluoroscopic imaging following bariatric surgery is not indicated due to the low pretest probability and the low sensitivity for detecting an anastomotic leak in asymptomatic patients [6]. Upper GI fluoroscopy and CT are the most commonly used modalities in this early postoperative period.

4.3.1 Upper GI Fluoroscopy Technical Aspects

Upper GI fluoroscopy studies give real-time information about the functional and anatomical appearances of the postoperative anatomy. Forward planning is important and a discussion with the surgical team should occur before the procedure. Important details to clarify include the exact time since surgery, type of surgery, nature of the anastomoses, lengths of any blind limbs, sites of drains and any intraoperative complications that may have arisen.

In every examination, a set of initial images as control views without any oral contrast medium should be obtained to identify metallic suture lines or surgical drains. This helps the operator to orientate and focus on the area of interest, to select the appropriate field of view and to demonstrate any densities present before contrast administration, which may be confused with a leak, particularly where contrast may have been given for another examination in the recent past. At least two views in different planes should be obtained – most often this will comprise an anterior-posterior and right anterior oblique to give the best views of the upper stomach and gastro-oesophageal junction. We advise that water-soluble iodinated contrast medium is selected to assess for anastomotic leak (Fig. 4.4) for two reasons: barium extravasation from a leak can lead to peritoneal contamination and barium peritonitis, and if a CT scan of the abdomen is subsequently required, then the scatter from retained barium in the bowel lumen can severely degrade image quality.

Surgical drains may be present in the early postoperative views and usually placed near to anastomoses. These should be included in the field of view as an early leak may only be demonstrated by contrast medium filling the drain lumen. Oedema around the anastomoses in the early postoperative phase can cause transient obstruction, which will resolve with conservative measures in distinction to an anastomotic stricture.

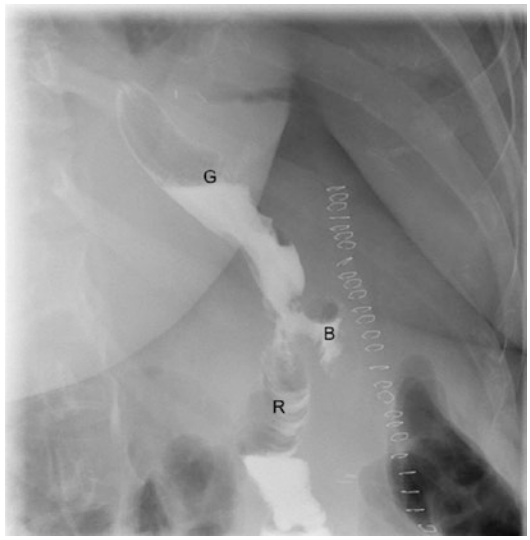

Fig. 4.4 Early post- Roux-en-Y fluoroscopy study for persistent vomiting on post op day 5, performed with non-ionic iodinated contrast medium, confirmed anastomotic integrity between the gastric pouch (G) and roux limb (R) and prompt gastric emptying. Note normal filling of the short blind limb (B), which should not be confused with a leak

4.3.2 CT Technical Aspects

Abdominal CT may be performed subsequent to fluoroscopy if there is uncertainty regarding whether a leak may be present, if the patient is showing signs of sepsis or when there is concern of other complications such as bleeding, ischaemia or small bowel obstruction. The CT protocol used depends upon the clinical concern. If there is concern regarding anastomotic leak or intra-abdominal collection, then we routinely administer 8% oral contrast medium, approximately 15–30 min before scanning to test the anastomotic integrity and perform a portal phase scan with intravenous contrast, provided that renal function is adequate. Alternatively, where there is concern about potential bleeding, then positive oral contrast medium should not be used as it may obscure any intraluminal bleed. We routinely perform a triple phase scan with non-contrast, arterial and portal

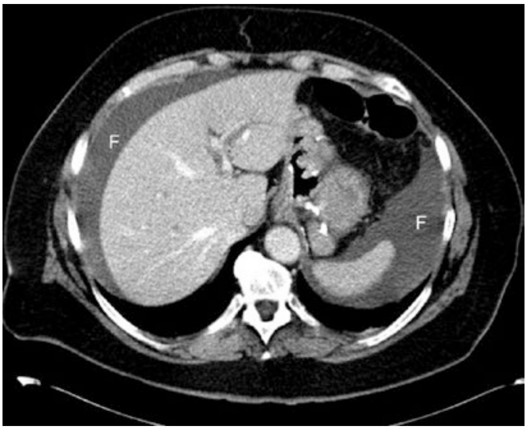

Fig. 4.5 Post RYGB. Generalized free fluid (F) without pneumoperitoneum, surrounding the spleen and liver. This could represent anastomotic leak (as in this case) or decompensated liver disease as causes depending on the clinical context

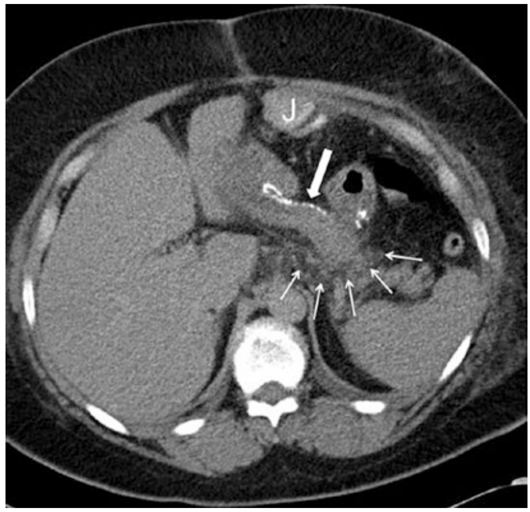

Fig. 4.6 Minor fat stranding (*thin arrows*) around the posterior gastric wall is an expected finding on day 3 post-RYGB. Note the trace of positive oral contrast medium in the roux alimentary limb (J). The fat adjacent to the gastric staple line of the excluded stomach looks clean (*large arrow*)

venous phase acquisition. Bolus tracking is recommended for the arterial phase imaging to optimally opacify arteries.

The postsurgical changes evident on the early postoperative CT depend upon the nature of surgery. Minimal fat stranding in the surgical bed and small traces of free fluid are expected after minimally invasive laparoscopic surgery such as LAGB or RYGB (Fig. 4.5). However the more challenging the surgery, and particularly revision bariatric surgical procedures, the greater the 'normal range' of postsurgical changes that may be expected. Important considerations in assessment include the volume of free gas present, which should be minimal in a patient undergoing laparoscopic surgery beyond the second postoperative day, but can persist in larger amounts for a longer period as a normal finding in patients undergoing laparotomy, and the volume of fluid present, which should be minimal in an uncomplicated operation, assuming there are no underlying cardiac or hepatic comorbidities – however, localized low volumes of fluid adjacent to the anastomosis or large volumes of free fluid (and gas) can herald a leak (Fig. 4.6). Extravasation of positive oral contrast is a clear sign of anastomotic disruption.

The planes surrounding the surgical sutures should be carefully examined for focal free fluid collections and gas, and if there is any concern in the context of sepsis, then positive oral contrast is recommended provided the patient can tolerate this.

4.3.3 Ultrasound Technical Aspects

Definitive exclusion of an intraperitoneal complication in any postoperative patient is very challenging with ultrasound in this obese cohort of patients. If there is a question of superficial abscess associated with surgical wound erythema, ultrasound may be used for exclusion, but ultrasound otherwise seldom plays a role in early postoperative imaging unless there are concerns for gallbladder and biliary pathology.

4.4 The Late Postoperative Phase

After recovery from the initial operation, which can take 6–8 weeks, imaging is most commonly requested to check the function of the postsurgical stomach, and therefore dynamic studies are more often used 30 days beyond the operation.

4.4.1 Fluoroscopy

Fluoroscopy still plays a major role in this stage, to assess the function and postsurgical anatomy [7]. Patients are adjusting to a diet that suits the postsurgical gastric anatomy and may present with symptoms such as discomfort on eating or even vomiting, particularly where they are failing to adjust the volume and consistency of their diet to the new alimentary arrangement. There is little concern for a leak at this stage, and so barium contrast medium can be used safely, particularly in the assessment for luminal stenosis, staple line disruption (producing fistula from gastric pouch to residual stomach in RYGB) and parastomal/perianastomotic ulceration. A normal barium study will reassure patients and focus the management of symptoms towards dietary modification rather than further intervention.

4.4.2 CT

CT has less of a role as it lacks the information on function and the ability to exclude incomplete or intermittent mechanical obstruction offered by fluoroscopic studies. Patients who have undergone obesity surgery may present with vague abdominal symptoms for a variety of reasons. Clinicians will often request CT to assess the cause, and it is key that the reporting radiologist can recognize the normal postsurgical appearances (Figs. 4.7 and 4.8) [8]. A particular difficulty is the diagnosis of internal hernia, since

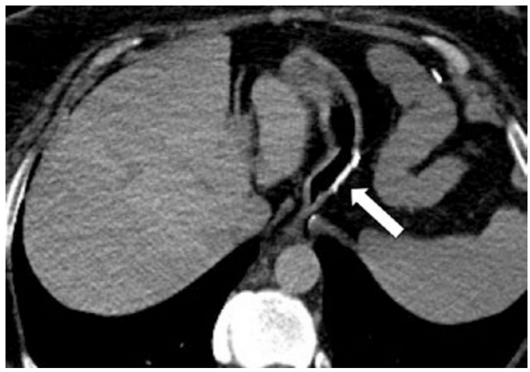

Fig. 4.7 Normal late post surgical appearance of a sleeve gastrectomy. The gastrectomy suture line (*arrow*) is in a normal position beneath the diaphragmatic hiatus, the fat planes adjacent are clean and there is no free fluid or gas. Note the tubular stomach after resection of the gastric fundus and greater curve

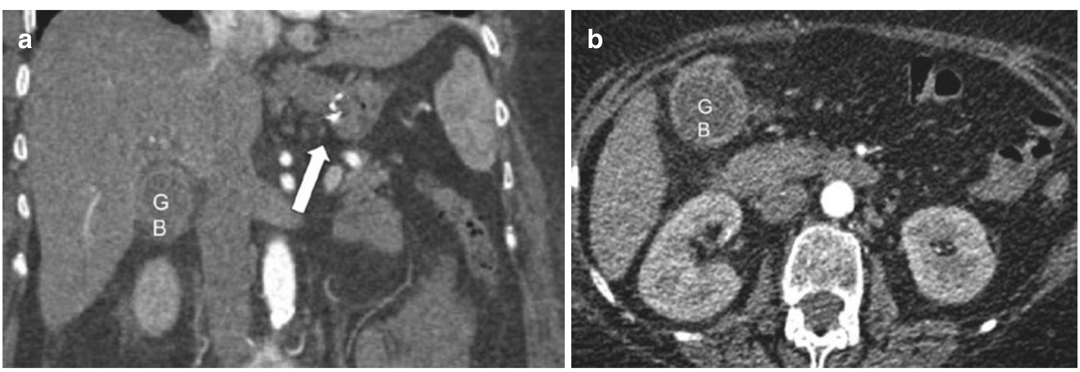

Fig. 4.8 2 years post RYGB with upper abdominal pain. (**a**) Clean fat around the surgical anastomosis (*arrow*) and non-dilated bowel in the left upper quadrant. (**b**) Cholecystitis explains the presentation, with gallbladder oedema and adjacent fat stranding (GB)

the imaging findings are sometimes non-specific and the scan can appear relatively normal when a hernia is actually present. We usually administer positive oral contrast in the postoperative period to allow easier differentiation of the alimentary limb from the excluded biliopancreatic limb. This can make the detection of abnormal orientation or displacement of bowel loops from internal hernia easier to appreciate in the author's experience.

4.4.3 Nuclear Medicine

In cases where the patient has longer-term ongoing vomiting despite normal fluoroscopic and CT studies, a nuclear medicine gastric emptying study may be performed, which reflects the volume and consistency of a normal meal (Fig. 4.9). While this may indicate normal transit, rapid transit may be present that signifies 'dumping' which can be extremely debilitating.

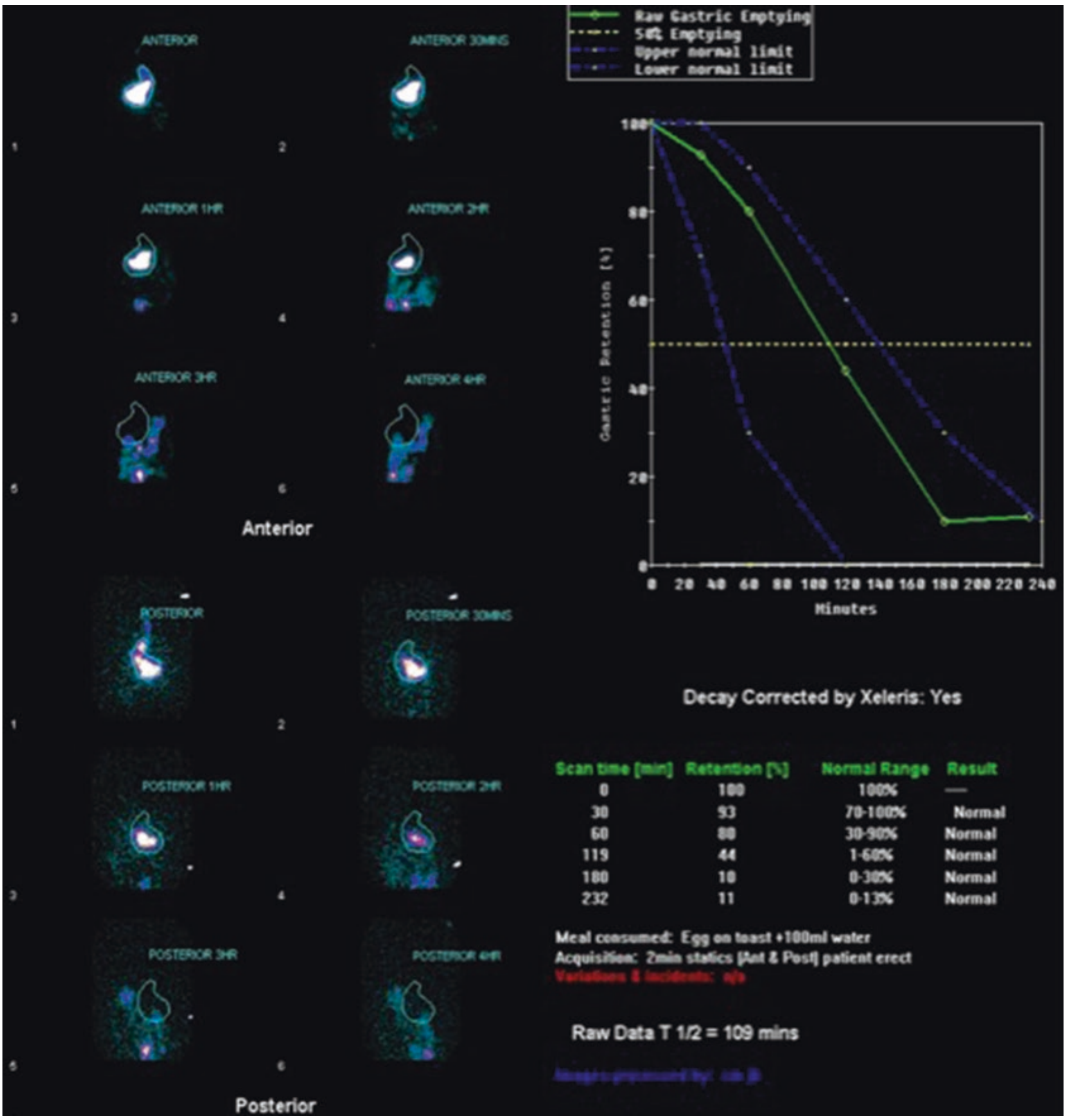

Fig. 4.9 Normal gastric emptying study in a patient with persistent vomiting post sleeve gastrectomy

4.5 Normal Postoperative Imaging of Laparoscopic Adjustable Gastric Band (LAGB)

This is a commonly used procedure as it is the least invasive. The following section describes the appearances of LAGB on various modalities.

4.6 Plain Radiography

The gastric band is placed just below the gastro-oesophageal junction and can be filled with different volumes of fluid to produce varying distensions to create a small gastric pouch, which acts as the food reservoir. The degree of distension is gradually increased allowing the patient to adjust to the restriction in diet. Water or iodinated contrast may be injected using an atraumatic needle to the subcutaneous port site seen projected in the left abdomen. An advantage of iodinated contrast injection is that it can assess for leaks along the catheter connecting the port reservoir to the band. A normally positioned gastric band lies just below the hiatus at approximately 45 degrees to horizontal (Fig. 4.10). The appearances and capacity of bands and ports vary between manufacturers, but the band position and the essential components and connections of the port site and line components to the band are consistent.

A normal gastric band position on a radiograph does not completely exclude displacement, and it obviously cannot assess the functional restriction. However it can diagnose a disconnection between the port and the other components when there is sudden loss of restriction [9].

4.7 Fluoroscopy

LAGB will need position check, functional assessment of band tightness and adjustment using fluoroscopy, particularly where simple functional assessment in the surgical clinic is inadequate or the patient remains symptomatic despite adjustment of the filling volume. Typical clinical scenarios justifying radiological assessment include determining the cause for possible band deflation, poor restriction despite a high band fill volume or conversely over restriction when there is a minimally filled or even empty band.

The control image should be reviewed initially to ensure the band sits in the correct position at around 45 degrees to horizontal. Provided the control image confirms a normal band position, the patient proceeds to contrast swallow with fluoroscopy in either a frontal or right anterior

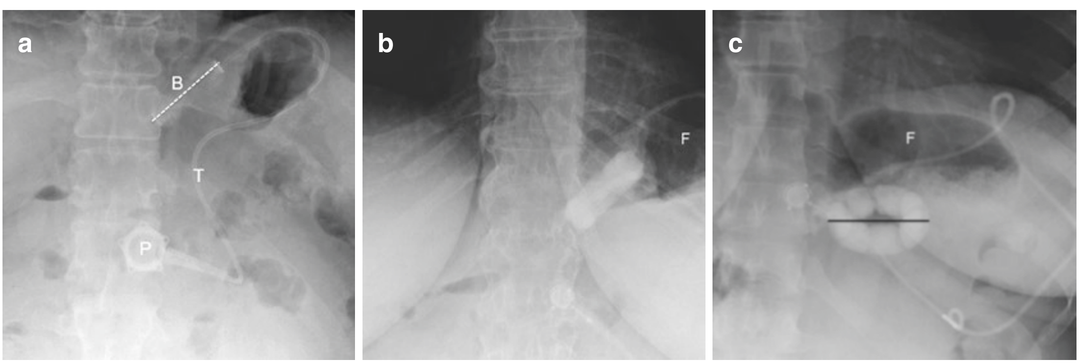

Fig. 4.10 (**a**) Normal band orientation (*dashed line*) at the GOJ, 45° to the vertebral bodies with a recommended field of view including all of the band components in continuity – band (B), tube (T), port site (P). The port is en-face in the expected position, enabling ready access for band adjustment. (**b**) A further example of normal band orientation, with the gastric fundus air bubble lying lateral to it (F). Compare these to (**c**) abnormal horizontal position (solid line) of a slipped band, with the fundus air bubble lying above the band (F)

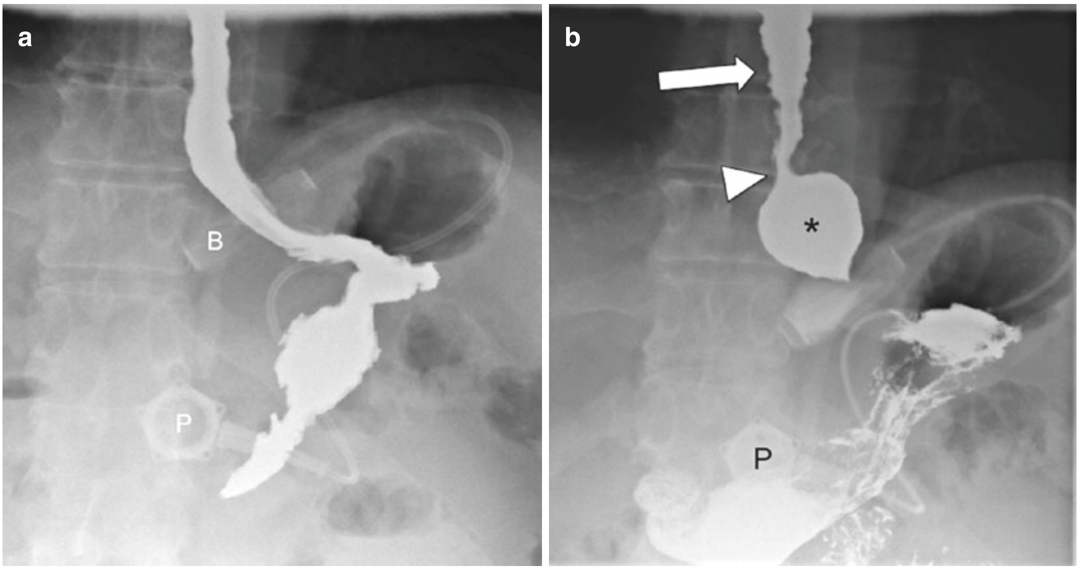

Fig. 4.11 LAGB adjustment. (**a**) Initial swallow shows no restriction from the band (B). (**b**) 3 mL injection into the port (P) produced over restriction and high grade obstruction. Note the strong peristaltic contraction (*arrow head*), tertiary contractions (*arrow*) and pouch dilatation (*asterisk*). A final 1 mL port aspiration produced satisfactory restriction while resoling the dysmotility (not shown)

oblique position [9]. The fundus should lie lateral to the band, and contrast should pass through the normal band with dilatation of a small pouch just below the GOJ, as a sign of adequate restriction. The strength of peristaltic contraction should be maintained to allow passage of liquid through the restriction. A weak or absent primary peristaltic wave or disordered tertiary contractions are a sign that the oesophageal contraction is inadequate for the band to be effective with that level of restriction, and the band fill volume is usually reduced when this is observed (Fig. 4.11).

4.8 CT

In general, CT is used less in the postoperative assessment, as no anastomoses are formed, and hence the risk of leak and bleed is minimal. Patients may present with vague abdominal symptoms after band placement and have a CT performed. Careful assessment of axial and coronal reformats will confirm normal orientation. It is particularly important to ensure that the band has not passed superiorly across the hiatus. Radiologists should be familiar with the shape, components and normal positioning on bands on CT (Fig. 4.12) [9].

4.9 Ultrasound

Ultrasound has no role in routine assessment but may be used to assess the port particularly where access to the port is difficult because of a deep-lying port, which is difficult to palpate for access clinically, and there is concern for infection (Fig. 4.13).

4.10 Normal Postoperative Imaging of Other Surgical Procedures

Fluoroscopy is the most frequently employed modality to routinely assess the anastomoses in both the early and late postsurgical phases. The benefits and aspects of fluoroscopy have already been discussed. We will now focus on some specific aspects related to interpretation in normal examinations.

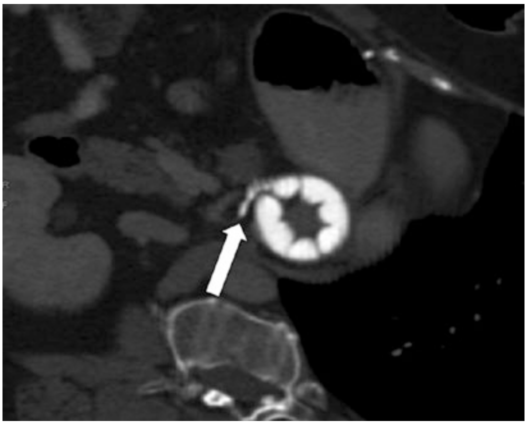

Fig. 4.12 Axial-oblique CT reformat with maximum intensity projection showing normal appearances of a band filled with iodinated contrast. Note the smooth outer contour and lobulated inner margin and the locking device, which holds the band in a closed loop (*arrow*)

and it is important that an adequate volume of contrast is swallowed to allow distension of the remnant stomach to test the full length of the stable line closure (Figs. 4.14 and 4.15).

4.10.2 Magenstrasse and Mill Procedure (M&M)

The Magenstrasse and Mill procedure has been superseded by other techniques, but a cohort of bariatric surgical patients will be referred for upper GI studies that have had this procedure, which is effectively a 'subtotal' gastric sleeve operation. Referrals for imaging may be made to 'clarify the postoperative anatomy' prior to a revision operation.

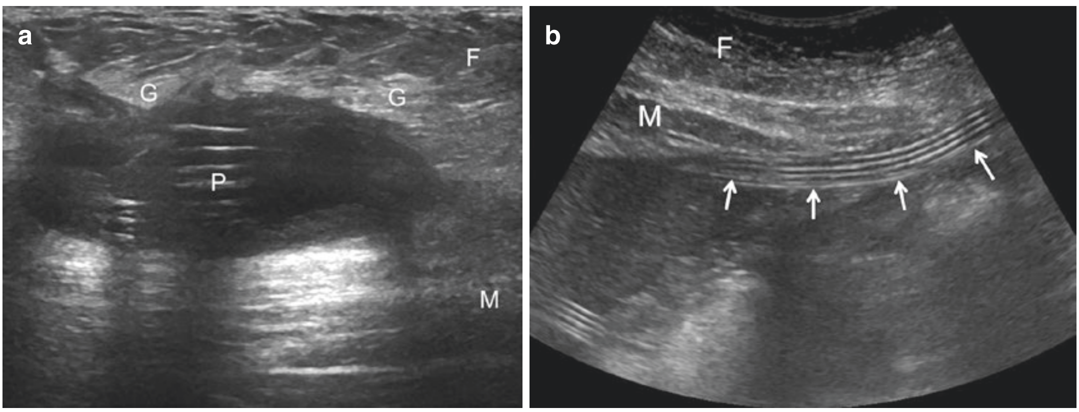

Fig. 4.13 (**a**) Ultrasound performed 1 year after band insertion demonstrates normal appearances of the port, which lies deep in the subcutaneous fat (F) but superficial to the abdominal muscles (M). Reverberation artifact can be seen from the port components, as well as normal echogenic surrounding granulation tissue (G). (**b**) The superficial part of the connecting tube can also be seen (*arrow*). A curvilinear probe can follow the tubing of the LAGB (*arrows*) deep to the abdominal wall muscles (M)

4.10.1 Sleeve Gastrectomy

In sleeve gastrectomy procedure, a portion of the stomach is removed with a metal stapler device along the greater curve creating a tubular stomach, producing a long surgical closure along the stomach. The pylorus, duodenum and jejunum retain their normal anatomical position, but the fundus and greater curve are removed, and the residual upper and mid-body of the stomach are narrowed. Careful scrutiny of the stomach closure line is therefore required in these studies,

The stomach is divided along its longitudinal axis, creating an excluded gastric reservoir that remains in continuity with the remainder of the reduced volume stomach via the pylorus. Initial gastric filling will appear similar to a sleeve gastrectomy with a tubular stomach, but later filling of the large remnant stomach is a characteristic of the postsurgical M&M appearances. Reflux up the excluded portion of the stomach can produce a very unusual appearance, until the radiologist recognizes that an M&M procedure has been performed (Fig. 4.16).

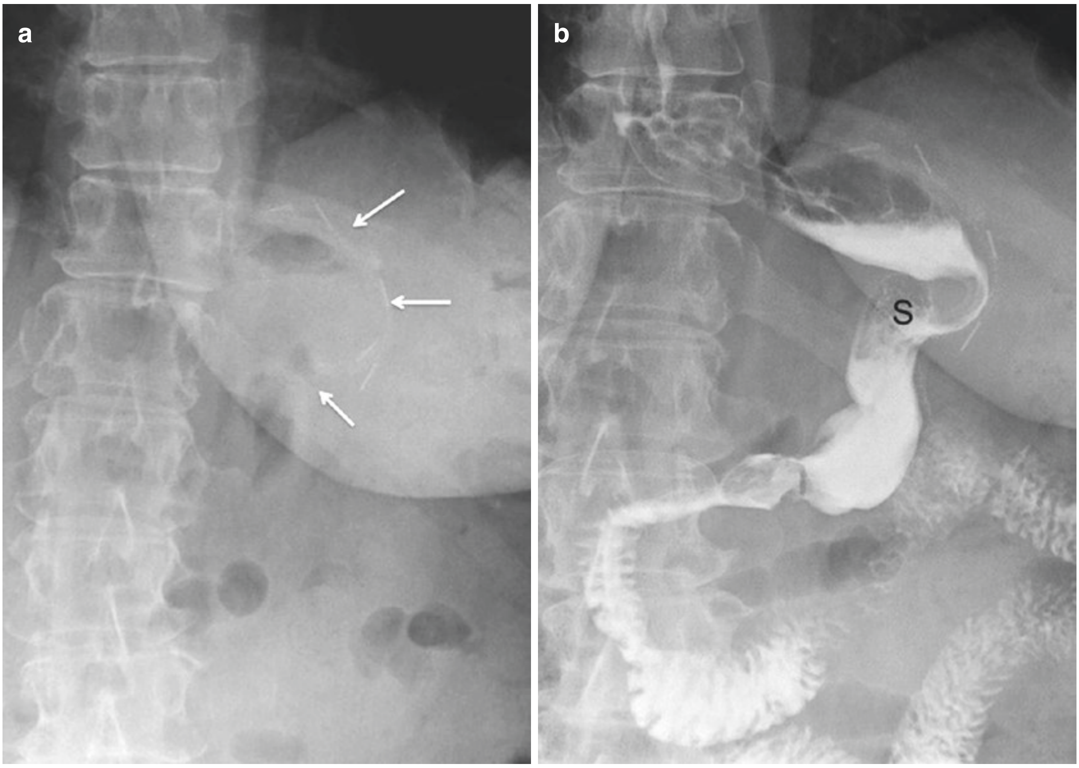

Fig. 4.14 (**a**) AP control radiograph demonstrates the suture lines (*arrow*) along the greater curve of the stomach post sleeve gastrectomy. (**b**) post contrast shows the normal appearances of a distorted tubular stomach (S) with adequate filling to assess the suture line and normal emptying into the duodenum

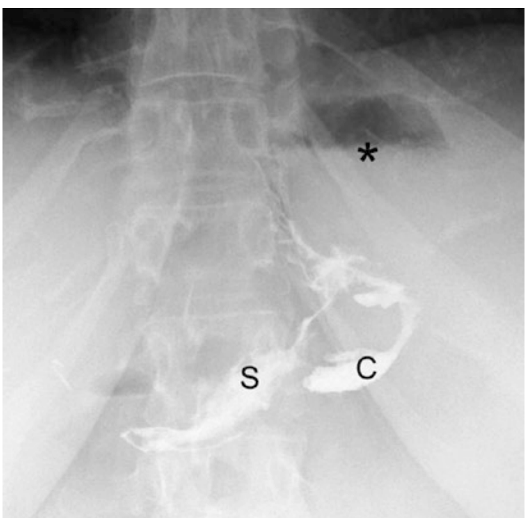

Fig. 4.15 Day 10 post sleeve gastrectomy. Water-soluble swallow demonstrates a leak and collection (c) lateral to the metal suture line. Note the air fluid level below the left diaphragm which is not the fundus, but instead represents a collection (*asterisk*) – the gastric fundus has been removed which is a potential pitfall, avoided by knowing the expected post- surgical anatomy

4.10.3 Roux-en-Y Gastric Bypass (RYGB)

4.10.3.1 RYGB Fluoroscopy

Fluoroscopy is used in the early postoperative phase to assess the gastrojejunal anastomosis for leaks and patency [2]. The alimentary limb is formed by the small new gastric pouch and jejunal Roux loop. This loop will have a blind limb of varying lengths (typically no more than 5–6 cm). The alimentary limb continues to the jejunojejunal anastomosis to meet the biliopancreatic limb where a common channel is formed, to allow digestion.

To confidently exclude a leak, the gastric pouch must be well distended with good opacification of the anastomosis and downstream jejunum [7]. Three views are recommended – usually a right anterior oblique, anteroposterior and left anterior oblique. These can be adjusted depending on patient anatomy, but the

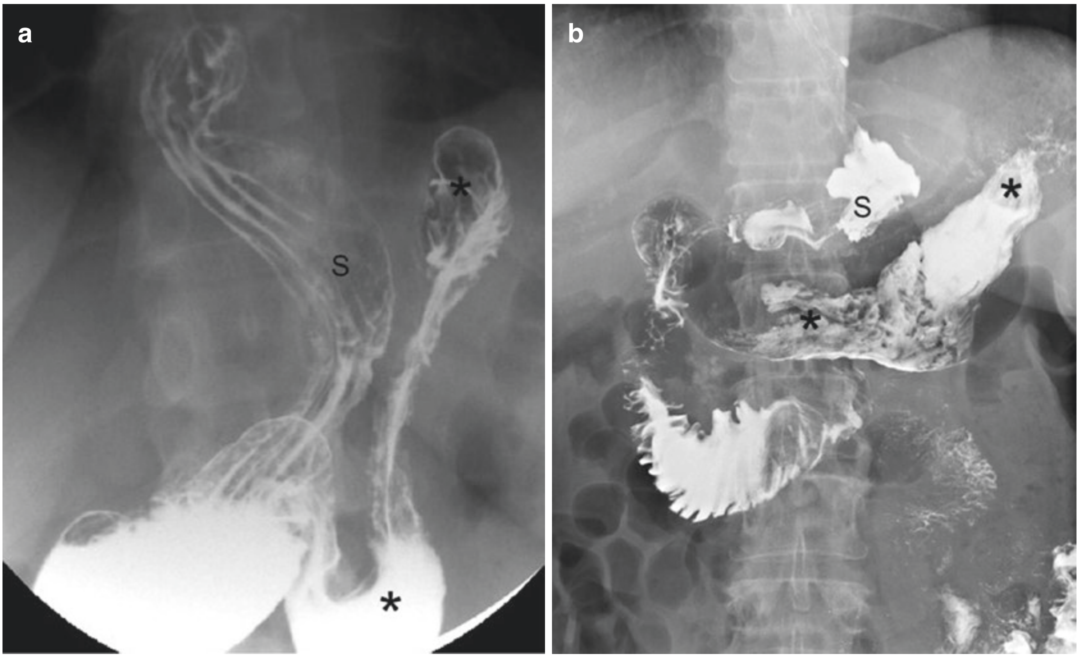

Fig. 4.16 (**a**) and (**b**) Shows two different patients with Magenstrasse and Mill procedures. The tubular stomach remains in continuity with the oesophagus and duodenum (D). The degree of reflux and the size of the excluded portion of the stomach (*asterisks*) can vary

key is to ensure that a leak has not been obscured by contrast in the pouch and Roux loop (Figs. 4.17 and 4.18). The gastric pouch can vary in size and may be particularly small in cases that have had revision of earlier gastric sleeve or other bariatric procedure. Due to contrast dilution, it is not usually possible to adequately examine the jejunojejunal anastomosis to look for a leak, and as this is not common, it does not form part of the routine postoperative assessment. Similarly it is not possible to assess the biliopancreatic limb.

In the immediate postoperative period, the opacified jejunal loops may be distended due to ileus. It can be difficult to differentiate this from obstruction due to adhesions or internal hernia. A delayed radiograph after an hour can be helpful in this situation, as ileus will usually demonstrate that contrast has passed into distal loops, whereas high-grade obstruction will show persistent stasis in the dilated segment.

4.10.3.2 RYGB CT

While the distal jejunojejunal anastomosis is not effectively assessed with water-soluble contrast fluoroscopy because of contrast dilution, CT can more effectively assess this (usually following a delay of at least 30 min after contrast ingestion), as well as the excluded stomach and the biliopancreatic limb. It is important on early post-RYGB CT to assess each staple line in turn – the pouch/excluded stomach, the end of the blind Roux loop, the gastrojejunal anastomosis and the jejunojejunal anastomosis (Fig. 4.19) [10]. Particular points to assess include; the excluded stomach and biliopancreatic limb are not over distended with fluid or gas, which may indicate obstruction from adhesions or internal hernia; the contrast has not passed into the excluded stomach from the pouch to indicate a fistula; the orientation of bowel loops looks normal, with no twisting or distortion of vessels or changes in the mesentery that might suggest an internal hernia [7, 8]. It is also important to assess the position of the gastric

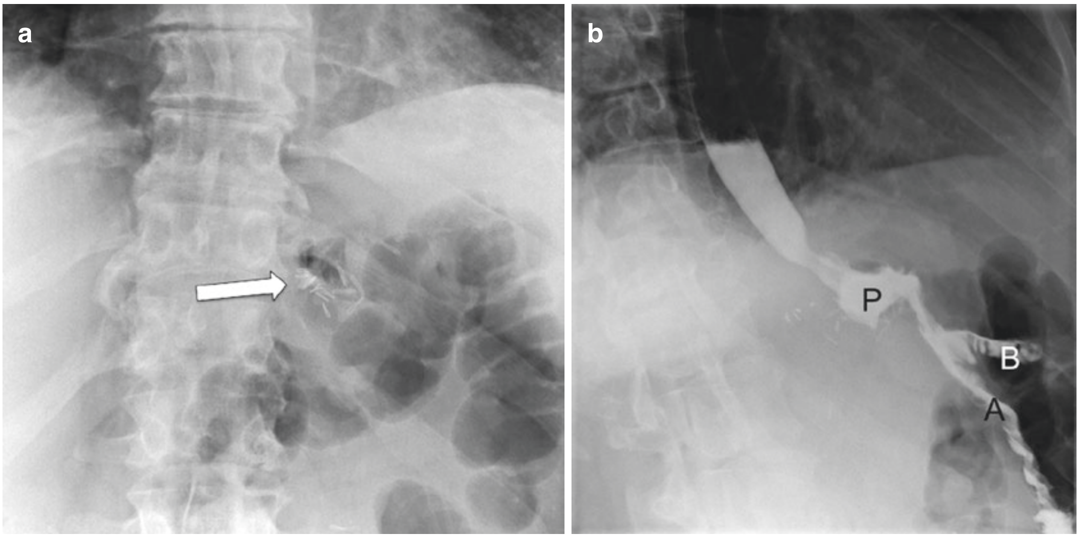

Fig. 4.17 (**a**) Normal post-operative anatomy of RYGB. The initial control view projected the gastric staple lines over the left lower ribs (*arrow*). (**b**) Using a right anterior oblique view, the anastomosis is more clearly visualized. The gastric pouch (P) is anastomosed to the Roux loop of jejunum with a blind limb (B) and the alimentary limb (A) in continuity with the remainder of the small bowel. The remainder of the stomach and duodenum is excluded from the bypass procedure and cannot be assessed

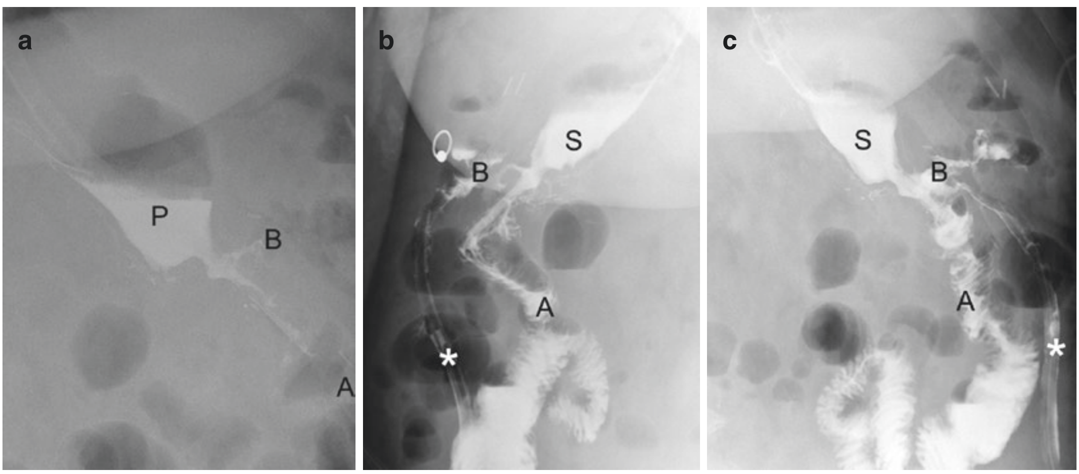

Fig. 4.18 The value of proper opacification of the gastric pouch and jejunum. (**a**) Poor examination without full opacification and adequate distension of the roux loop blind (B) and alimentary (A) limbs. (**b**) Repeat examination with left anterior oblique and (**c**) right anterior oblique with optimal jejunal filling demonstrate a large leak from the blind limb with contrast medium filling the surgical drain (*asterisk*)

pouch and proximal Roux loop to ensure that it has not herniated through the diaphragmatic hiatus, which can produce a sudden deterioration in symptoms, such as vomiting and reflux.

4.10.4 Vertical-Banded Gastroplasty

Vertical-banded gastroplasty (VBG) was a restrictive procedure introduced in 1982 that has

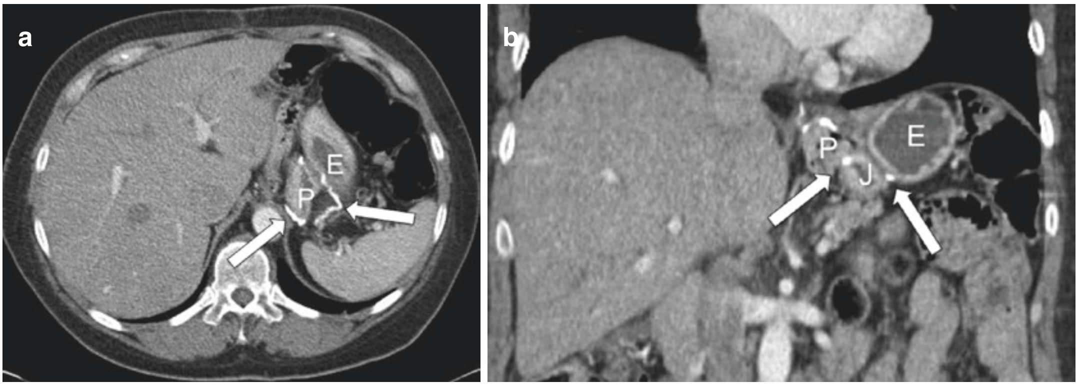

Fig. 4.19 (**a**) Axial and (**b**) coronal CT showing normal post operative appearances with clear and intact staple lines between the excluded stomach (E) and the gastric pouch (P). The jejunal roux loop (J) anastomosis is attached to the pouch

been replaced by other procedures. This created a small gastric pouch at the lesser curve by using a staple line to vertically partition the stomach. A band and mesh created a small proximal gastric pouch, and a small stoma connects this to the remainder of the stomach. As with M&M it is important to recognize this pattern if it is encountered during routine upper GI assessment, particularly where revision surgery is being considered [7].

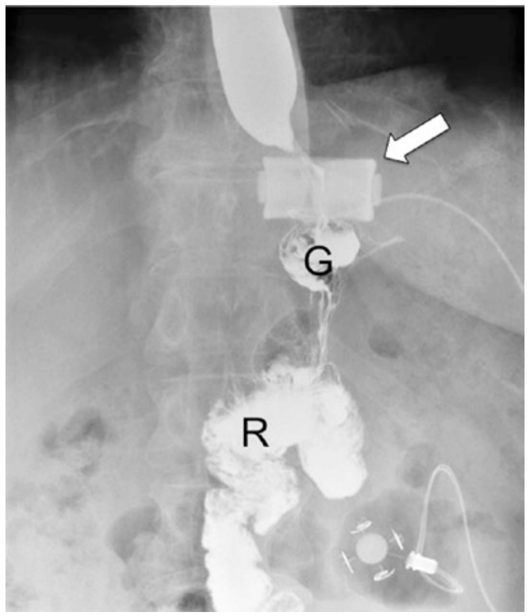

Fig. 4.20 Weight gain after Roux en Y gastric bypass. A gastric band (*arrow*) has been fitted to restrict pouch inflow to the gastric pouch (G) and Roux loop (R)

4.10.5 Combined Revision Operations

Where a bariatric procedure does not achieve weight loss, a surgeon may consider performing a revision procedure. This may for example add restriction from LAGB to the initial sleeve gastrectomy or RYGB. In this setting the postoperative appearances are more complex, representing a fusion of the normal appearances that have been described above (Fig. 4.20).

4.10.6 Duodenal Switch with Biliopancreatic Diversion

This is a combined restrictive and bypass surgical technique which is performed infrequently. The restrictive surgery is a vertical or sleeve gastrectomy removing 70–80% of the stomach at the greater curvature, creating a tubular gastric remnant which preserves the pylorus. The stapled margin of the stomach is important to review for leaks. Next an anastomosis is formed between the post-pyloric first part of duodenum and the enteric or alimentary limb of ileum, approximately 250 cm upstream from the ileocaecal valve. A separate duodenobiliopancreatic limb is formed, which is no longer in continuity with the stomach – the downstream anastomosis is joined to the mid ileum, usually 75–100 cm proximal to the ileocaecal valve forming a common channel with the alimentary limb for absorption [10].

Water-soluble contrast studies can assess the sleeve gastrectomy closure and the enteric anastomoses, but the biliary limb is not opacified by contrast medium [7]. The principles for assessing the remnant stomach closure are the same as for the sleeve gastrectomy. Hold up at the proximal enteric anastomosis is a common finding due to postoperative oedema which may take up to 1 week to resolve [11].

4.10.7 Intragastric Balloons

These are not commonly used but are recognized for their efficacy in short-term weight loss. They are usually placed with endoscopic guidance. The most common postoperative clinical question is whether the balloon remains in the stomach or has deflated because of apparent under restriction. Where the balloon is filled with water, this can be shown with ultrasound confirming fluid within the balloon and placement within the stomach. A normal intragastric balloon is a round structure with a thin hyperechoic wall, internal hypoechogenicity (from water) and a hyperechoic valve may be seen on the surface. Where the balloon is filled with gas, then a plain film of the upper abdomen may suffice to answer the clinical question.

Key Points

1. Radiology service provision for bariatric patients requires specific equipment with appropriate size and weight limits and trained staff with the technical ability to optimize each modality and care for these patients in the radiology department. All radiological techniques have limitations.
2. Fluoroscopy is an important tool for assessing postoperative anatomy, whether functional obstruction is present, and to evaluate leaks. Radiologists should ensure optimal filling of postoperative structures with contrast medium and that adequate views are obtained to increase the sensitivity of leak detection.
3. CT can offer supplementary information when fluoroscopy is equivocal or when the patients are unstable or bleeding is suspected. It is also useful for assessing patients where there is concern regarding non-opacified bowel, typically the biliopancreatic limb, or where there is concern for internal hernia.
4. Knowledge of the expected surgical anatomy is required to correctly interpret imaging findings. This should include an understanding of the historic bariatric procedures that were performed so that these can be readily recognized.

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5 How Imaging Can Rule Out Complications After Surgery

Stephen H. Lee

The risk of complications related to the effects of surgery and general anaesthesia is increased in the high-risk, obese population. These include chest and wound infections as well as an increased risk of deep vein thrombosis and pulmonary emboli. Complications which occur as a direct result of the bariatric surgery itself include haemorrhage, anastomotic leakage and localised trauma to the liver and spleen as a result of traction injuries. Late complications of surgery include port-site herniae and small bowel obstruction from internal herniation and adhesions.

The risk of surgical complications also increases in those patients who have undergone previous bariatric surgical procedures.

The commonest surgical procedure now performed in the developed world for the management of morbid obesity is the Roux-en-Y gastric bypass (RYGB) which is usually performed laparoscopically (Fig. 5.1).

The stomach is divided and there is a band of staples which occludes the proximal stomach. The proximal retrained gastric pouch has a volume of approximately 20–30 mL.

The jejunum is divided approximately 30–40 cm distal from the ligament of Treitz, and a side-to-side gastro-jejunostomy is performed with the proximal gastric pouch. As a result of the side-to-side anastomosis, a small afferent, “blind” loop is left in situ.

A distal jejuno-jejunal anastomosis is created approximately 100–150 cm distal to the proximal gastro-jejunostomy. This procedure provides a combination of both restriction and malabsorption. Early complications include anastomotic leaks from one of the two surgical anastomosis, i.e. from the gastro-jejunal anastomosis or the jejuno-jejunal anastomosis. Leaks can also occur from the two staple lines at the divided stomach or the short, blind ending of the afferent jejunal limb. Late complications include small bowel obstruction and marginal ulcer formation. The risk of complications increases in those patients who have had previous failed bariatric surgery such as a laparoscopic band where there may be fibrosis or scarring around the gastric fundus.

Common complications of the Roux-en-Y gastric bypass procedure are as follows [4–10]:

- Intestinal hernias (incisional or internal) in 6–17% of cases
- G-J or J-J anastomotic strictures in 3–9%
- Anastomotic leak in 3–9%
- Small bowel obstruction in 1–5%
- Marginal ulceration in 0.5–13%

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Contrast studies with CT and/or fluorosopy have been shown to have a sensitivity and specificity of around 50% in the diagnosis of complications following bariatric surgery. Routine postoperative imaging has not been shown to be of significant value [2–5] in improving patient outcome.

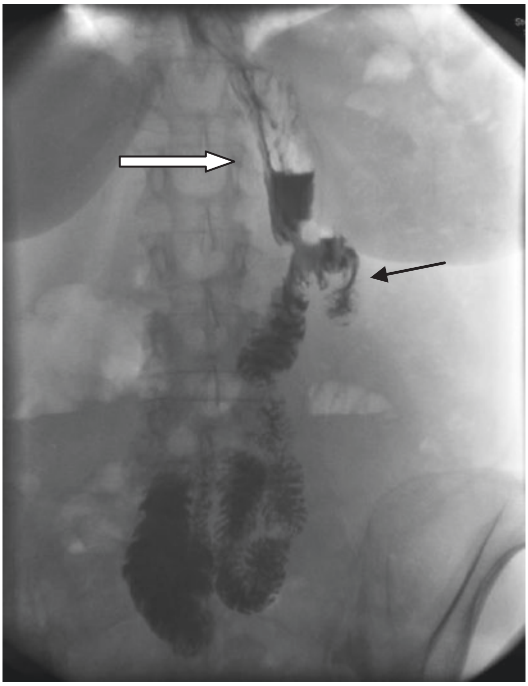

Fig. 5.1 shows gastric pouch (*white arrow*) and short proximal, blind-ending afferent jejunal limb (*black arrow*)

Postoperative complications are best demonstrated by a combination of CT and/or oral contrast studies. One of the most common and potentially fatal complications is that of a postoperative leak which occurred in 5.3% of cases in a series of 906 patients who underwent Rouxen-Y gastric bypass surgery of which 77% occurred at the gastro-jejunal anastomosis (Fig. 5.2 a, b) [7].

Contained leaks can be treated by percutaneous catheter drainage, whereas larger leaks with clinical signs of peritonitis will require open or laparoscopic surgery with a peritoneal washout together with repair of the leak and placement of a surgical drain.

Small bowel obstruction may occur as a result of stricture formation at the distal jejuno-jejunal anastomosis or by internal herniation (Fig. 5.3a, b) through the mesocolic window via the roux loop (Petersen's space). Diagnosis is often difficult and may require a combination of barium follow through studies and CT scanning and occasionally can only be determined by way of laparotomy. Patients present with typical symptoms of small bowel obstruction.

Normal appearance of end-to-side gastro-jejunal anastomosis (Fig. 5.4a) with short blind-ending afferent loop (arrow).

A rare complication which can result in persistent gastro-oesophageal reflux and vomiting

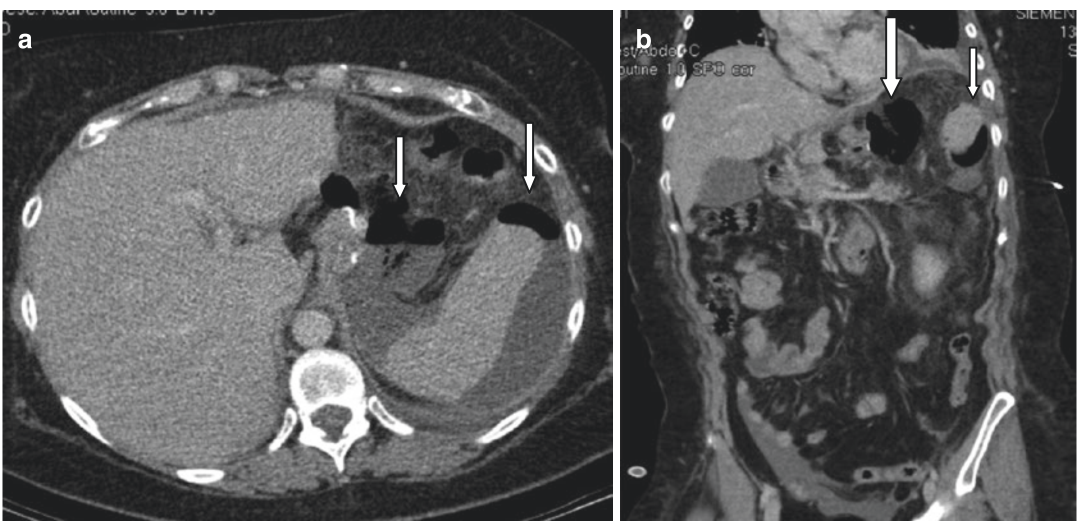

Fig. 5.2 (**a** and **b**) Axial and coronal views showing gas and fluid (*arrows*) from leak at G-J anastomosis

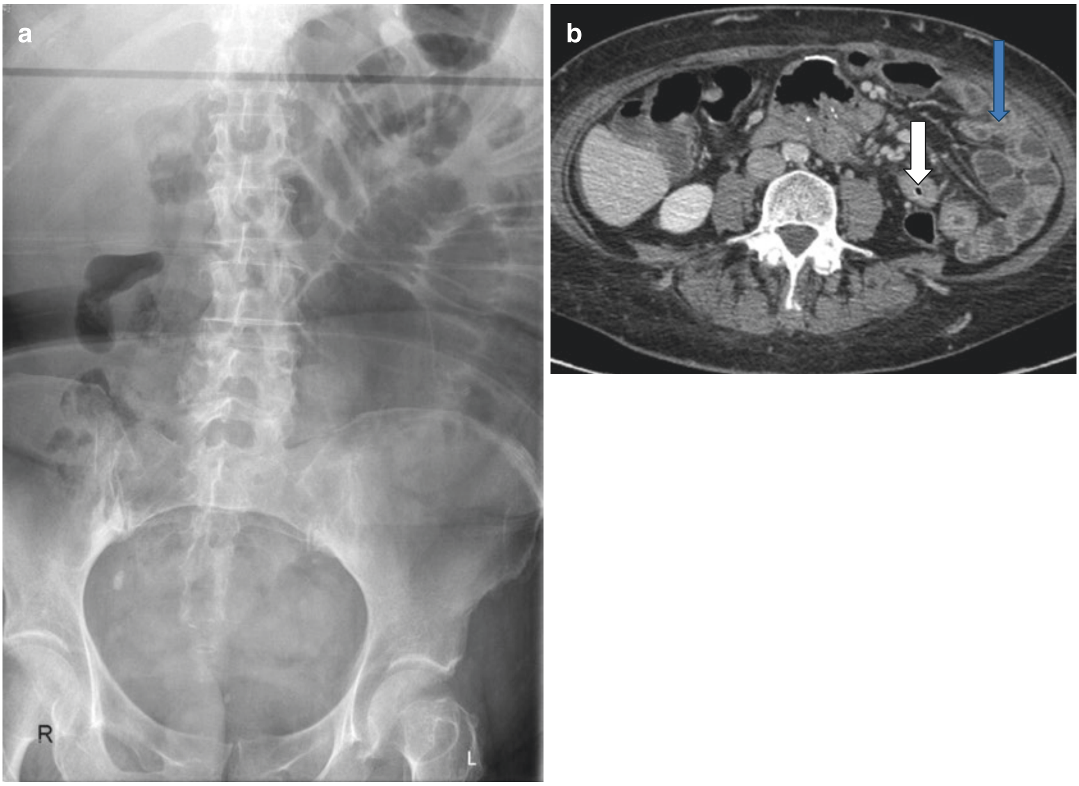

Fig. 5.3 (**a**) Abdominal X-ray showing proximal small bowel obstruction with dilated jejunal loops in the upper left side of the abdomen. (**b**) Corresponding CT scan showing dilated, fluid-filled loops of jejunum (*blue arrow*) on the left side of the abdomen lateral to the descending colon (*white arrow*)

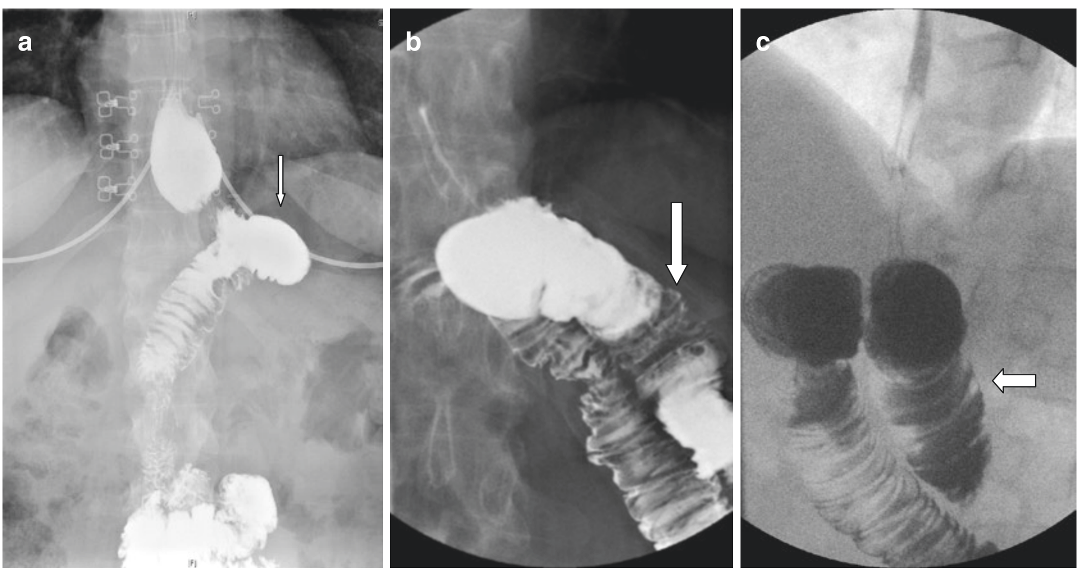

Fig. 5.4 (**a**) Normal appearance of end-to-side gastro-jejunal anastomosis with short blind-ending afferent loop (*arrow*). (**b** and **c**) Excessively formed long afferent jejunal loop (*arrows*)

is due to a long afferent proximal blind-ending jejunal loop, the so-called "candy cane" or "hockey stick" appearance (Fig. 5.4b and c).

Strictures at the gastro-jejunal anastomosis are due to the presence of fibrosis and patients present with reflux and vomiting which can be treated by endoscopic dilatation. They tend to appear in the later stages after surgery and have been reported in up to 9% of cases [8] (Fig. 5.5).

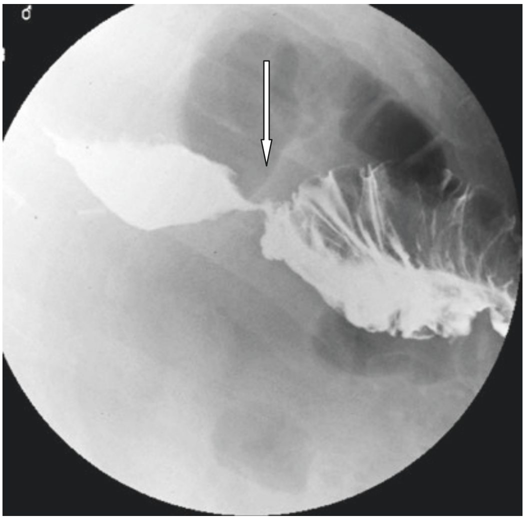

Fig. 5.5 Gastro-jejunal stricture (*arrow*) post-RYGB

5.1 Ulceration at the Gastro-Jejunal Anastomosis

Patients present with epigastric pain and bleeding Treatment is usually conservative with appropriate proton pump inhibitors (Fig. 5.6).

Ulceration and oedema can also rarely develop in the more distal jejunum, usually as a result of ischaemic damage to the mucosa.

5.2 Laparoscopic Adjustable Gastric Banding (LAGB)

This procedure provides restriction only and is more commonly used for patients with less severe obesity.

Early complications are usually a direct result of the surgery such as ileus or haemorrhage.

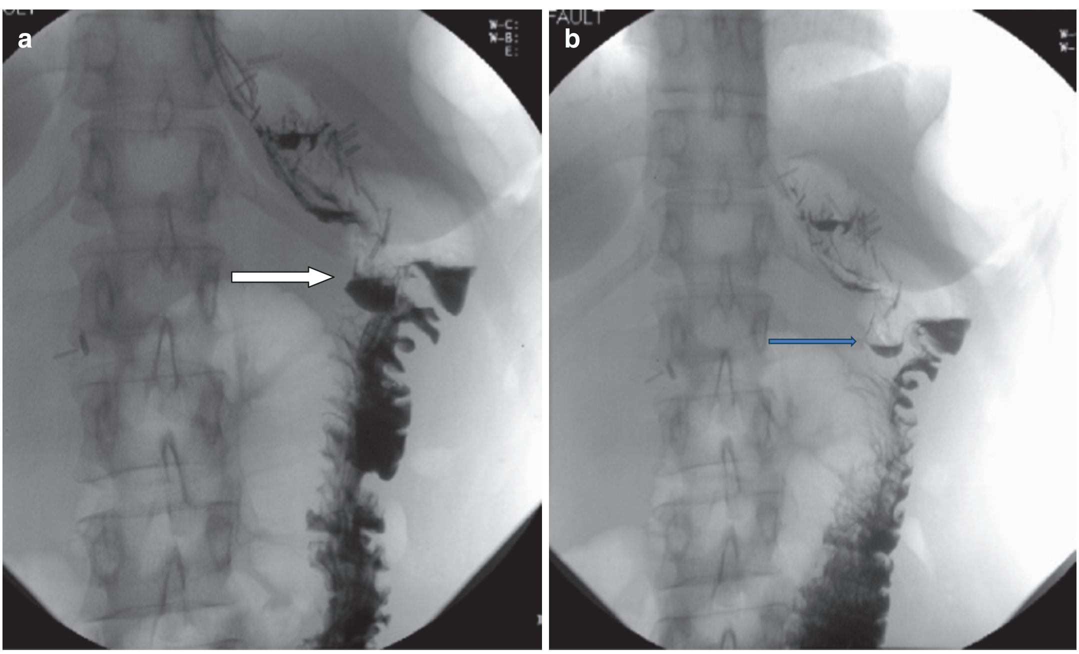

Fig. 5.6 (**a** and **b**) shows a large marginal ulcer (*arrow*)

There are multiple late complications which can occur, the commonest of which is due to pouch dilatation which occurs in 3–10% of patients and band slippage in up to 13% of patients.

The reported long-term results of LAGB are not as good as LAPG or sleeve gastrectomy with a 3-year failure rate reported to be up to 40%.

5.3 Pouch Dilatation

This complication occurs due to a combination of overeating in the presence of a tight band. The patient can usually be adequately treated without resort to surgery by full or partial deflation of the band under fluoroscopic guidance. Patients may present with acid reflux and waterbrash which is usually worse when lying down at night or with a failure to lose weight as the dilated gastric pouch acts as a reservoir for undigested food.

Barium study show showing a persistently dilated gastric pouch (arrow) pre- (Fig 5.7a) and post-band (Fig. 5.7b) deflation.

Pouch dilatation can progress to band slippage and increasing pouch dilatation. This can be diagnosed by demonstrating a transverse lie of the band on plain abdominal X-ray (Fig. 5.8) and a large overhanging pouch on barium studies (Fig. 5.9).

CT scanning can also demonstrate a slipped band (Fig. 5.10a and b), but this is not usually performed unless there are other worrying symptoms present.

Treatment of band slippage is by surgical revision with repositioning of the band or removal of the band.

Band slippage can progress to massive gastric dilatation (Fig. 5.11a and b). This occurs in up to 13% of LABG patients and is due to a combination of a chronically tight band with overeating resulting in band slippage and increasing dilatation of the proximal gastric pouch.

The common causes of late vomiting following LAGB are as follows:

- Overeating
- Excessive tightening of the band
- Long haul air travel
- Stress and hyperacidity
- Effects of the menstrual cycle

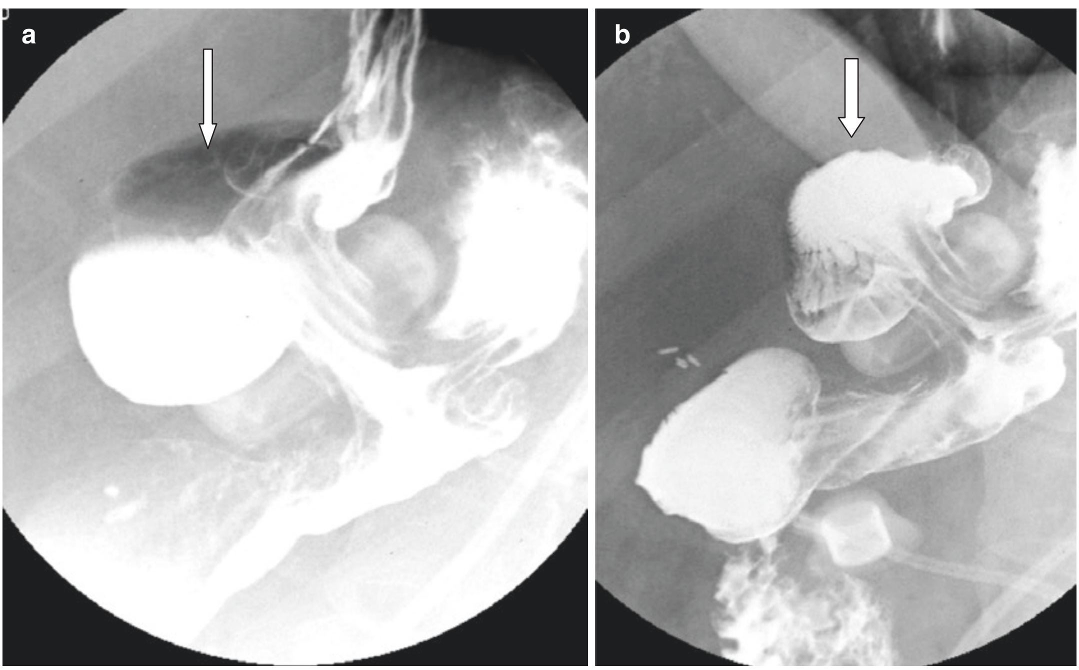

Fig. 5.7 Barium study show showing a persistently dilated gastric pouch (*arrow*) pre- (**a**) and post-band (**b**) deflation

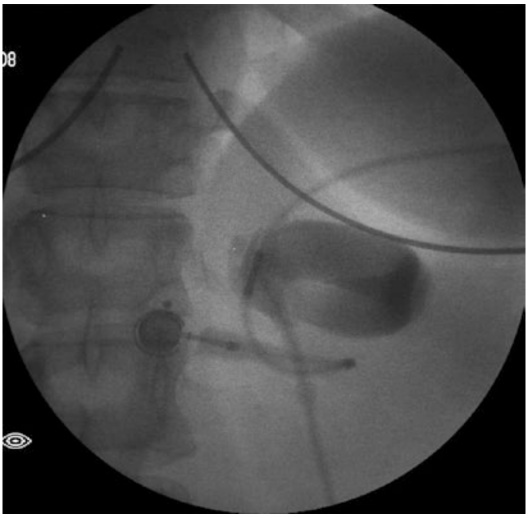

Fig. 5.8 shows a transversely lying band due to band slippage

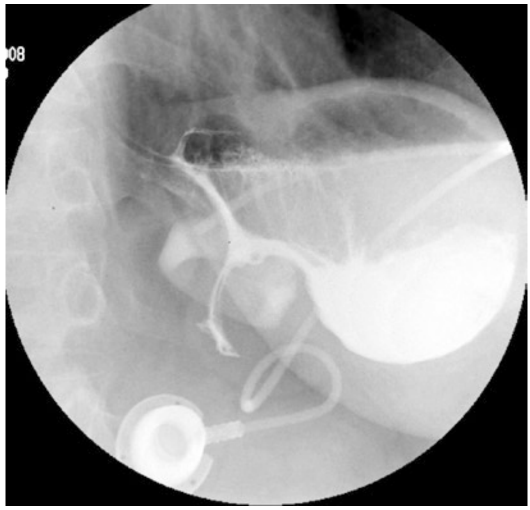

Fig. 5.9 showing a large, fluid-filled proximal gastric pouch which overhangs the band

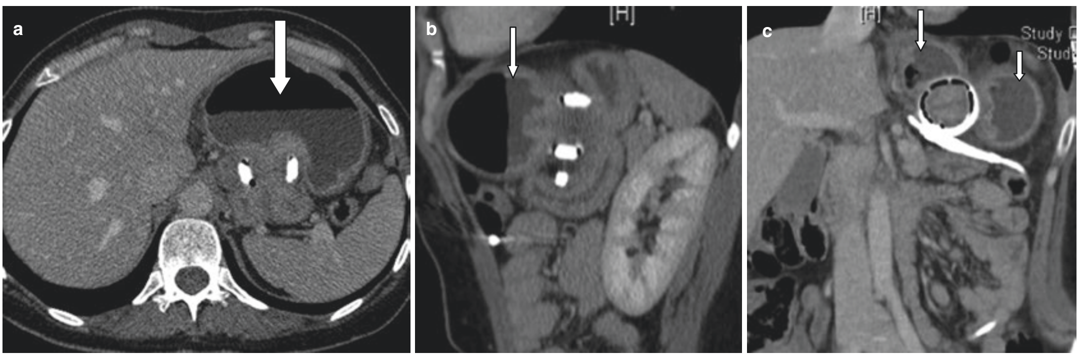

Fig. 5.10 (**a**)showing fluid-filled dilated, overhanging gastric pouch (*arrow*) with a transverse lying band, indicating a slipped band. (**b** and **c**) showing a sagittal and coronal reformat with the same dilated gastric pouch above the slipped band (*arrows*)

Treatment is by band deflation, either partial or full, followed by a period of rest, usually 4–6 weeks, with a delayed band reinflation, as requested by the patient.

A chronically tight band can also lead to fibrosis and scarring around the gastric fundus at the level of the band which may result in a persistent stricture, despite full band deflation, causing mechanical obstruction. This will usually require surgical division at the time of revisional surgery.

Oesophageal dilatation (Fig. 5.13) and *dysmotility* (Fig. 5.14) are also fairly common complications and can occur from a combination of a tight band with excessive eating causing dilatation of the oesophagus. The oesophagus then acts as a reservoir. Patients complain of failure to gain weight or excessive food intake with a lack of satiety. Oesophageal dysmotility is more common in the over 50 age group and in thos patients with long term band placements. Management of this group of patients is by deflating the band in order that the oesophagus can return to a more normal function.

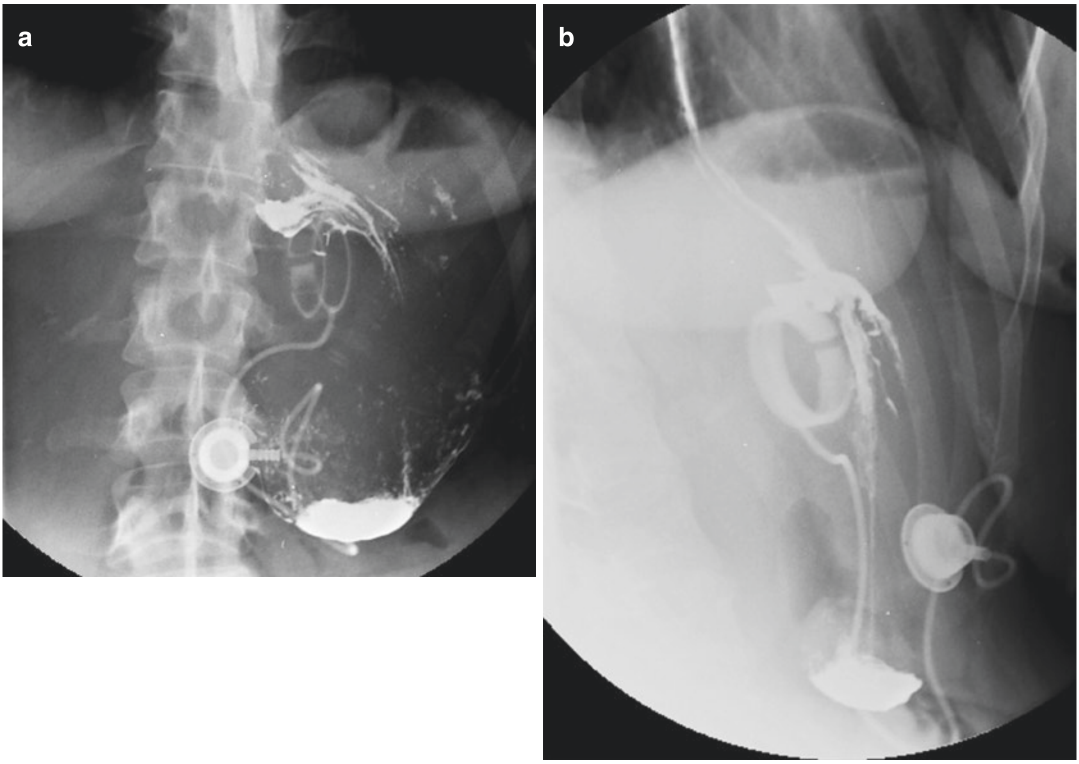

Fig. 5.11 (**a** and **b**) showing massive proximal gastric dilatation with band slippage. There is a large fluid level in the stomach. Note the vertical orientation of the band which has slipped from the horizontal to the vertical position

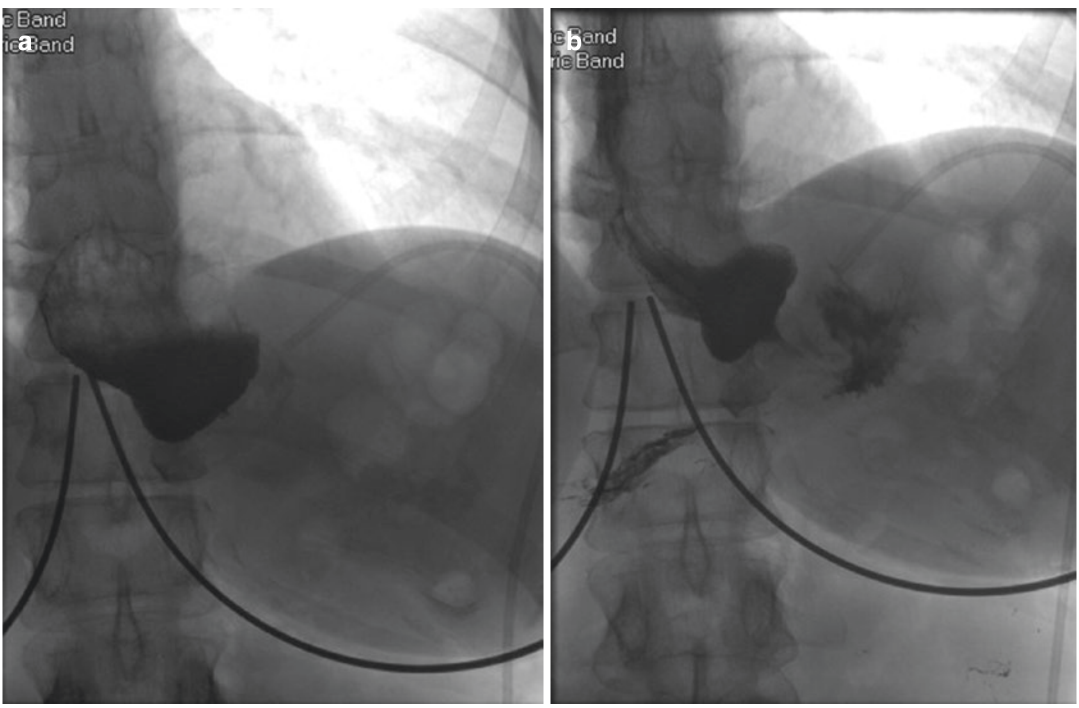

Fig. 5.12 (**a**) shows a tight band with complete obstruction. (**b**) shows a persistent stricture at the level of the band despite full deflation

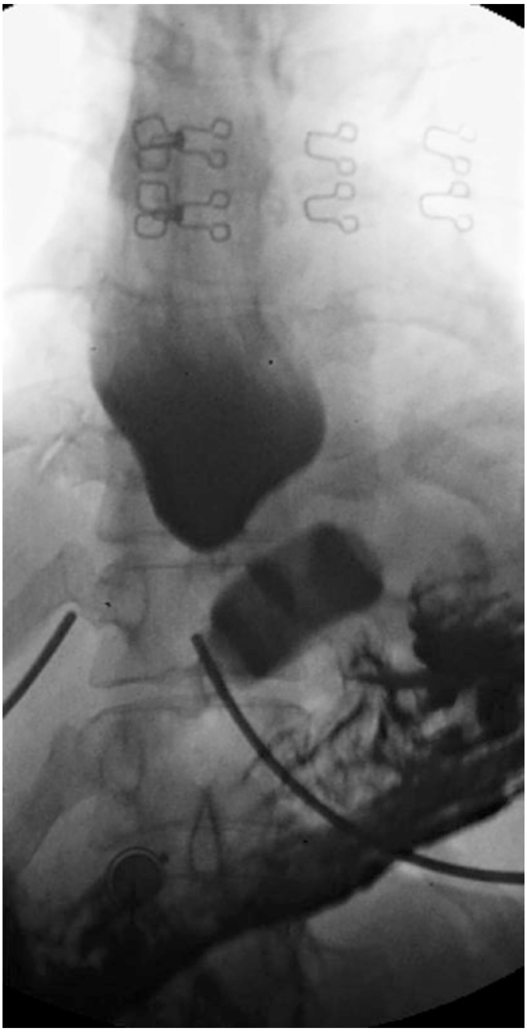

Fig. 5.13 shows a dilated, fluid-filled oesophagus with a tight band

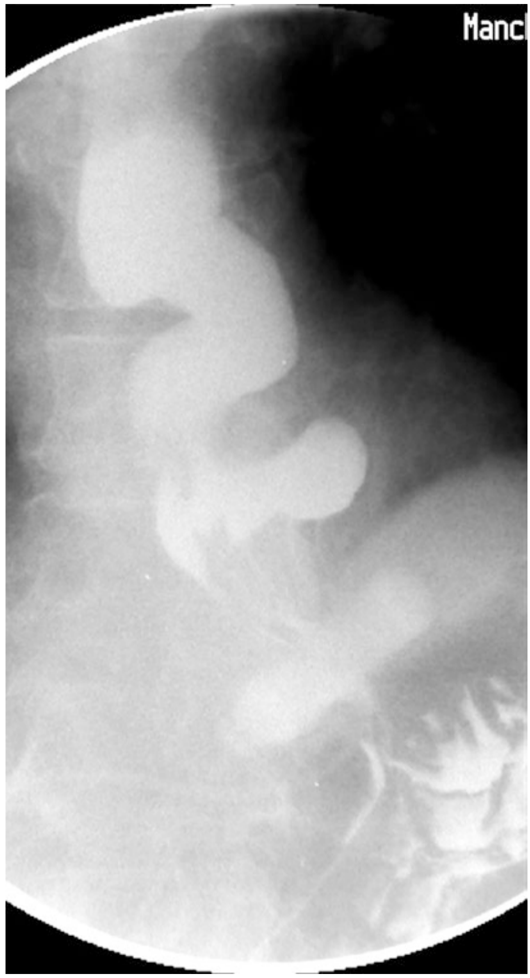

Fig. 5.14 shows gross oesophageal dysmotility with a “corkscrew”-like appearance in a 56-year-old lady.

5.4 Leaking Band/Port Site has Been Reported in Up to 5% of Band Placements

Tube leakage can occur by repeated needling of the port site causing damage to the port or from disruption or partial separation at the metal-tubing connection (Fig. 5.15a). This can occur spontaneously or from poor surgical placement.

Port site leakage may occur as a result of direct needle trauma as a result of multiple blind attempts at needle placement (Fig. 5.15b).

This complication can be detected by aspirating air and sometimes yellow stained fluid as a result of contamination and/or infection from the port site when the patient attends for a band fill. A leak of contrast can usually be readily seen on radiological screening when full-strength contrast is best used to detect such a leak.

Slow leaks can be much more difficult to diagnose, and the patient may require repeated attendance in order to assess the volume of fluid in the band. Careful screening is required to demonstrate these subtle leaks which occasionally may only be confirmed at the time of surgical band revision.

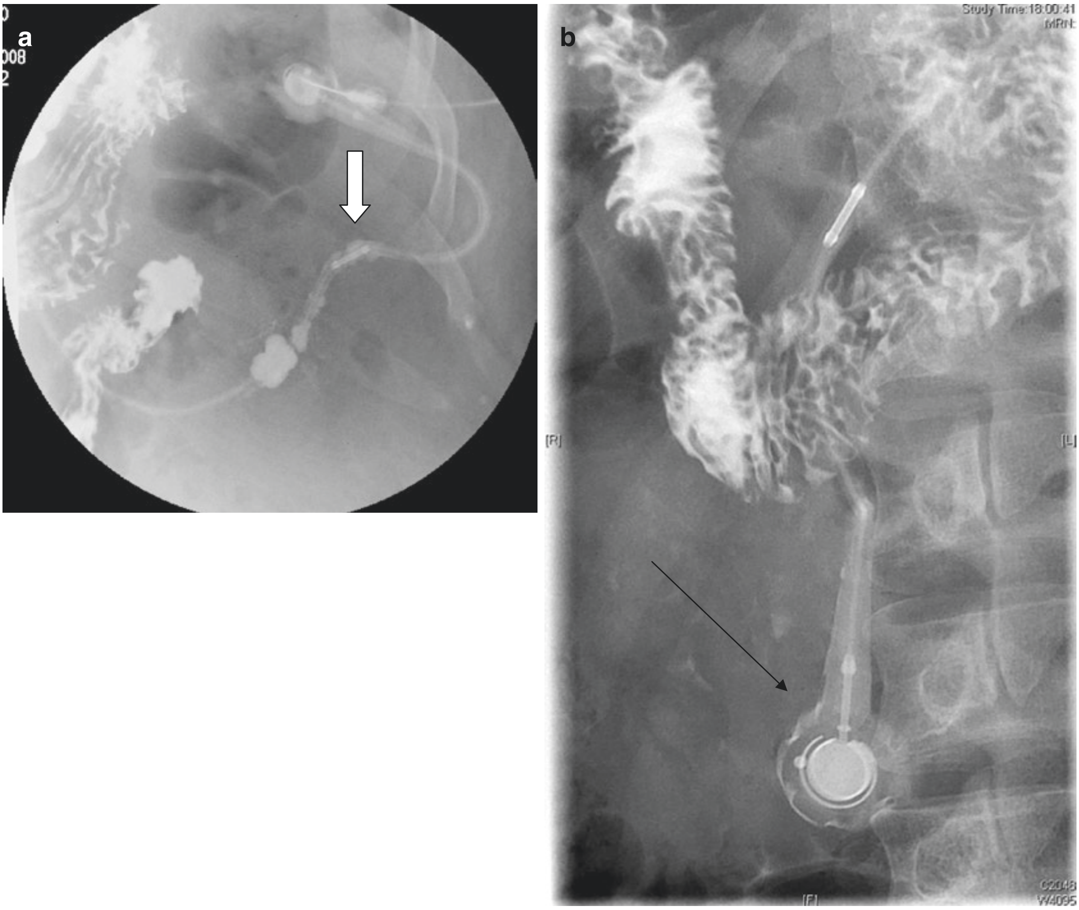

Fig. 5.15 (**a**) showing contrast leak from tubing at the catheter/metal junction (*arrow*). (**b**) showing contrast leak from port site which outlines the port and proximal tubing (*arrow*)

5.4.1 Food Bolus Impaction

This occurs with a tight band when the patient ingests a large food bolus such as meat. Contrast studies show the food bolus stuck above the band (Fig. 5.16).

This can easily be managed by fully deflating the band and allowing the bolus to pass through the band and then partially reinflating the band to allow continued restriction. Endoscopy is usually not necessary to remove the impacted bolus.

5.4.2 Detached Tubing

Patients present with loss of band restriction. Abdominal x-ray or radiological screening shows the loss of continuity of the tubing (Fig. 5.17) usually at the metal catheter interface. If the port site is cannulated (as with a leaking band), there is little or no fluid in the band, and aspiration reveals air only.

5.5 Intraluminal Band Erosion

Band erosion has been reported in up to 3% of patients. The aetiology is not certain but can occur as a result of a chronically over inflated band and is usually asymptomatic but can result in haematemesis. Patients usually complain of lack of restriction and weight gain as food passes around the band into the stomach. Confirmation of the radiological findings is by way of endoscopy, and the band will require removal.

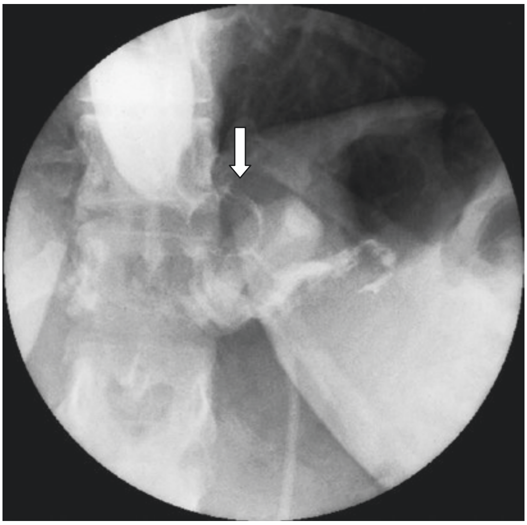

Fig. 5.16 shows food bolus impaction above the band (*arrow*)

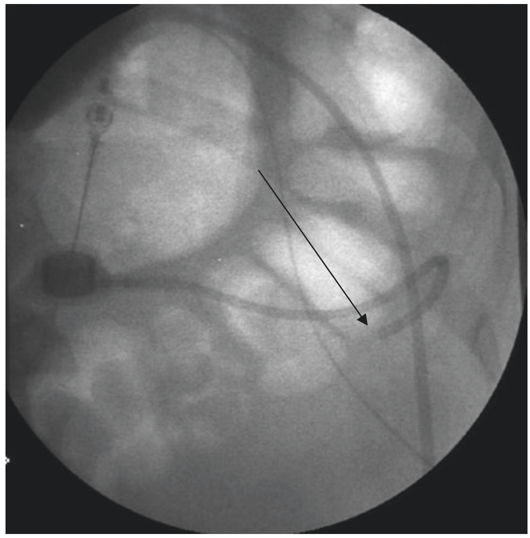

Fig. 5.17 shows detached tubing (*arrow*)

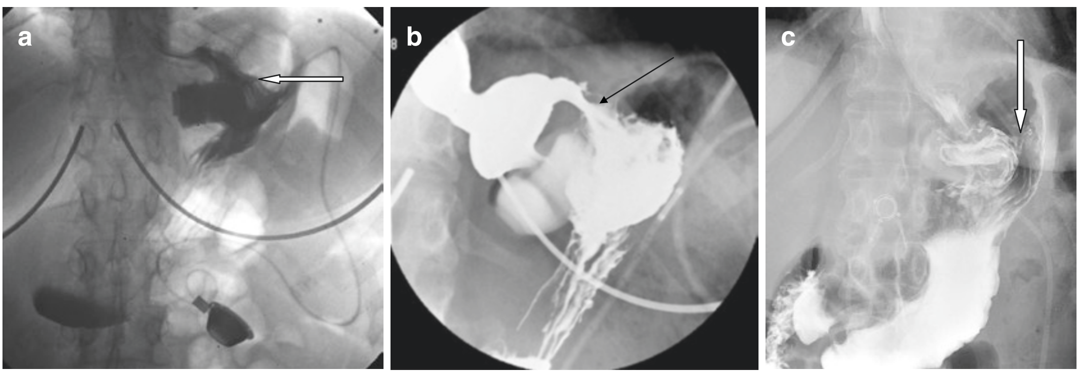

Fig. 5.18 (**a**-**c**) shows band erosion with barium (*arrows*) passing around the band rather than through the middle of the band

Multiple oblique views during contrast screening are important to demonstrate contrast passing around the band (Fig. 5.18a–c) and also to demonstrate the position of the band in relationship to the gastric fundus. This can be a subtle finding and be difficult to demonstrate and confirmation with endoscopy is usually required.

Unclipped band can occur spontaneously or as a result of overfilling the band. Patients present with sudden loss of restriction. The band requires deflation followed by surgical re-clipping.

The diagnosis is made during fluoroscopic screening with oblique views (Fig. 5.19).

Malpositioned band at the time of the initial surgery. This should be an uncommon occurrence and can only be diagnosed at the time of barium studies (Fig. 5.20).

Port site complications include mobile or inverted ports which are difficult to access

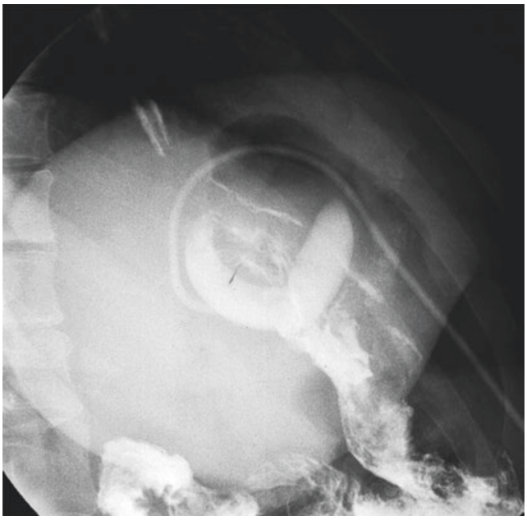

Fig. 5.19 showing a "horseshoe" appearance to the band where it has become unclipped

Fig. 5.20 shows the band lying completely outside the line of the oesophagus and stomach

percutaneously. This complication has been reported to occur in up to 5% of cases and will require revisional surgery to reposition or fix the band to the rectus muscle.

Port site infection can be diagnosed by aspirating the band or surrounding soft tissues and sending a specimen for microbiological analyses. If the band fluid is discoloured (usually yellowish) or if infection is confirmed on testing, then the band will require removal. Infections usually arise from poor aseptic technique during fills.

Management of the failing LAGB patient can be difficult, and this can sometimes fall within the remit of the radiologist who has to make a decision whether or not the failure to lose weight is due to difficulties with the patient's dietary intake or whether the failure to lose weight is due to a complication related to the band. It is important for the radiologist to not only be aware of the potential complications but to discuss the pros and cons of appropriate band adjustment in order that the patient can achieve the best short- and long-term outcomes. This may require a frank discussion between the patient, radiologist and surgeon to decide whether or not revisional surgery is required in order to achieve adequate weight loss or whether other dietary factors need addressing.

5.6 Sleeve Gastrectomy

Early complications include leakage from the gastric staple line resulting in abscess formation and/or peritonitis. Leaks have been reported in up to 1.3% of cases [5] and can result in both abscess and fistula formations. These complications will require a combination of CT with contrast imaging to demonstrate the leak or fistula which is often managed conservatively where possible by percutaneous catheter drainage (Fig. 5.21).

Late complications include gastric stricture formation and stenosis as a result of fibrosis (Fig. 5.22a and b).

In summary, radiologists must be aware of the normal findings of the common bariatric surgical procedures and their complications. A combination of CT and careful fluoroscopic contrast studies is used to detect the

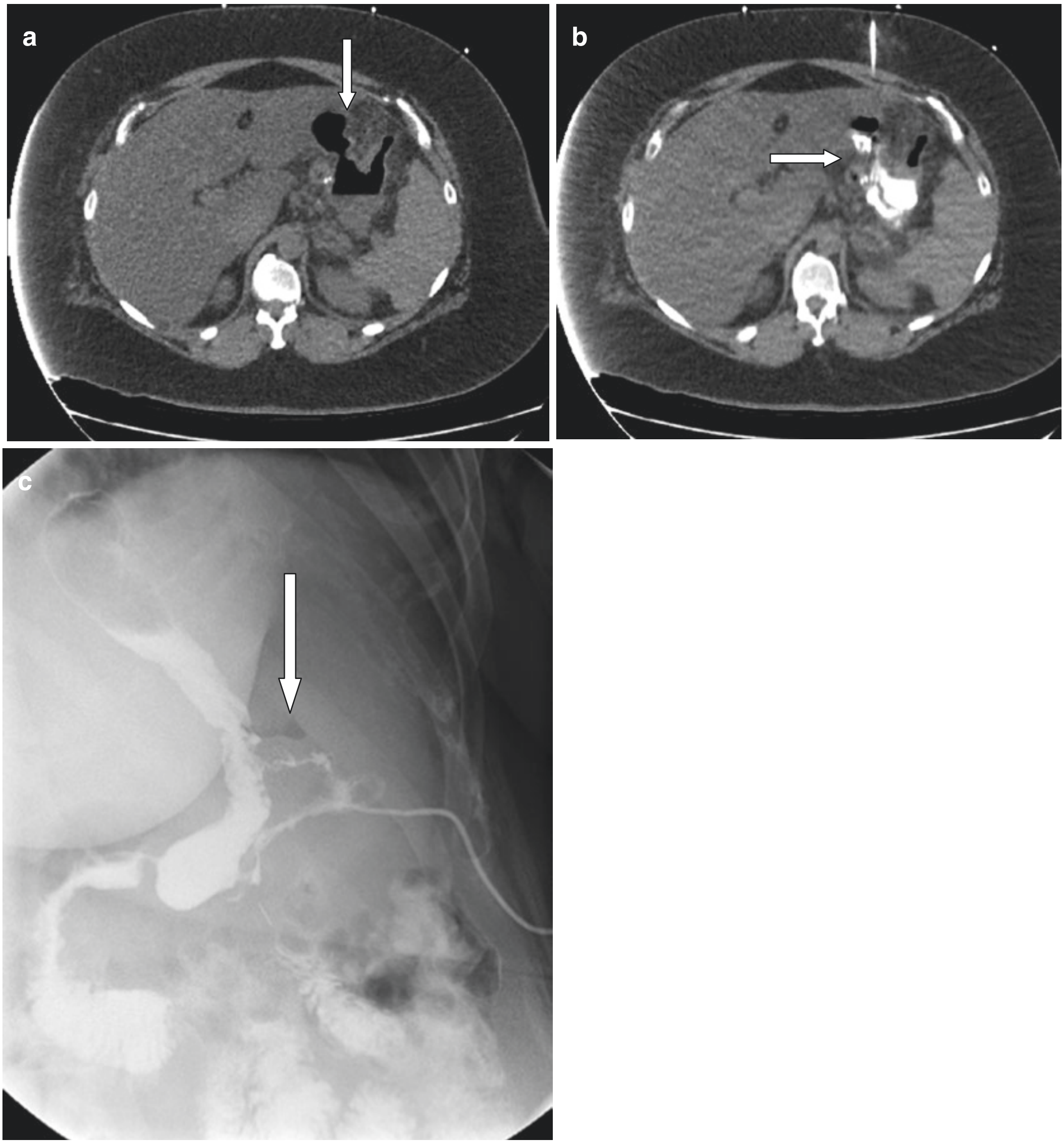

Fig. 5.21 (**a**-**b**) shows a CT scan showing gas within postoperative collection before and during percutaneous catheter drainage. (**c**) shows corresponding contrast study demonstrating leak of contrast into cavity with radiologically placed drain in place

complications of RYGB, LAGB and sleeve gastrectomy. There is an important role for the radiologist in diagnosing and managing the complications following laparoscopic banding as well as dealing with the "failing" band patient.

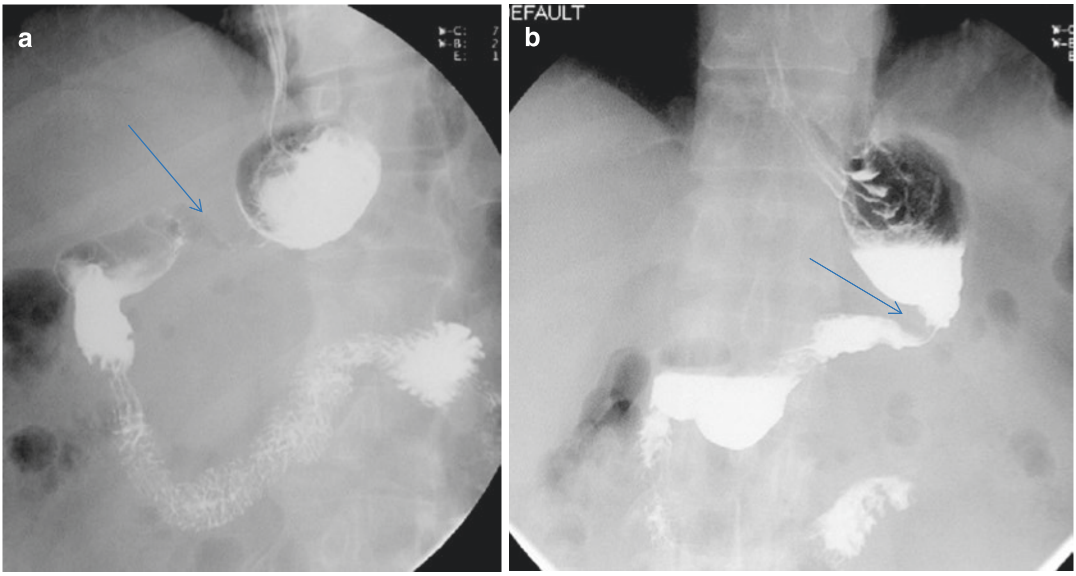

Fig. 5.22 (**a** and **b**) shows a mid-body gastric stenosis (*arrow*)

Key Points

1. Contrast studies with CT and/or fluoroscopy have been shown to have a sensitivity and specificity of around 50% in the diagnosis of complications following bariatric surgery. Routine postoperative imaging has not been shown to be of value.
2. Postoperative complications are best demonstrated by a combination of CT and/or oral contrast studies.
3. CT is the imaging modality of choice for the evaluation of suspected complications after Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy.
4. CT is not recommended for the evaluation of suspected complications after laparoscopic adjustable gastric banding (LAGB). In this setting fluoroscopy can also be used to guide the treatment of such complications.

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6 The Role of Interventional Radiology in the Management of Post-Operative Complications

Chiara Zini, Rhys Llewelyn, Mario Corona, and Simon Jackson

6.1 Introduction

Estimates suggest that 1.7 billion people worldwide are clinically overweight with a prevalence that increases year-on-year [1, 2]. The body mass index [BMI, kg m^{-2}] which is widely used as the measure of obesity defines the term "clinically overweight" as an individual with a body mass index between 25 and 30 with the definition of obesity as a patient with a BMI of greater than 30. Currently two thirds of individuals living in the United States (USA) are overweight, and of those, almost half are obese [2]. In Europe, the proportion of adults who were considered to be overweight or obese varied in 2008 between 37.0 and 56.7% for women and between 51.0 and 69.3% for men [3].

Conservative management including both lifestyle and patient medication has historically offered the main choices for patient management although these do not necessarily achieve effective long-term weight reduction. Recent evidence has demonstrated the effectiveness of bariatric surgery in this group of patients by not only inducing weight reduction but also reducing the significant associated comorbidities and long-term mortality by up to 40% [4].

Currently approximately 350,000 bariatric surgical procedures are performed annually worldwide with 63% performed in the USA and Canada [5, 6].

In 2011, the global total number of bariatric surgical procedures was 340,768; the global total number of metabolic/bariatric surgeons was 6705. The most commonly performed procedures were Roux-en-Y gastric bypass (RYGB) 46.6%, sleeve gastrectomy (SG) 27.8%, adjustable gastric banding (AGB) 17.8%, and biliopancreatic diversion/duodenal switch (BPD/DS) 2.2%. The global trends from 2003 to 2008 to 2011 showed a decrease in RYGB, 65.1 to 49.0 to 46.6%; an increase, followed by a steep decline, in AGB, 24.4 to 42.3 to 17.8%; and a marked increase in SG, 0.0 to 5.3 to 27.89%. BPD/DS declined, 6.1 to 4.9 to 2.1% [7].

These surgical procedures can be broadly categorised into restrictive, malabsorptive, and combined types.

Restrictive procedures significantly reduce gastric volume in order to induce weight loss by restricting gastric capacity and thus promoting early satiety. Typical examples include laparoscopic

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Table 6.1 Mortality rate, reoperation rate, and complications of the common bariatric surgery procedure [10]

	Mortality at less than 30 days	Mortality at more than 30 days	Reoperation rate	Complications
Adjustable gastric banding	0.07% (0.02–0.12)	0.21% (0.08–0.37)	7.01% (3.99–11.24)	7.80% (3.90–13.00)
Sleeve gastrectomy	0.29% (0.11–0.63)	0.34% (0.14–0.60)	2.96% (1.70–4.71)	8.90% (5.60–13.00)
Roux-en-Y gastric bypass	0.38% (0.22–0.59)	0.39% (0.01–0.86)	5.34% (4.48–6.48)	12.00% (7.30–17.00)

adjustable gastric banding (LAGB) and laparoscopic sleeve gastrectomy (LSG). Gastric banding which is currently in decline worldwide includes the implantation of a silicon band around the proximal stomach in order to create a small pouch. The band may be adjustable via a subcutaneous port in order to create a stomal communication to the distal stomach. LSG utilises a vertical transection of the stomach resulting in a reduction of functional gastric capacity of approximately 75%. Research suggests that the restrictive procedure also contributes to a decrease in appetite by the reduction of available ghrelin-producing cells in the gastric fundal region [8].

Malabsorptive procedures act by limiting food digestion and thus rate of absorption by reducing the length of effective small bowel. The group of procedures include jejunoileal bypass, biliopancreatic diversion, and the duodenal switch procedure. The procedures however are associated with significant complication rates including intermittent diarrhoea and steatorrhoea due to the malabsorption and metabolic effects. They are now rarely performed.

Mixed procedures however take advantage of both groups of operation. For example, the Roux-en-Y gastric bypass (RYGB) uses proximal gastric stapling in order to create a small gastric pouch (restrictive) with a jejunal diversion to shorten the functional length of small bowel (malabsorptive). Other rarer combinations include gastroplasty with gastric bypass, biliopancreatic diversion with gastric bypass, and gastric banding with gastric bypass**.** Today the three procedures of LSG, RYGB, and LAGB comprise the vast majority of bariatric surgical procedures performed worldwide.

Multiple publications have demonstrated that bariatric surgical procedures are safe with an overall low morbidity (Table 6.1).

However, a mortality rate of 29.4% has been described in 2007 from the Italian Society for Obesity Surgery during a 10-year analysis [9]. The mortality risk has been related to different factors including type of surgery, prolonged operative time, comorbidities, and volume of activity [9].

Interventional radiology (IR) plays an important role in the multidisciplinary management of post-operative complications. A number of relevant IR techniques will be covered in more detail during the forthcoming chapter.

6.2 Post-operative Complications Following Bariatric Surgery

Each bariatric surgical procedure presents a different spectrum of complications. The most common procedures with their associated complications are as follows [11]:

6.3 Gastric Banding (GB)

GB includes procedures involving both adjustable and nonadjustable band placement.

Whilst the technique is in decline, many patients have implanted bands in situ.

Complications include:

- *Malpositioning of the gastric band*: Commonly related to band slippage in the perigastric fat or distal stomach which can occur at various (early and late) periods of post-surgery.

- *Infection and gastric perforation* (0.1–0.8% of patients): Band infection usually manifests in the early post-operative period with variable symptoms ranging from fever to severe abdominal pain and hypotension. Gastric perforation is uncommon and can lead to gastric obstruction/perforation.
- *Pouch dilatation* occurs when there is overexpansion of the gastric pouch proximal to the band. This complication is usually due to band slippage/overinflation/overeating/stomal oedema; gastro-oesophageal reflux with vomiting may be the presenting symptoms.
- *Gastric band slippage and prolapse* is defined as herniation of the distal stomach upward from below the band which may occur in an anterior or posterior direction. Slippage results in an abnormal band position with eccentric pouch dilatation and may lead to chronic stomal stenosis, which has been observed in 4–13% of patients. Slippage clinically presents with limited weight loss, severe gastro-oesophageal reflux, and nocturnal vomiting.
- *Intragastric erosions* (occurring as 0.3–14% of patients in various series) are defined as partial or complete. Their aetiology may be secondary to small gastric wall injuries that can occur during band placement. Over-distension of the band can result in gastric wall ischaemia, band site infection, and inflammatory reactions. In addition, use of non-steroidal anti-inflammatory drugs may contribute to the degree of gastric erosions.
- *Oesophageal dysmotility and dilatation* typically occur before oesophageal dilatation, but pre-existing insufficiency of the gastro-oesophageal sphincter may contribute. Other causes of oesophageal dilatation include insufficient change of dietary habit after the procedure, proximal pouch dilatation, and stomal narrowing.
- *Other delayed complications* include disconnection of the band components, port site infection, and small bowel obstruction.

6.4 Sleeve Gastrectomy (SG)

- *Gastric leak* is the most common complication with an incidence of 1–10% of patients in published gastroplasty series [12]. The incidence can rise to 16–20% following repeat operative surgery [12]. Gastric leak has been defined by the UK Surgical Infection Study Group as "the leak of luminal contents from a surgical join between two hollow viscera" and is classified based on the timing of the leak during the post-operative period, namely, early (≤3 days after surgery), intermediate (≥4 and ≤7 days after surgery), and late (≤8 days after surgery) [13].

Classically leaks tend to appear between 5 and 6 days after surgery because of a lack of mural/anastomotic integrity. The typical location of gastric leak is the proximal third of the stomach, close to the gastro-oesophageal junction (85.7%), and less commonly occurs in the distal third (14.3%) [12]. Gastric leak management is still relatively empiric without accepted guidelines [13].

- *Collection/abscess* is usually the result of gastric leak/fistulas and in many cases can be drained percutaneously under image guidance.
- *Haemorrhage and haematoma* can be treated by percutaneous embolisation.

6.5 Roux-en-Y Gastric Bypass (RYGB)

RYBP includes both gastrojejunal anastomosis and enteroenteric anastomoses with both anastomoses susceptible to complications, which include:

- *Anastomotic leaks* occur between 1.1 and 8.3% of patients during the early post-operative period and are managed in a similar fashion to leaks following the other main bariatric surgical procedures [12].
- *Gastrogastric fistulas*: This rare complication, which may be the sequelae of a leak, results in a fistula between the proximal gastric pouch

and excluded gastric remnant. The complication can lead to long-term problems of gastro-oesophageal reflux and stomal ulceration as well as patient weight gain.

- *Gastrojejunal anastomotic strictures* are uncommon, and many are treated using endoscopy with balloon dilation.
- *Degradation of pouch restriction* integrated often presents with a rapid passage of contrast material through a patulous anastomosis. The loss of the restrictive properties on the laparoscopic Roux-en-Y gastric bypass may cause the patient to feel insatiable and produce weight gain.
- *Small bowel obstruction* is more common after laparoscopic gastric bypass than after open procedures with an incidence of up to approximately 8% [14]. The aetiology of small bowel obstruction may be due to a variety of causes including anastomotic leaks and narrowing, mural and mesenteric haematomas, post-operative adhesions, and internal hernias. Internal hernias may occur through defects in the small bowel mesentery and transverse mesocolon or through a potential space posterior to the Roux limb termed the Peterson space. Various simplified classification systems have been proposed to stratify the varied aetiologies.
- *Haemorrhage and haematoma* commonly occur from the staple line. Endoscopic management using clips, adrenaline injection, and electrocautery can be used to manage bleeding from the proximal pouch, but haemorrhage from the distal pouch is more difficult to treat. Percutaneous embolisation techniques play a role when managing this complication.
- *Abscess* is usually the result of intestinal perforation. These can be drained percutaneously under image guidance.

6.6 The Role of Interventional Radiology in the Management of Post-operative Surgical Complications

Interventional radiology (IR) plays an important role in the minimally invasive management of various post-operative bariatric surgical complications particularly when further surgical re-intervention increases the complication risk to the patient.

Since the advent of IR techniques, diagnostic imaging technology along with IR equipment has undergone rapid technological advances. In particular, developments in IR techniques and equipment have led to various safe and effective procedures. For example, manufacturing advances have resulted in a variety of catheters and guide wires with characteristics such as torsional strength, diameter, hydrophilic properties, and specific shape to the type of procedure undertaken.

In parallel, equipment used to guide interventional procedures has advanced with in particular the cross-sectional techniques of ultrasound (US) and computed tomography (CT) now widely available allowing the precise placement of interventional equipment. Multimodality imaging is also now routinely used during interventional procedures with more recent developments facilitating image fusion such as the overlay of 3D cross-sectional datasets with fluoroscopy. These advances have also been associated with the significant reduction in radiation exposure to both patients and staff.

The type of interventional procedure performed will depend on the specific post-operative complication, with IR techniques most commonly used to aspirate and drain collections, embolise/stent bleeding vessels, dilate anastomotic strictures, and more recently facilitate GI tract stent placement following leaks.

In addition, IR can play an important role in delayed complications including choledocholithiasis formation in patients following RYGB (Table 6.2).

Table 6.2 Demonstrating a temporal classification of complications

Early complications	Post-operative bleeding
	Acute anastomotic leak
	Acute gastroenteric perforation/ breakdown
	Gastric band malposition/ slippage
Late complications (more than 30 days post-operatively)	Delayed leak from anastomosis
	Delayed leak from gastroenteric perforation/breakdown
	Choledocholithiasis
	Stomal stenosis (at both anastomosis and gastric band locations)

6.7 Aspiration/Drainage of Collections

Percutaneous drainage (PD) of post-operative collections is the first-line therapy for patients who do not have other indications for immediate surgery. This is particularly true for the post-operative bariatric patient with a well-contained collection.

Primary SG may have a leak rate of up to 9% with an increase in incidence of up to 13% following revision surgery.

Whilst authors have recommended immediate surgical re-intervention in order to close the anastomotic defect, other minimally invasive techniques may be used with Corona et al. reporting that PD has been the stand-alone procedure in 58% of patients in their unit with gastric leak after SG [15].

Whilst PD is generally safe and effective, procedures require careful planning in order to determine the optimum access pathway to a collection. In particular, a pathway should be direct and straightforward and avoid inadvertent injury to adjacent structures and organs. Pre-procedure planning and guidance are in most cases performed using either US or CT. The choice of modality depends on various parameters including collection characteristics, operator choice, and imaging availability.

US offers a number of advantages such as real-time imaging, no ionising radiation, accurate assessment of collection contents due to high-contrast resolution, and equipment mobility allowing procedures to be performed in the IR suite or at the patient's bedside. The modality however is very operator dependent particularly in obese patients, and collections containing gas may be poorly visualised. In addition, enteric leaks that occur from anastomoses following gastric bypass procedures commonly present in anatomical locations adjacent/deep to gas-filled organs including the stomach, duodenum, small bowel, and colon making ultrasound guidance challenging or impossible. Therefore, whilst US can be used in large and superficial collections, CT plays an important role in this group of patients.

Despite the disadvantage of requiring ionising radiation, CT is widely used when feasible in the bariatric patient in order to plan the access pathway to a collection. The modality allows accurate assessment of the collection position, depth, and adjacent structures thus facilitating the calculation of the optimal angle/direction for the access pathway. The standard CT scanner however has a maximum allowed patient weight of around 160 kgs with a bore of 70 cms, thus restricting the use of the modality in this group of patients. In response to this drawback, a number of manufacturers have developed dedicated bariatric machines allowing up to 300 kgs bodyweight with an enlarged bore of 80 cms.

6.8 Equipment Choice

Needles: The majority of abdominal collections can be aspirated through an 18 gauge needle which offers approximately 1/20th the resistance to flow when compared to a 21/22 gauge needle. In addition, an 18 gauge needle is easier to visualise and control using both US and CT guidance as well as accepting a 0.038 inch guide wire.

The majority of 21/22 gauge needle systems however require insertion of an initial 0.018 inch guide wire followed by a coaxial dilator thus adding to the complexity of the procedure.

The typical manufacturing needle length is 15–20 cm, which may be inadequate to reach a deep collection in the bariatric patient. The use of a 55 cm Colapinto needle (Cook Incorporated, Bloomington, IN) will however allow access to most collections.

Catheters: Drainage catheters vary in size and design but invariably involve a locking pigtail design. Catheter effectiveness is based on the degree of kink resistance and internal diameter as well as choice of coating facilitating ease of placement.

Pigtail catheters are preferred because the design allows a reduced risk of accidental displacement. The choice of catheter size can be determined by the needle aspiration test, which dictates that if fluid can be easily aspirated through a 10 mL syringe (1 mL in 1 s) using an 18 gauge needle, then an 8.5 F catheter diameter will be effective.

Complex collections however may require a catheter size of up to 16 F.

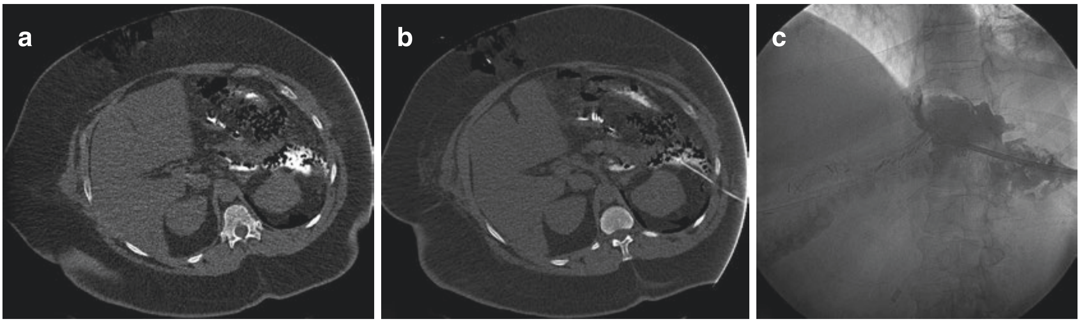

Fig. 6.1 CT-guided percutaneous drain placement using the Seldinger technique: (**a**) Non-contrast CT scan with oral contrast (Gastrografin), confirming a leak and perigastric collection. (**b**) CT-guided puncture of the collection using an 18 gauge coaxial needle. (**c**) Subsequent fluoroscopic image confirming position of a 12 French Malecot (Cook Medical) drain within the collection

6.9 Technique

The two standard techniques for percutaneous collection drainage are the trocar or "one-step" and Seldinger or "two-step" procedures.

Trocar technique: This uses a catheter mounted on a central trocar and stylet.

Following subcutaneous infiltration of local anaesthetic, a direct puncture with the mounted catheter is used to access the collection. The central stylet is then removed, and aspiration is performed to confirm correct catheter tip location. The catheter is then advanced over the trocar into the collection. The technique is only suitable for large and superficial collections.

Seldinger technique: The technique is more appropriate and in most cases much safer for use in bariatric patients. Following subcutaneous infiltration of local anaesthetic, an appropriate needle (usually 18 gauge) is introduced into the collection under image guidance. After successful aspiration, a guide wire is then inserted through the needle into the collection, and following needle removal, the tract is dilated over the wire to the required diameter prior to wire-guided placement of the catheter. If a smaller needle diameter is initially used to puncture the collection, then either further guide wire exchanges can be used to upsize the tract or a second 18 gauge needle can be introduced adjacent to the initial needle (Fig. 6.1).

Both techniques require appropriate final catheter fixation to the skin with a range of devices available. Importantly an adequate specimen must be sent to microbiology and free drainage of collection contents confirmed into the catheter bag.

Collections containing viscid contents require regular flushing using 10–20 mL of saline once or twice daily in order to maintain catheter patency.

6.10 Role of Covered Stents in the Management of Leaks

Whilst the percutaneous drainage of postoperative collections is very effective, further minimally invasive techniques may be required to manage anastomotic or staple line leaks, which carry a mortality rate of up to 6.5%.

The placement of covered self-expanding metallic stents has been recommended. Stents provide a barrier between endoluminal bacteria/acidic bowel contents and the disrupted anastomosis [16]. The use of covered stents is effective allowing enteral nutrition and earlier patient discharge thus avoiding surgical re-intervention.

Stents can be placed under endoscopic guidance, fluoroscopic guidance, or using a combination of the techniques. If endoscopic placement is unsuccessful or contraindicated, multidisciplinary team management using interventional radiology can offer an alternative technique for stent insertion using fluoroscopic guidance.

Table 6.3 Examples of commonly available stent systems

		Delivery system (Fr)	Length (cm)	Max outer diameter (mm)
WallFlex stent system (Boston Scientific, Natick, MA)	Covered	18.5	10–12–15	23–25–28
Ultraflex Esophageal Stent System (Boston Scientific, Natick, MA)	Covered	20	10–12–15	18–23–28
Cook-Z stent (Cook, Inc.)	Covered	24	10–12–14	18–25

6.11 Equipment Choice

Stents: Common stents used today are listed in Table 6.3. They can be divided into uncovered self-expanding metal stents (SEMS), partially covered self-expanding metal stents, and covered self-expanding plastic stents (SEPS). Uncovered stents are not commonly used due to the difficulty of stent retrieval with covered stents allowing ease of removal.

Stent placement is successful in 80–94% of patients with acute post-operative anastomotic leaks, and most patients resume an oral liquid diet within 1–3 days.

Stents are normally left in situ over varied times ranging from a mean of 41 days to 3.2 months depending on the stent characteristics [13].

The most common post-procedure side effects include early satiety, nausea, epigastric pain, and hypersialosis [17, 18].

Stent placement is associated with a number of recognised complications [19]:

- Stent migration has been reported in 15–60% of cases. Whilst covered stents have an increased risk of migration when compared to uncovered stents, the indications for their use are a likely confounding factor [19]. Partially covered SEMS appear to have the least potential for migration [12].
- Granulation tissue formation (0–13%) leading to perforation/fistula (0–7% cases) and haemorrhage (0–19%). Emergency surgical procedures for stent erosion through the gastrointestinal wall resulting in blood vessel laceration have also been described, and IR can contribute to the management of patients in this area [12].

6.12 Technique

The procedure for stent placement is most commonly performed under general anaesthesia with endotracheal intubation.

If following multidisciplinary discussion a combination technique is performed, an endoscope is used to identify the location of the dehisced anastomosis and mark the location with radio-opaque clips. Following removal of the scope and under fluoroscopic guidance, a 0.035′ hydrophilic wire and catheter (100–120 cm) are used to access the appropriate lumen and cross the marker clips. The site of the leak is demonstrated by injecting contrast media via the catheter.

A 0.035′ stiff or super stiff Amplatz guide wire is then placed across the anastomosis under fluoroscopic guidance. The stent delivery system is advanced over the wire and positioned across the leak prior to deployment of the stent (Fig. 6.2).

Overall length of procedure can range from 23 to 47 min [17, 18].

If endoscopy is contraindicated, a fluoroscopic technique can be performed. This requires initial placement of a catheter at the level of leak followed by contrast injection in order to define the position and severity of the leak. A 0.035′ stiff or super stiff Amplatz guide wire is then placed across the anastomosis and the stent deployed to cover the leak.

Fig. 6.2 Enteral stent placement: (**a**) Fluoroscopic image following fluoroscopy-guided stent placement demonstrating no evidence of a residual anastomotic leak. Note tip of percutaneous drain within adjacent collection. (**b**) Subsequent fluoroscopic image post-stent removal shows complete resolution of the leak

Subsequent removal of the stent is normally performed using endoscopy under light sedation.

Stent extraction has been demonstrated to be most straightforward with fully covered SEMS or SEPS because the stent can be grasped with large toothed graspers and withdrawn using firm but steady pressure. Partially covered SEMS may have tissue ingrowth at either end resulting in more complex endoscopic extraction.

6.13 Balloon Dilatation of Strictures

Anastomotic strictures are late complication of RYGB (7%) and SG (<1%). Stomal obstruction can also occur following gastric banding due to post-operative oedema and is normally managed conservatively using nasogastric tube decompression with removal of band reserved for refractory cases. Balloon dilation has been reported to be effective especially if repeated with varying different balloon calibres [19].

Endoscopic balloon dilation is performed for the vast majority of patients. However, in cases that prove refractory due to difficult access or poor procedure tolerance, fluoroscopic-guided balloon dilatation by the IR team is usually successful.

The technique of fluoroscopic-guided balloon dilatation is in many ways similar to stent insertion with initial manipulation of a 0.035′ hydrophilic wire and catheter (100–120 cm) across the anastomotic stricture followed by exchange to a 0.035′ stiff or super stiff Amplatz guide wire in order to facilitate safe positioning of the balloon prior to dilatation.

Whilst the use of cutting balloons has been described for the dilatation of strictures secondary to neoplasia, the evidence base for their role in anastomotic strictures post-bariatric surgery is currently insufficient to recommend their use.

6.14 Postsurgical Haemorrhage

The post-operative risk of bleeding after bariatric surgical procedures has been estimated to be between 1 and 4%. Bleeding can occur either intra- or extraluminally.

In many cases, endoscopic management of haemorrhage using adrenaline or procoagulant materials remains the first-line treatment following surgery, as anastomotic suture lines are dependent on good blood supply and are prone to dehisce if rendered ischaemic.

Nevertheless, percutaneous embolisation techniques offer a safe and quick method of controlling haemorrhage in inaccessible locations. In addition, procedures avoid the need for general anaesthetic in patients who have significant comorbid disease. With careful pre-procedure planning and the pragmatic use of IR techniques, effective trans-arterial control can be achieved in the vast majority of patients. In addition, IR plays an important role in the subsequent percutaneous drainage of haematomas, which are prone to infection.

6.15 Equipment Choice

A range of embolisation materials are commercially available for use in this group of patients, including:

Coils: These are available in different sizes and are made of stainless steel or platinum with or without Dacron fibres. Coils use mechanical obstruction with platelet activation to fully and permanently occlude the bleeding vessel.

Gelfoam (Upjohn Company, Kalamazoo, MI): This is a water-insoluble haemostatic agent that induces haemostasis. The effect is temporary with vessels recanalising over 1–2 weeks.

Microparticles: These include polyvinyl alcohol (PVA, Cook, Bloomington, IN; Contour Boston Scientific, Natick, MA, USA) and spherical embolics (microsphere) (Embosphere BioSphere Medical, Rockland, MA, USA). These produce semi-permanent mechanical occlusion of vessels. Microspheres are more predictable as occlusion agent.

Onyx (ev3, Inc., Plymouth, MN, USA): This is an ethylene vinyl alcohol copolymer dissolved in various concentrations of dimethyl sulfoxide (DMSO) and opacified with tantalum powder. The material forms a soft elastic embolic agent when in contact with blood.

The choice of embolic material varies depending on target vessel size, potential risks of nontarget embolisation, and vascular hyper−/hypo-dynamism.

6.16 Technique

Pre-procedure planning is essential in the non-emergency setting with a haemodynamically stable patient. Procedures should commence with dedicated CT angiography (CTA) because of the increased sensitivity of CTA in detecting haemorrhage when compared to conventional angiography. In addition, the CTA provides an anatomical road map of vessel anatomy in order to facilitate subsequent catheter placement. Careful evaluation of anticoagulation history,

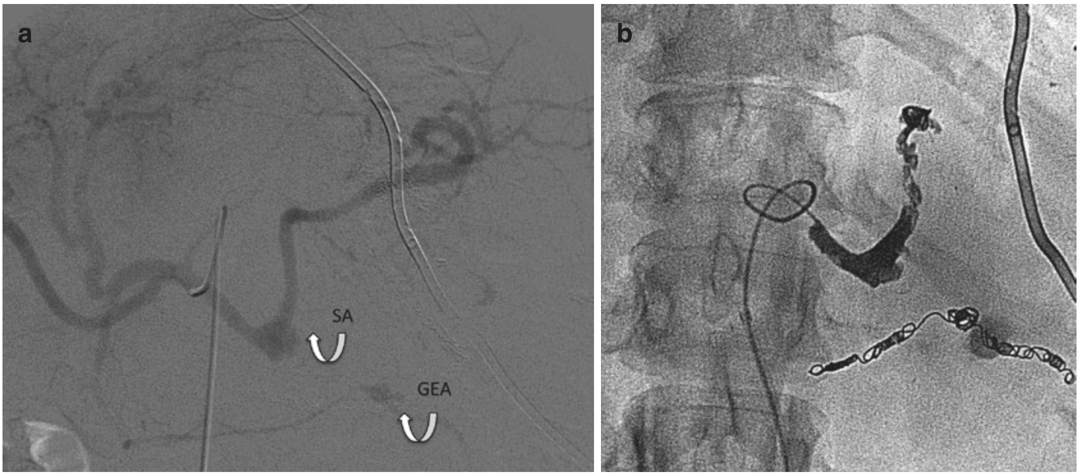

Fig. 6.3 Endovascular management of a patient with post-operative pseudoaneurysm formation following sleeve gastrectomy: (**a**) Digital subtraction angiogram with catheter placed in coeliac axis demonstrating splenic (SA) and gastroepiploic (GE) artery pseudoaneurysms (**b**) Post-embolisation image demonstrating embolisation coils (Balt Extrusion, Montmorency, France) within GE and coil/Onyx 34 (EV3, Micro Therapeutics, Inc., Irvine, CA) embolisation of SA

renal insufficiency, and any contrast allergy must be carried out prior to angiography.

Access is typically via the common femoral artery (CFA). Exceptions include patients with known iliac obstruction.

Diagnostic angiography should be undertaken following selective cannulation of the celiac axis and superior mesenteric artery (SMA). A microcatheter system is then commonly used to select smaller vessels such as the superior or inferior gastroepiploic plexus or gastroduodenal artery (Fig. 6.3).

Once the haemorrhaging vessel is identified, this is superselectively catheterised prior to embolisation. As discussed, the choice of embolic material will depend on a number of factors.

Following the procedure, careful review of the patient's vital signs as well as measurement of serial haemoglobin and haematocrit levels is mandatory to establish continued haemostasis.

6.17 Venous Filter Placement

In addition to other post-operative complications, patients with severe obesity have a 0.34% risk of deep venous thrombosis and embolism after bariatric surgery according to a 2011 database containing 73,921 patients [20]. Anticoagulation is contraindicated during the post-operative period following surgery, and interventional radiology plays an important role in the placement of filters within the inferior vena cava (IVC) in order to reduce the risk of pulmonary emboli (PE). Due to wide heterogeneity in patient populations and indications and diagnostic criteria on the role of IVC filters, defining appropriate guidelines is challenging; hence at the time of writing, there are no widely agreed consensus guidelines published. For example, a study by Vizaki et al. which evaluated a small group of high-risk bariatric patients concluded that 44 patients had an acceptably low incidence of DVT (5%) and no clinically evident PE [21].

The use of venous filters to prevent PE was first described in 1967 [22]. Rapid technological advances soon led to percutaneous device placement with more recent developments which have heralded the use of removable devices increasing the acceptance of the technique.

The aetiology and natural history of venous thromboembolism (VTE) have been well described. Sapala et al. identified four comorbid factors associated with a risk of PE: severe venous stasis, body mass index (BMI) >60, truncal obesity, and obesity hypoventilation syndrome/sleep apnea [20]. Additional risk factors include a previous documented history of DVT/PE, hypercoagulable state, strong family history of DVT, use of oral contraceptives, age >60 years, and expected prolonged immobilisation.

In addition, an accepted indication for IVC filter placement includes bariatric patients who receive post-operative epidural analgesia for pain control. The resulting lower limb immobility increases the risk of DVT with anticoagulation contraindicated due to the high risk of an epidural haematoma [23].

6.18 Equipment Choice

Vena cava filters: Retrievable filters are now preferred to permanent filters because the long-term placement of a permanent filter is associated with an increased lifetime risk of PE. This risk is magnified in younger bariatric patients.

Manufacturer guidelines vary with regard to recommendations for the timing of filter removal, typically in the range of 6 weeks. Retrieval failure rates are described between 5 and 50%. The incidence of retrieval failure increases with time, due to the risk of anchor penetration into the IVC wall and associated fibrotic reaction. The technique for filter retrieval varies between devices, and thus individual manufacturer recommendations should be carefully considered (Table 6.4).

6.19 Technique

Whilst bariatric patients present a number of technical challenges for successful IVC filter placement, these challenges can be safely overcome with meticulous pre-procedure planning.

Initially the femoral and iliac venous systems should be assessed using US for existing thrombus.

Venous access is often the most challenging step in bariatric patients, and any puncture should be ultrasound guided in order to reduce the risk of complications. Filters can be placed via the internal jugular or superficial femoral veins. In addition, a brachial venous approach has also been described.

A standard Seldinger approach using an 18G needle is typically used, although some reports advocate initial use of a small-gauge (22G) seeker needle in order to prevent “tenting” of the vein which can result in an increased risk of contralateral sidewall puncture. Gentle rotation of the needle can however reduce the degree of tenting.

A 0.035 inch guide wire is then manipulated into the IVC prior to placement of an appropriately sized sheath (typically 6 French) to allow insertion of the filter carrier system.

Venography is then performed via a catheter placed at the L2–L3 in order to assess the presence of thrombus in the IVC, diameter of the IVC, position of the renal veins, and anatomical variants. The filter is typically placed with its tip at or just below the level of the renal veins.

Final fluoroscopy is undertaken to confirm a centrally placed filters without angulation within the IVC lumen. This reduces the risk of subsequent complicated filter retrieval.

6.20 Transhepatic Percutaneous Management of Choledocholithiasis

Cholelithiasis and choledocholithiasis are late complications following bariatric surgery and in particular are seen following bypass procedures.

Stone formation is thought to be the sequelae in alterations to bile salt concentration and circulation. Intraoperative cholecystectomy has been suggested but is considered by many centres to represent an unnecessary additional risk to the patient.

In addition, the management of gallstones following bariatric restrictive and bypass procedures can be problematic as the postsurgical anatomy prevents ERCP. There are also significant risks associated with obese patients, which limit subsequent laparoscopic or open cholecystectomy.

Interventional radiology and in particular modern percutaneous trans-hepatic access tech-

Table 6.4 Common vena cava filters [24]

Filter device	Company	Material	Design	Cath size (Fr)	Approved use
Stainless steel Greenfield	Boston Scientific, Natick, MA	Stainless steel	Conical	12	Permanent
Simon Nitinol	Bard Peripheral Vascular, Tempe, AZ	Nitinol	Conical bi-level	7	Permanent
Recovery G-2	Bard Peripheral Vascular, Tempe, AZ	Nitinol	Conical bi-level	7	Permanent/optional
G-2 Express, Eclipse		Nitinol	Conical bi-level	7	Permanent/optional
Vena Tech LGM	B. Braun/Vena Tech, Bethlehem, Penn	Phynox	Conical	10	Permanent
Vena Tech LP		Phynox	Conical	7	Permanent
TrapEase	Cordis Endovascular, Miami, FL	Nitinol	Double basket	6	Permanent
OptEase				6	Permanent/optional
Gunther Tulip/Celect	Cook, Inc., Bloomington, Ind	Conichrome	Conical	8.5 (femoral)	Permanent/optional
				7 (NavAlign)	Permanent/optional
ALN Optional	ALN, Corsica, France	Stainless steel	Conical	7	Permanent/optional
Option	Angiotech Pharmaceuticals, Vancouver	Nitinol	Conical	7	Permanent/optional
Safeflo	Rafael Medical Technologies, Denver, Del.	Nitinol	Double ring/spiral	6	Permanent/optional

niques can therefore play an important role in the multidisciplinary management of patients with choledocholithiasis. A detailed review of the various procedures is beyond the scope of the chapter although trans-hepatic access for the management of obstructing biliary calculi is commonly performed worldwide. Various case reports also describe the use of trans-catheter balloons for the mobilisation of obstructing calculi. These minimally invasive procedures can avoid the significant risks associated with more traditional open procedures [25].

6.21 Summary

Bariatric surgical procedures offer the obese patient an effective solution for weight loss as well as a significant reduction in associated long-term morbidity and mortality. The role of the multidisciplinary team is central to achieving optimal patient outcomes, and IR services continue to expand and evolve worldwide in order to meet the ever-increasing demand for minimal access procedures.

IR services are thus increasingly being incorporated into surgical pathways as the benefits of multimodality image-guided procedures are recognised. In addition, an expanding evidence base and increasing IR service profile are helping to consolidate these techniques as a core part of modern patient management. Familiarity with the discipline of IR is essential for all members of the clinical team in order to achieve the best outcomes for their patients, and as the prevalence of obesity increases worldwide, pioneering technological advances will continue to offer exciting new avenues in this important field.

Key Point

1. Multimodality imaging is routinely used during interventional procedures with more recent developments facilitating image fusion such as the overlay of 3D cross-sectional datasets with fluoroscopy.

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