Robotic Surgery for Abdominal Wall Hernia Repair

A Manual of Best Practices

Ricardo Z. Abdalla
Thiago Nogueira Costa
Editors

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ISBN 978-3-319-55526-3 ISBN 978-3-319-55527-0 (eBook)
DOI 10.1007/978-3-319-55527-0

Library of Congress Control Number: 2017954916

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

Surgeons owe it to their patients to optimize their skill sets by staying up to date with emerging hernia repair techniques that may enhance outcomes. Surgeons should avoid thinking that one repair is good for all hernias and instead strive to learn new techniques to broaden the scope of what they can offer patients.

The rise of robotic instruments and platforms to assist in the repair of all types of hernias is upon us, achieving global penetration. Much of this rise in general surgery is secondary to a popular explosion of robotics in hernia repair. A true visionary, Dr. Ricardo Abdalla, performed some of the very first robotic hernia repairs in the world, and as such he has also started one of the first robotics programs at his hospital. To share what he has learned with the world, he has successfully gathered some of the most pioneering robotic hernia surgeons from various countries to compile a comprehensive overview of robotic-assisted hernia repairs and general surgery procedures.

This book is essential for any surgeon who wishes to begin or to enhance their robotic hernia experience. From learning how to start a robotic program and training to learning expected short- and long-term outcomes following robotic incisional hernia repairs, Dr. Abdalla's book successfully teaches how to perform every different hernia operation.

I have had the privilege of learning directly from Dr. Abdalla, but now through the chapters in this book, all surgeons wishing to embark into the world of robotic surgery can learn from him and his colleagues as well. A true robotic surgeon must have this on his or her shelf!

New York City, NY, USA — Brian Jacob

Preface

*"**Technology happens, it's not good, it's not bad. Is steel good or bad?**" It is a question of when barriers to the adoption of technology will be circumvented not whether it will happen. Technology itself is morally agnostic. "I think that technologies are morally neutral until we apply them. It's only when we use them for good or for evil that they become good or evil." Andrew S. Grove, former President and CEO of Intel Corporation (1997)*

The abdominal wall is a very wide part of the human body and one of its most prevalent problems are abdominal hernias. Although these conditions are common and taken for granted, they tend to cause major problems in the daily routine of the patient and in their overall treatment.

The main therapy for them is the surgical method, but there is a lack of standardization regarding the type of procedure, localization of the problem, size of hernia, classification, and even the approach. With the improving surgical technology novel techniques started to appear and gain space such as laparoscopy. It is very difficult and challenging to consider or understand when a minimally invasive procedure will help, get rid of, or facilitate this problem solution. These procedures are sometimes bogged down due to the instruments' movement limitations, two-dimensional view, and patients'/surgeons' positioning. There is a long list of restrictions in some procedures that could be cleared as we apply new facilities in diagnosis and preparation to preoperative issues. Robotic technology can overcome these problems in a way that new techniques could be developed and complex hernias could be treated by minimally invasive procedures, which was unthinkable. Fundamentals are the same. The first step is to be familiar with the robot and its development history. That will change a lot in the near future and we need to be prepared.

However, because robotic surgery has emerged only recently in the hernia field, there are few standardizations regarding techniques, approaches, and overall setup. *Robotic Surgery for Abdominal Wall Hernia Repair* intends to be a guide for surgeons who want to use this evolving method in the treatment of such a prevalent disease. This book is composed mainly of three parts: how to build a robotic hernia center, how to do the procedures, and the other components such as herniosis and technical issues.

In this practical guide we invited experts in robotic hernia repair and surgical leaders to explain the best way to organize a center in all ways, including training, setup, and procedures. The abdominal wall and the trunk were imagined as one

individualized compartment. We divided the hernias by location and complexity, and each of them is explained step by step by specialists in the area from around the world, using figures and drawings. And most of all, we didn't forget associated concerns such as quality of life, anesthesia, pain management, meshes, and adhesions.

Surgical practitioners who want to perform in the world with expanding technology have to be guided to facilitate their path and *Robotic Surgery for Abdominal Wall Hernia Repair: A Manual of Best Practice* is a great way to do so in the hernia field.

Sao Paulo, Brazil

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Acknowledgments

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Preparing a Robotic Program and Surgeon Training Regimen for Hernia and Abdominal Wall

Ivan Cecconello and Evelise Pelegrinelli Zaidan

Key Points Summary

- Implementation of robotic program in an academic conservative service
- Implementation of new technology surgical training
- How to deal with a professor, assistant, and resident formation in robotic surgery, all together
- Progression evaluation
- Surgical procedures and nontechnical skills integration

Robotic Program and Surgeon Training

As a gastrointestinal surgical professor, the actual dilemma is how to begin a robotic-assisted surgical technique infrastructure in an academic well-established field to allow one whole department, or more than one surgical department in different specialties, to implement this new technology, an electronic mechanical armament in the surgeon's hands [1, 2]. The commercially well-known robotic surgery is strong enough to cause a revolution of operative staff [9]. The solution: a 100% prospective randomized clinical trial.

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R.Z. Abdalla, T.N. Costa (eds.), *Robotic Surgery for Abdominal Wall Hernia Repair*, DOI 10.1007/978-3-319-55527-0_1

The adoption of robotic surgery in a very important opinion leaders' environment is difficult but at the same time challenge encouraging. There is only one device commercially available in the market worldwide, which brings higher prices and limits of acquisition in some academic services [10]. The challenge accepted, the university began the robotic program as a clinical trial. The idea was to combine all kind of professors in different specialties with academic doubts in the Hospital das Clínicas at University of São Paulo.

The federal government invested a grant to have the machine and the state of São Paulo in counterpoint undertook the maintenance of the system and instruments to operate robotic-assisted around 580 patients (ClinicalTrials.gov Identifier: NCT02292914). Our goal is to introduce a secure, under academic criticism, new technology in a high-quality assistance institution. The university is responsible for replicating knowledge and for that has in-house opinion leaders, professional tutors, and high-quality public assistance.

During the organization the team defined requirements for training, as responsible experts, related nonmedical professionals, one-to-one practice relationships as needed, international preceptorship, and department adjustments [3, 7, 8]. A medical tutor was assigned to be with all surgeons from the beginning of their training and their first five operations [6]. This was considered important to decrease the learning curve as the mutual discussion should anticipate problems and present solutions [4, 5, 7, 11].

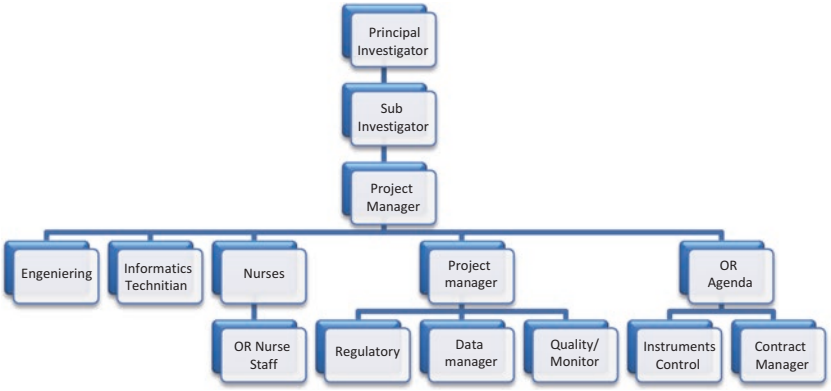
The team flow was designed as a research site with all hospital services under the research umbrella (Fig. 1).

The site had the investment and strategy to begin the project. The Institutional Review Board (IRB) received the project for ethical approval and regulatory affairs. The research site principal investigator and the project manager defined and recruited the medical staff and the stakeholders. The patient allocation started after IRB approval.

The first position was the principal investigator (PI), followed by the subinvestigator who would execute the project. Both knew how to do operations with basic and advanced skills. A project manager was responsible for planning the project details and leading the project team [12].

The research sector team was responsible for all ethical and regulatory documents, informed consent form (ICF), patients' follow-up, random spreadsheets, monitoring, and inventory control of the investigational devices and data management [13].

Having one reference for everybody was the most important point for project success and information availability. All involved hospital departments were considered. Each department must work with its own personnel under the command of the project manager and the principal investigator to include regulatory documents,



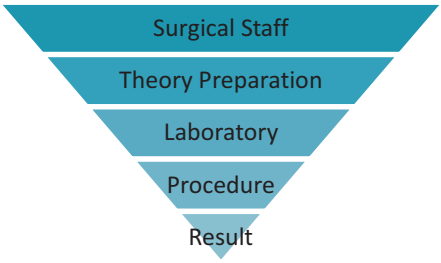
Hospital organogram	Research	Engineering	Information Technology	Nurse Staff	Material Arsenal
Principal Investigator Chief Professor	Sub Investigator Executive Professor	Project Manager Physician Executive	Tutor Assistant Surgeon	Surgical Team Surgeons Nurses	Research Sector Regulatory Study Nurses Data Manager

Fig. 1 Organization Chart by Hierarchy. This chart considers hospital departments and academic hierarchy

patient informed consent, data management, quality control, nurses, monitor, agenda, instruments control, contracts, and external audition or an involuntary specific situation that needs outside revision (Fig. 1).

Hospital Organogram	Research	Engineering	Information Technology	Nurse Staff	Material Arsenal

For the surgical organization, we considered a scale as: specialists, theory, laboratory, patient, and results, as follows.



Surgical Staff

The tutor considers all the personnel involved. All departments were invited to the first meeting, regarding administration, structure, engineering, informatics, and support [14]. We had small meetings, peer to peer or distant professionals' teleconferences for further punctual fine adjustments, as needed, including international invites. The OR was prepared to broadcast live locally, inside the university institutes and internationally considering the most updated communication technology available [15, 16]. Surgical procedures could be broadcast for distant supervision and tutoring [17].

The fluxogram begins with the principal investigator, who is responsible for the brainstorming and idea sum. The project design is in his head, from zero to complete, even with some imaginary results to be conquered. He is observing everything from a macro view, doing some adjustments and changing strategies, avoiding conflicts and obstacles.

The disease must be part of the executive plan, but the reference is always the patient [18]. Each group took care of its disease. General knowledge, basic concepts, anatomy, physiology, functional behavior, and patient lifestyle were important and respected. The principal investigator was concerned with how to prepare an adequate safety procedure. This was essential to develop a consistent pathway for a new technology and robotic academic facilities in this environment [19].

A step-by-step specialist training was initially done by virtual robotic computer basic concepts training [20, 21]. This was accomplished by merging a portfolio from the robot manufacturer and the university staff. It was a mechanical theory explanation about the robot itself regarding technical procedure details, including videos, sketch charts, technical explanations, safety rules of functioning, and mechanical details [22]. This was around 10 h in computer and by presence and could be updated as needed [23]. This comes from industry orientation and it has FDA approval. The training continued in the laboratory after that [24]. It was still sometimes virtual but it was done with the robot itself inside the OR for planning. The machine in the OR was used for "physical training." The surgeon, engineering, scrub nurse, and informatics technician went to the OR as one surgical team before the surgery itself. Each person rehearsed his or her responsibilities inside the room as a preparation for the operating day. This should take 2 h training [25–27]. One important detail was always to have the tutor with this team (Photo 1).

Another training step was added to this beginning as a 4 h laboratory complement: 1 h in dry lab, with instruments management, repetitive movements, object/instruments training, and update procedures as the experience was brought to the lab. Three consecutive hours were offered to the staff with wet lab, animal side, for dissection, hemostasis, stapling, and suturing exercises after that. Every training was the same until this point, no matter the area of interest [7, 8, 28].

Because of the necessity to deal with complex cases in a reference institution we figured out the necessity to offer more straightforward laboratory training to a refinement completion [29, 30]. Eight more hours were followed to enhance confidence in the surgeon before the first patient robotic meeting. These hours were divided in 4 h of animal lab to a specific organ management, repetitive movements,

Photo 1

object/instruments specific training, and updated training. This training was for the group who was interested in a specific organ, who sometimes does not need to make a dissection or movement done in another situation. The interest was stressed in its area alone and the skill was developed for that procedure. The further 4 h were used for team integration, working on time-saving exercises, patient side positioning, and staff fine tuning. Patient side simulation, difficult situations, and special needs could give confidence to the team before dealing with real patient contact. This was the opportunity for procedure simulation, precautions, and safety rules. We defined table positioning, equipment, and staff position in the room, as sign in and time out.

All this previous training was essential for standardization of the surgical site [31, 32].

Theory Preparation

Surgeons, research nucleus, hospital logistics, nurses, and OR agenda had the same goal of making a high-quality automatic system with enough instruments and conditions for good practicing. A multidisciplinary meeting must be done before the first robotic surgery. The patient must be presented and the surgical team must know the case in advance as a team. The surgeon must be confident and he must show his team how advanced the procedure and their technical ability must be. These meetings, as a committee, were needed for identifying trending issues and improving surgery as to its time and quality. It was a continuous educational environment in an adequate institution. This organization was done for retaining developed skills to assist in mentoring new teammates. It was good for immediate answers, for knowledge, and development of new procedures.

From time to time reviewing training and lab attendance must be done, as needed. New technologies must be well discussed by the group.

Laboratory

The procedures permit development of criticism. Every time the principal investigator sees a problem one must go back to the lab and change for better results. The high-level technical leader needs to go back to her team for small changes. A peer-to-peer meeting analyzes reports in a fine-tuning spot trend. Broken instruments should be recognized and discussed in the group to clarify why they broke and how to avoid their breaking again. Repetitive exercises are important to change one evitable error. It is important to go back to the lab any time necessary.

Procedure

The program could change any time. All the risks must be observed, from the smallest to the most significant. The principal investigator could call the staff any time. The staff should be prepared for management changes. Patient postoperative interactions in the hospital must be evident to the group. Revisions should be done constantly. Continuous communication and permanent information in all areas are important as part of organization.

Mentoring and coaching are necessary to maintain the staff under constant development [33]. The hospital must provide this condition and could consider surgical time for performance evaluation [34].

Senior surgeons were chosen primarily to conduct the program. They were prepared to recognize and introduce new surgeons for training. The program must be opened for any novel conduct, transition, and/or changes.

The databank was the reference for all these changes. It was kept in the research department and updated on time. Alerts could be released for exceptional meetings, training plan changes, and calls for re-education and GCP. The department was reference for regulatory papers and topics. It was responsible for data, storage, and staff meetings regarding quality/monitor control. This departmental control was considered essential for developing our future leaders in the educational institution. It was responsible for information trade between the department professors and other university areas for other area studies development.

Result

Patient health was the main reason for the program. Patient outcome must determine our continued training. We need to make an annual review, with annual reports. The research department must check current certifications, administration reviews, staff meetings, and quality assurance.

Concluding Remarks

- It was very important and interesting to organize a new technology surgical procedure in an academic field.
- The criticism was greater than in normal institutions and the challenge was to understand the safety points and keep patients as the main issue.
- Well-trained surgeons are difficult to introduce to this or any new technology, but once logical understanding was clarified, the learning curve was overcome and experience became practice.

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Robotic Setup

Thiago Nogueira Costa

Key Points Summary

- Robotic surgery is an important tool in the hernia repair armamentarium and should be considered depending on the type of patient and defect.
- Preparation is very important to secure the best place to work on and patient safety, with the best ergonomics and possible changes throughout the procedure to achieve the right outcomes.
- By doing the preparation and the procedure in a standardized way one can overcome possible problems and make the procedure better and as easy as possible.

Introduction

Robotic surgery has grown over the past years and more types of procedures have been done using that technology. Hernia repair is one of the rising fields of surgery where robotic intervention has gained that space [1]. Mechanical arms with wrist movements can work better against the anterior abdomen, from inside.

Although many surgeons are adopting this type of technology in their hernia repair practice, there is little standardization regarding the overall setup, such as materials used, patient's preparation and positioning, types of robotic docking, instruments, team roles, and the operating room (OR) setup itself [2].

Various ergonomic studies of the workplace in fields other than medicine have demonstrated the link between workplace setup and overall performance [3]. In the surgical area, it is proved that crowded or unplanned operating rooms can affect the

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R.Z. Abdalla, T.N. Costa (eds.), *Robotic Surgery for Abdominal Wall Hernia Repair*, DOI 10.1007/978-3-319-55527-0_2

surgical outcome and time spent in the procedure, lowering the efficiency of the surgical staff and the patient's treatment [4].

Although the patient's procedure and OR staff are the centers of the operating theater, many other factors may have a more important role in the facility. Things such as electric cables, anesthesia cannulas, and even trash bins are put in a better position than the OR team and the patient. In that way, the setup has to be centered on the main procedure actors, leaving the other parts of the act in a comfortable position to support what is really important in the surgery.

When we add robotic technology to this setup, the scenario is even worse, because this type of surgical procedure comes with more cables, carts, and arms that have to be allocated in the OR, once more leaving less space to the surgical team.

Thus, there is the need for developing a straightforward program for the standardization of the surgical room setup before even starting the procedure. Because there are many procedures that can be done with various types of setup this becomes even more important.

In this chapter, there is a suggestion of how to create that standardization based on the experience of the abdominal wall and hernia repair department centered in the use of robotic technology.

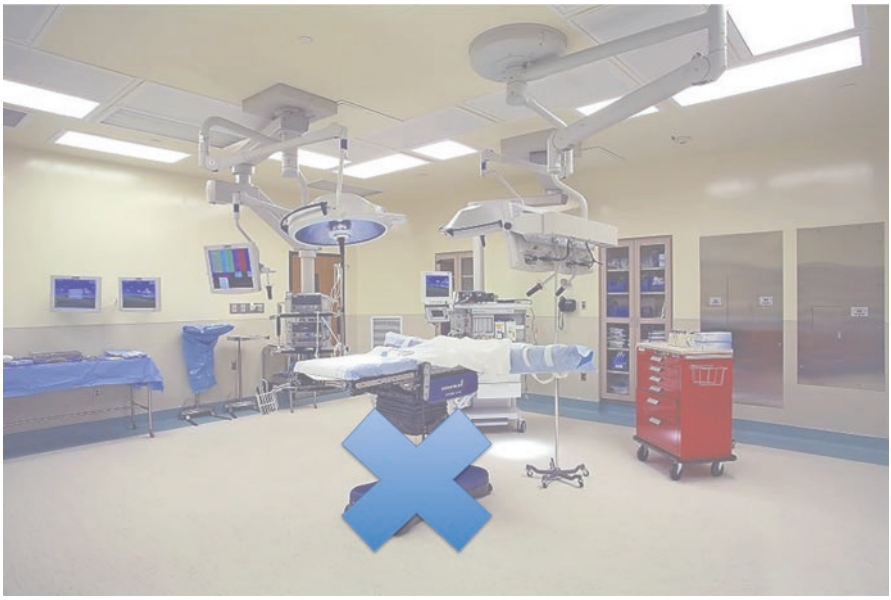
Operating Room (OR) Setup

The first part of the setup is organizing all the space inside the room and how the other things can be brought to the facility before, after, or during the procedure. This organization has to be made with respect to the patient, the OR team, laparoscopic and robotic devices, connecting cables, and possible changes, even emergency situations, throughout the operation to be done [4].

First of all the patient needs to be in the center of the room, not necessarily geographically, but in the middle of the entire planning agenda. All the other parts of the OR will be allocated respecting the patient's place. At this point an X can be drawn on the ground to mark his position. After that the other parts can be placed following the logic proposed later in this section (Fig. 1a).

In the second place we need to think of the OR staff and the ergonomics involved in the procedure to be done in the room. Now there are different people with various roles to be allocated [5]. The surgeon will lead the team, not just during the operation, but she will help determine the complete setup in the room, troubleshooting the system, and eventual changes in plans and parts' placement. The first assistant has to have a similar knowledge of the space and he will be the person beside the patient during the procedure, in a way that he has to master the trocar placement, laparoscopic skills, and basic surgical actions such as irrigation, clipping, suction, and retraction.

Another important part is the anesthesiologist. She will be close to the patient at all times to secure the best relaxation and take care of possible changes in respiratory



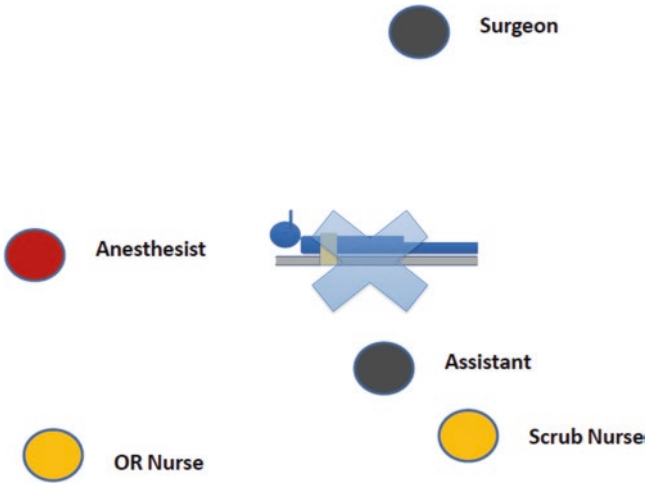


Fig. 1 (**a**) Operating room setup: patient's marking. (**b**) Operating room setup: OR staff positioning. (**c**) Operating room setup: overall positioning

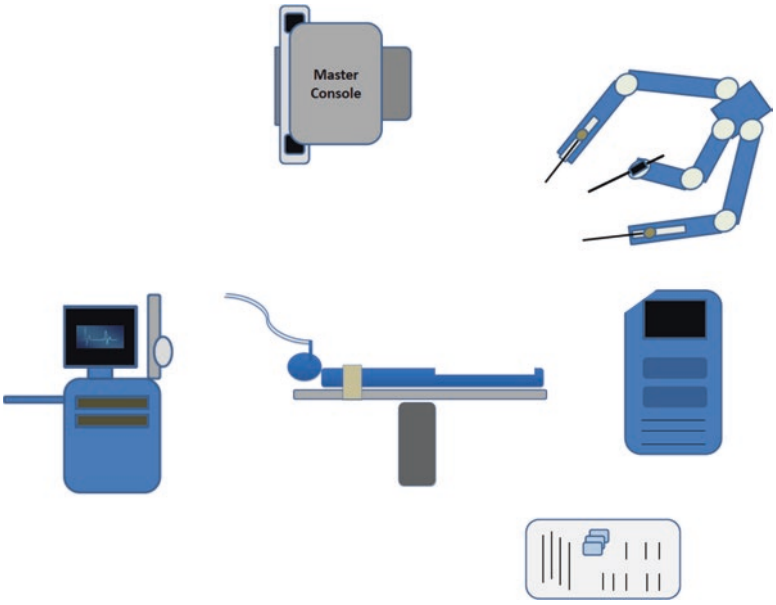


Fig. 1 (continued)

pressure, blood flow alterations, and fluids. This member of the team has a very important role in the hernia surgery. It is well known that this kind of repair needs a very good relaxation and can lead to changes in the abdominal pressure and consequently in the respiratory physiology. With that professional, come the anesthesia cart and the cannulas such as the endotracheal cannula and peripheral lines.

At last the OR nurses have to be well allocated in order to move throughout the room and help with large and small materials. They can move the devices and bring new things inside the room at any time (Fig. 1b).

Having them placed, now it is time to allocate the large devices that robotic surgery entails [6]. There are three main parts [7]: the master console, the patient's cart, and the core cart. The first one is where the surgeon has the controls of the robotic arms, can see the surgical tridimensional image, input other information from previous exams, and even make a call or receive orientation from a tutor. This console can be moved around as necessary. The second one is the device that carries the robotic arms and is placed close to the patient during the procedure. The choice of its position is crucial to facilitate the progression of the procedure, despite that the new robot generation has changed the limits of moving this cart all over for a better level. In some aspects it can be detached and reallocated as a second docking from the patient after the beginning of the operation. It is prepared with sterile drapes by the OR nurse, before the surgery starts. This cart has to move in many directions because it can be docked in various ways depending on the type of abdominal wall defect. In that manner, it has to have great mobility around the patient.

At last the core cart is where the image processor, light source, energy source, and insufflator are placed. It can be close to the patient and its cart in order to have no large cables on the OR's ground (Fig. 1c).

All the other cables, cannulas, and other small devices are then placed respecting the robotic pathway as well as the surgical staff mobility. It is important not to have cables misplaced or in positions that could cause accidents to the electrical devices or people.

After all that setup it is important to think of the possibilities that can happen before, during, and after the procedure. Before the surgery, other devices can be placed in the room, such as energy cables or other screens, and it is important not to cause problems for the OR parts placed earlier. During the surgery is even worse because that is when unexpected problems occur. Conversions to open surgery or changes in robotic docking have to be foreseen so that possible changes in the OR setup can be made. And at the end of the procedure the patient has to come off the table to the bed, and the room setup has to be ready for it.

In the beginning of each procedure a checkout list has to be made to make sure the entire setup is done properly, so that no problems can occur during surgery. At the end it is important to check for possible problems that occurred during the operation so they can be corrected in other procedures and discussed in planned OR meetings. One person could be in charge of the complete setup, including the surgical room setup, care with the specific materials, and the patient's preparation and positioning.

Patient's Preparation and Positioning

Another important part of the setup begins with the preparation and positioning of the patient on the surgical table. Many studies show the influence of these items in the efficiency and outcome of the procedure [8]. With respect to that, all the materials to be used and placed on the patient as well as the possible types of positioning have to be well known before the surgery starts.

In order to have a standardized practice, all patients receive the same treatment and preparation for the robotic procedures to be done (Table 1).

Table 1 Patient's preparation

Patient's preparation
Antibiotics
Urinary catheter
Peripheral lines
Fixation strap
Chest protector
Head/eye protector
Endotracheal cannula
Anesthesia cannulas
Energy cables
Surgical drapes
Sterile film
Heater device

Patients are positioned on the table depending on hernia location, that is, the concept to keep trocars over 20 cm from the main object (hernia imaginary center). After that, they receive only one dose of antibiotics, depending on the guidelines of each hospital, in our case a second-generation cephalosporin. Following that, the anesthesia is done and all the cannulas are placed lateral to the patient, contralateral to the wall defect. A urinary catheter and peripheral lines are installed; depending on the patient's comorbidities, sometimes a central line is placed. He is secured with a fixation strap, at the chest and legs, and a head and/or eye protector. A body heater is then placed above the xyphoid or at the legs with a blanket.

The patient is then prepped from the xyphoid to the perineum and draped. After that a sterile film is placed, leaving the entire anterior abdominal area exposed. All the energy cables and other devices are now placed lateral to the patient and secured so as not to cause problems.

There are many types of procedures to be done robotically, and when we talk about hernia they can be very different one from the other. The abdominal wall is very wide and it has many angles on which to work. Depending on the defect one can work upwards, downwards, or both. Thinking about that and a way to standardize, the patient's position on the table is planned to wide-expose the abdomen, combining lumbar flexure, anterior abdomen hyperextension, lateral right or left tilt degree, and the same freedom to move throughout the room to secure the best robotic docking possible (Fig. 2).

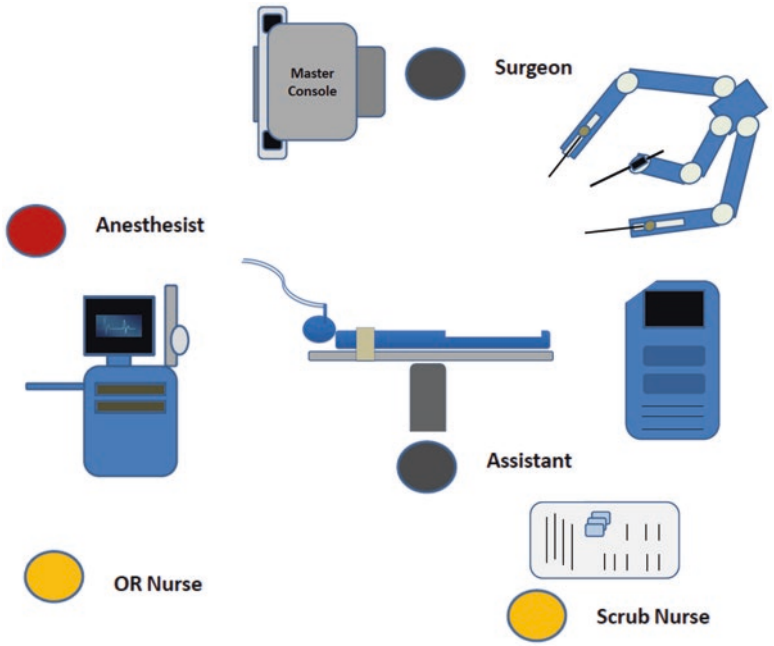


Fig. 2 Patient's positioning

The patient is positioned on the table in a dorsal horizontal decubitus with the arms and legs close to the body. As mentioned before he is secured to the table with straps and chest protectors. Depending on the procedure the legs can be opened to facilitate posterior docking. The surgical table must be placed in the desired position before the docking (e.g., Trendelenburg, etc.). All the catheters, cables, straps, and protectors have to be checked before the procedure starts.

After all that is done it is time for the robotic docking.

Robotic Docking

The robotic docking is the act of placing the robot in the surgical field and attaching it to the patient's cannulas. It can be done in many ways, depending on the abdominal defect, type of patient, and procedure to be done [9, 10].

With the patient well positioned, abdominal access is obtained and the pneumoperitoneum is made. All the cannulas are placed prior to the robotic docking. Then the patient cart is maneuvered in order to attach to the cannulas. The first cannula to be attached is the camera; this is done by aligning the cart's tower, camera arm, and the defect to be operated on. At this stage we use the numbers 1 and 2 written in the cart's arms to navigate the device towards the patient.

After the camera arm is connected, the other arms are placed on the trocars inserted in the patient. At this point we can use arms 1 and 2; sometimes it is necessary to use the third arm, mainly in the most difficult cases or more complex hernias (pelvic). An auxiliary port can be used to help with clipping, suctioning, or inserting other materials such as a mesh, stapler, or sutures. All the ports are placed respecting the minimal distance between them (10/5 cm) following the "double triangle" rule, explained better in the intuitive guidelines.

It is necessary to review the correct positioning of the patient before connecting the arms to the cannulas. At all times care must be taken to avoid collision with the patient, who is well secured with the protectors and straps placed earlier [9].

The surgical team must do a final evaluation, watching after the patient's skin tractions and trauma, abdominal wall hazard, and any other fine repositioning before the surgeon leaves the patient's side to be at the console. After that is done it is time to start the procedure.

There are many types of docking; even patients with the same abdominal defect can have different approaches regarding the docking [10]. The cart can be placed above one of the shoulders or the head, laterally, or even between the legs; the plan comes with disease study and sometimes defect understanding (Fig. 3).

All types have advantages and disadvantages depending on the surgical or patient difficulty [10, 11]. Fat patients could be accessed as far as possible from the defect, regarding the length of instruments that they can use at farther tissues to prepare where the mesh will be laid. A larger abdominal cavity must be considered to be double checked at all distances, because of dissection of all muscles and tissues of interest for abdominal wall reconstruction. These anatomical references go farther

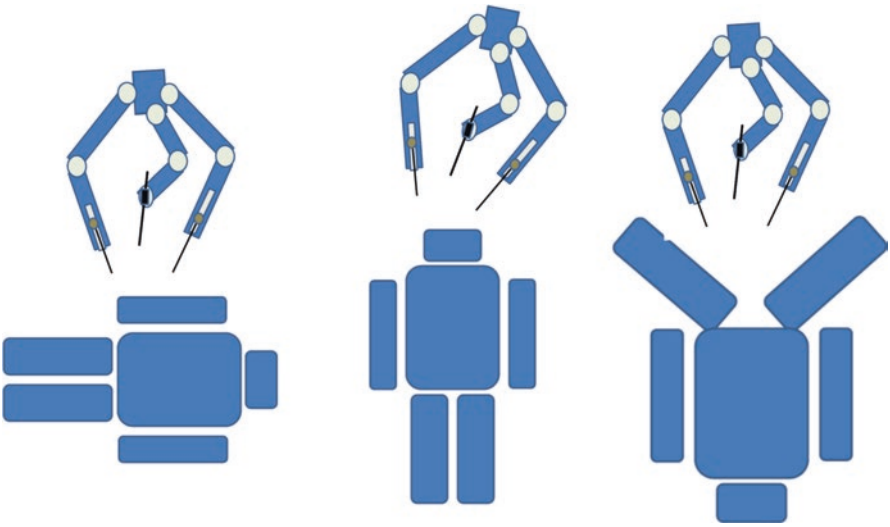


Fig. 3 Types of robotic docking

than the defect borders. Robot arm positioning must permit working to the anatomical limits of all of these.

When the docking is made from above the anesthesia cart must be relocated, sometimes close to the legs, and the anesthesiologist stays far from the head of the patient. In this scenario, large connectors and cannulas have to be connected to the patient and the protectors have to be well placed to secure the patient's head. Sometimes, the anesthesiologist has to look at the head and endotracheal cannula to check them. This check time is always made after robot docking.

Lateral docking is done close to the limbs as well as the docking done between the legs. In these types, the patient's arms and legs are secured and checked for possible injuries or problems regarding peripheral lines or monitoring cables.

Another important part of the docking is the possibility of changing the docking and moving the robot through the room. Some types of defects demand double docking, patient 180° turning, or even more robot movement (dislocation) during the surgery. Thus it is important to have space in the room and mobility of the robot, anesthesia, and the patient's table.

The undocking disconnects the cannulas from the patient cart. That is done after checking that all the instruments are loose and straightforward and then they are taken out of the patient. Then, the patient cart is moved away on the same path as before, during docking time.

Robotic hernia repair can lead to problems during the surgery, such as bleeding or bowel perforation. Thus, in emergencies and conversions the surgical team has to be prepared to move the robot away from the field to have the best place to work and solve the problem that occurred at that moment. At all times the surgical assistant, at the patient's side, has to be prepared to operate laparoscopically or even opening the patient while the surgeon prepares to enter the surgical field.

Getting Started

When that is done the surgery can be started and during the procedure the OR nurse can see and write down all the problems that could occur due to the OR setup and discuss them with the surgical team. In the next cases changes can be made to gain more efficiency and correct some mistakes that can happen before the surgery, or even while the procedure is being done [12, 13].

All that feedback is useful to build a setup program for the robotic procedure itself, and it is also interesting for other fields of surgery, such as urology or other general surgery procedures.

Summary

In conclusion, the robotic setup is an assemblage of actions and factors to be gathered in the construction and organization of the OR and the materials and people involved in this procedure. In this action group ergonomics has an important role mainly in the OR setup; as discussed before this can impact the effectiveness of the team and the procedure itself [3].

Another important part is the robotic surgery that can have an impact on the OR and overall setup. With the growing use of robotic technology in hernia repair this impact becomes even more important in the preparation of the room and the patient [2].

In this scenario all the parts of the room and specific preparations and preventions regarding the patient have to be recognized. The OR becomes important in organizing the large devices and adding them to all the electric cables, cannulas, and surgical staff. The patient's preparations become more important, regarding caution with the robot arms, cart, supporting devices, and patient-preserving integrity during the procedure [14].

Robotic surgery has the necessity of moving the patient's cart through the room, because there can be many types of robotic docking and even more than one docking depending on the procedure.

All that preparation and setup of the OR has to be standardized, in order to be reproducible and feasible. In this way, changes and feedback can be done to improve surgical quality.

Concluding Remarks

- The entire setup has to be standardized in order to obtain the maximum performance and reproducibility.
- All the people involved in the procedure have to work together and help with the setup.
- Ergonomics is a key part of the whole setup and it is linked to the overall performance.

- The usage of correct materials can prevent injuries, facilitate the entire procedure, and gain time during the surgery.
- Feedback is always important to the improvement of any procedure; regarding setup it becomes even more useful.

Glossary [15]

Ergonomics The applied science of equipment design, as for the workplace, intended to maximize productivity by reducing operator fatigue and discomfort. Also called *biotechnology*, *human engineering*, or *human factors engineering*. Design factors, as for the workplace, intended to maximize productivity by minimizing operator fatigue and discomfort.

Master console The main terminal used by the computer operator or systems programmer to command the computer. The system seamlessly translates the surgeon's hand, wrist, and finger movements into precise, real-time movements of surgical instruments.

Patient's cart The patient-side cart is where the patient is positioned during surgery. It includes either three or four robotic arms that carry out the surgeon's commands.

Robotic docking The act of placing the robot in the surgical field and attaching it to the patient's cannulas.

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Robotic Repair of Upper Abdominal Hernias

Jeremy A. Warren and Alfredo M. Carbonell

Keypoints Summary

- Fascial mobilization for hernia defect closure in the upper abdomen is limited by the costal margin and muscular attachments to the chest wall.
- Robotic myofascial release using a retrorectus technique allows greater medialization and ability to close hernia defects in the upper abdomen.
- Placement of mesh in the preperitoneal or retromuscular space minimizes the need for fixation above the costal margin.
- A single-dock robotic approach is suitable for most hernias of the upper abdomen, but is limited to those at least 3–5 cm above the umbilicus.
- A double-dock robotic approach allows for repair of larger defects that extend up to or below the umbilicus.

Introduction

Hernias in the extremes of the abdomen, whether lateral, superior, or inferior, each present unique challenges for the hernia surgeon. The bony limits of the abdominal cavity, the rib cage superiorly and the pelvis inferiorly, limit the ability to mobilize the musculofascial abdominal wall for hernia closure, as well as the degree of mesh overlap beyond the defect. Positioning of mesh in a sublay position is ideal for these locations, as placement within the abdominal cavity or interparietal layers will accommodate larger mesh overlap. However, fixation of the mesh is limited by these same structures, and typically requires suture or adhesive fixation superiorly where standard tack or transfascial suture placement is not possible. The robotic

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R.Z. Abdalla, T.N. Costa (eds.), *Robotic Surgery for Abdominal Wall Hernia Repair*, DOI 10.1007/978-3-319-55527-0_3

platform enhances the surgeons' ability to dissect and suture in some of these difficult to access areas through the use of articulating instrumentation and three-dimensional high-definition imaging. This chapter discusses the robotic approach for hernias of the upper abdomen.

Anatomy

The abdominal wall is bound superiorly by the xiphoid process in the midline and the costal margin extending laterally, and the abdominal cavity continues below the dome of the diaphragm several centimeters above the level of the xiphoid and lower ribs. The paired rectus abdominis muscles insert on the cartilaginous portion of the fifth, sixth, and seventh ribs, interdigitating with the fibers of the pectoralis major [1]. The muscle is typically 5–10 cm wide, becoming wider as it progresses superiorly from its origin on the pubic bone. The superior epigastric artery, a terminal branch of the internal mammary artery, supplies the upper portion of the rectus abdominis muscle, and derives its innervation from the intercostal neurovascular bundles, which traverse the plane between the transversus abdominis (TA) and internal oblique (IO) muscles to enter the lateral posterior rectus sheath.

The external oblique (EO) originates from the lower ribs posteriorly and inserts along the semilunar line, contributing to the anterior rectus sheath, and finally interdigitating with fibers from the contralateral EO and IO to form the linea alba. The IO lies just deep to the EO and originates from the thoracolumbar fascia, also inserting along the semilunar line and contributing to both the anterior and posterior rectus sheath above the arcuate line, and the anterior sheath below. Superiorly, the muscle also inserts onto the anterior surface of the lower three ribs and interdigitates with the intercostal muscles. The TA is the deepest of the lateral abdominal muscular layers, traversing the abdomen transversely and creating circumferential, hoop-like tension. Its fibers insert to the posterior aspect of the lower ribs in the upper abdomen, interdigitating with the insertions of the diaphragm, and contribute to the posterior rectus sheath. Importantly, the muscle belly actually makes up a substantial portion of the posterior rectus sheath in the upper abdomen. The TA layer becomes increasingly aponeurotic as it progresses inferiorly, which is a critical anatomic detail when performing a transversus abdominis release (TAR).

Deep to the TA are the transversalis fascia (TF) and peritoneum. The TF, or investing fascia of the abdomen, covers the deep surface of the TA, but can be fairly easily separated from the muscle. Below this, an areolar plane, containing variable amounts of adipose tissue, separates the transversalis fascia from the peritoneum, making this plane fairly easy to dissect. The parietal peritoneum envelops the whole of the abdominal cavity, including the inferior surface of the diaphragm. The TF extends below the diaphragm as well, and is continuous with the endothoracic fascia around the esophageal hiatus, forming the phrenoesophageal ligament [2, 3].

The xiphoid process is cartilaginous and attaches to the linea alba anteriorly, the diaphragm posteriorly, and the costoxiphoid and transverse thoracic muscles to the ribs and costal cartilage [4]. The retroxiphoid space can be easily developed with

blunt dissection, dropping the fatty preperitoneal tissue away from the posterior surface. The upper extent of the dissection is the myocardium, which is adherent to the posterior sternum. This anatomic plane can be utilized for mesh placement.

Background

The majority of upper abdominal wall hernias are incisional, occurring along the midline after a variety of abdominal operations as well as median sternotomy. Primary epigastric hernias can also occur along the midline. These are often small defects amenable to primary suture repair, although they can certainly be approached laparoscopically or robotically as well. Hernias also occur laterally after subcostal incisions, but are less common than after midline laparotomy [5]. The optimal management of these hernias, particularly subxiphoid defects, is difficult to discern, and technical details are often sparse in reports of incisional hernia repairs. Open repair can be difficult due to limited superior mesh overlap and mesh fixation. Tension-free closure of the linea alba is also restricted by the musculofascial insertions of the costal margin and xiphisternum. The retromuscular space can extend easily to the costal margin, where the posterior sheath and TA attachments to the posterior costal margin can be incised to enter the preperitoneal space. The peritoneum can be separated from the diaphragm, which allows adequate superior mesh overlap. Relaxing incisions of the anterior rectus fascia can accommodate closure of the fascia over the mesh.

Laparoscopic ventral hernia repair (LVHR) for defects of the upper abdomen affords superior visualization of the hernia defect, and overlap of the mesh above the hernia defect in an intraperitoneal position [6–9]. For LVHR, the falciform ligament is taken down to allow the mesh to lay flat against the peritoneal and subdiaphragmatic surface. Peripheral mesh fixation is mandatory for intraperitoneal placement, therefore the superior overlap of mesh placed to reinforce subxiphoid defects is problematic. Transabdominal sutures and tacks are not an option, and severe complications, such as pericarditis and cardiac tamponade have been reported [4]. Thus, the superior edge of the mesh must be left unfixed, relying on intra-abdominal pressure and the liver to hold it in position, or fixated with bioadhesive or intracorporeally placed sutures (Fig. 1). Preperitoneal placement of mesh in this region is also feasible laparoscopically, as the falciform ligament and subxiphoid preperitoneal fat planes are typically easy to develop. This approach requires less mesh fixation than intraperitoneal placement, but requires a more technically demanding dissection.

Our preferred technique is placement of mesh in the extraperitoneal position, either preperitoneal or retromuscular, with complete closure of the hernia defect. Retromuscular repair requires a more extensive dissection, releasing the posterior fascia from the rectus muscle, followed by closure of the anterior fascial defect, mesh reinforcement, and posterior sheath closure. The superior visualization, articulating instruments, and favorable ergonomics of the robotic platform greatly facilitate both preperitoneal and retromuscular repairs of upper abdominal hernias.

Fig. 1 Laparoscopic repair of subxiphoid incisional hernia. Mesh fixation is limited by the costal margin superiorly

Robotic Repair of Upper Abdominal Hernias

Single-Dock Retromuscular Repair

Most upper abdominal hernias can be approached using a single-dock technique. The patient is placed in a reverse Trendelenburg position on a split-leg table or low lithotomy. The bed is flexed slightly to allow greater clearance of the robotic arms above the patients' pelvis and legs, particularly the center camera arm. Three trocars are placed across the lower abdomen, and a fourth assistant trocar is placed laterally. The robotic cart is placed parallel to the operative table for docking (Figs. 2 and 3a). Any necessary adhesiolysis is completed and the extent of the hernia defect assessed. Beginning at least 5 cm below the hernia defect, a transverse incision is made through the posterior rectus sheath to enter the retromuscular plane (Fig. 3b). The incision is extended from the semilunar line on one side, dividing the posterior sheath below its insertion on the linea alba to enter the preperitoneal space along the midline (Fig. 4a), and continuing to the retromuscular space contralaterally and ending at the opposite semilunar line. This creates three separate compartments that must be dissected: the right retromuscular space, the midline preperitoneal space, and the left retromuscular space. As each plane is developed cephalad, the only remaining partition is the posterior sheath as it inserts onto the linea alba. This is simply divided to create a contiguous space between these three compartments.

Dissection is continued until the inferior edge of the hernia sac is encountered. When possible, the hernia sac is separated from the subcutaneous tissue and completely reduced, leaving the hernia sac in continuity with the posterior sheath and peritoneal flap. Resection of the hernia sac can be technically challenging, and is not necessary in every case. The peritoneum can simply be incised and the dissection continued in each retromuscular space until the upper extent of the hernia is reached. At this point, the hernia sac is incised to re-enter the midline preperitoneal space above the defect, and dissection is continued at least 5 cm above the hernia in similar fashion as below (Figs. 3c, d and 4b). If there is inadequate space in the retromuscular compartment to accommodate superior mesh overlap, the transversus

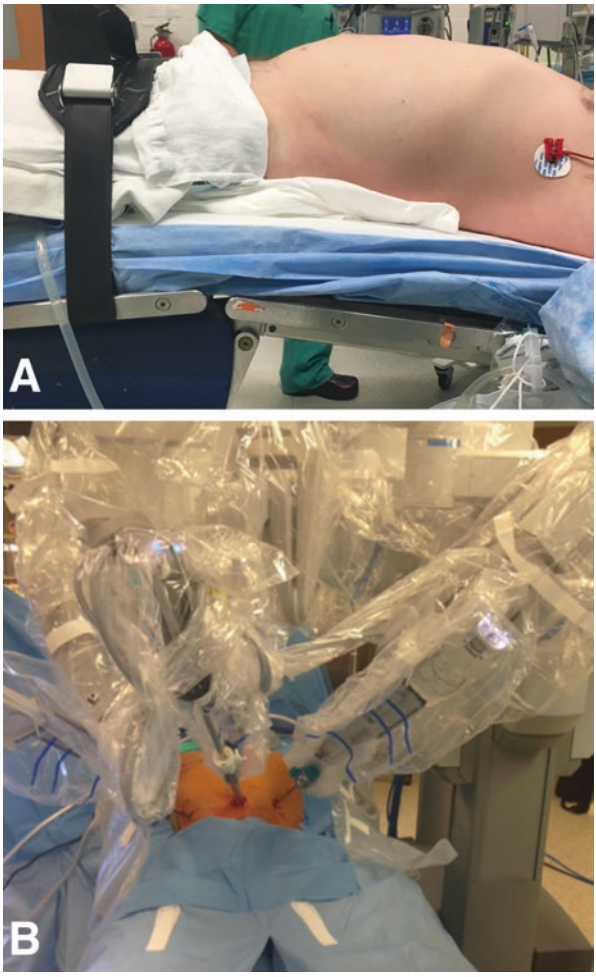

Fig. 2 (**a**) Patient is positioned with arms out and the bed flexed slightly. (**b**) Trocars placed in the suprapubic position with the patient in reverse Trendelenburg on a split-leg table. Robotic cart is aligned parallel to the operating table

abdominis fascia and muscle can be divided along the posterior costal margin, entering the preperitoneal space. This plane can then be extended superiorly by stripping the peritoneum from the diaphragm to allow adequate superior mesh overlap. The retroxiphoid space is easily dissected at the midline to complete the dissection.

The hernia is measured intracorporeally using a metric ruler. The defect is then closed using a #1 absorbable self-fixating, barbed suture, including bites of the overlying hernia sac or soft tissue in order to imbricate and obliterate the dead space (Fig. 4c). The dissected space is measured to determine the appropriate mesh size. We prefer a large-pore, midweight polypropylene mesh, which is cut to occupy the entire retromuscular dissected space, and placed against the anterior abdominal wall.

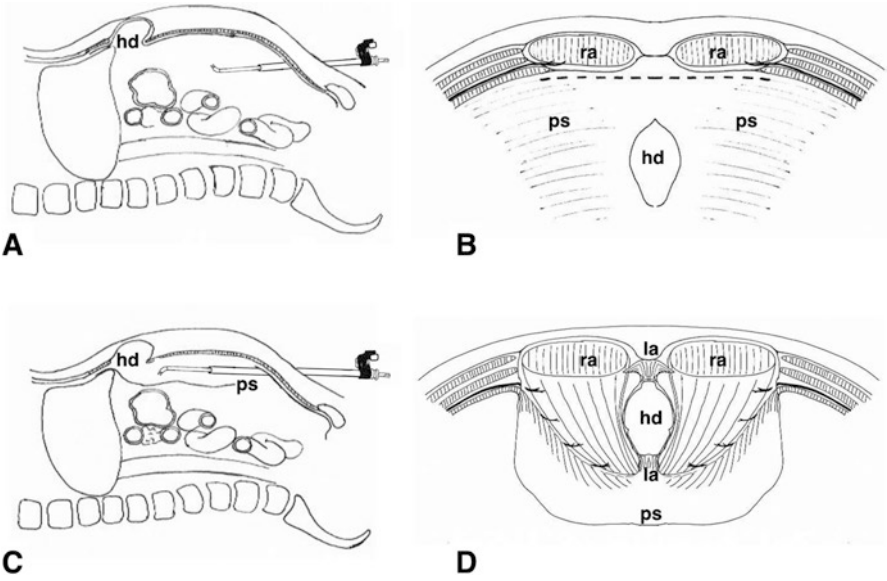

Fig. 3 Schematic representation of single-dock robotic repair of upper abdominal wall hernias. (**a**) Sagittal view of suprapubic trocar placement and docking; *hd* hernia defect. (**b**) *Dashed line* indicating the transverse incision created to initiate the retromuscular dissection; *ra* rectus abdominis, *ps* posterior sheath. (**c**) Sagittal view demonstrating the dissection of the posterior sheath, including the hernia sac. (**d**) Completed dissection of bilateral posterior rectus sheaths and preperitoneal space, including the hernia sac. Note the intact linea alba above and below the hernia defect; *la* linea alba

The mesh is secured with a few interrupted absorbable sutures. Minimal fixation is typically required, as the mesh should widely overlap the closed defect and be sized to match closely the dimensions of the dissected retromuscular space. Once the posterior sheath is closed, physiological intra-abdominal pressure will aid in maintaining the mesh in position. After the mesh is secured, the posterior sheath is closed transversely using a 2–0 absorbable self-fixating, barbed suture. Any peritoneal defects created during dissection of the hernia sac should be repaired with absorbable suture prior to closure of the posterior sheath (Fig. 4d). The single dock is represented schematically in Fig. 3, with accompanying operative images in Fig. 4.

The retromuscular approach is particularly useful for larger defects, as the release of the posterior rectus fascia facilitates medialization of the rectus muscles towards the midline. The addition of a transversus abdominis release is possible with this approach as well to allow greater medialization, wider overlap, or to address any more laterally oriented defects along the costal margin. The TAR is initiated by incising the transversus abdominis fascia and muscle just below the costal margin and medial to the perforating segmental neurovascular bundles. The preperitoneal plane is then developed laterally as far as necessary, and superiorly along the diaphragm as high as necessary to provide adequate mesh overlap. If a TAR is required, the lower transverse incision will typically need to be extended as well.

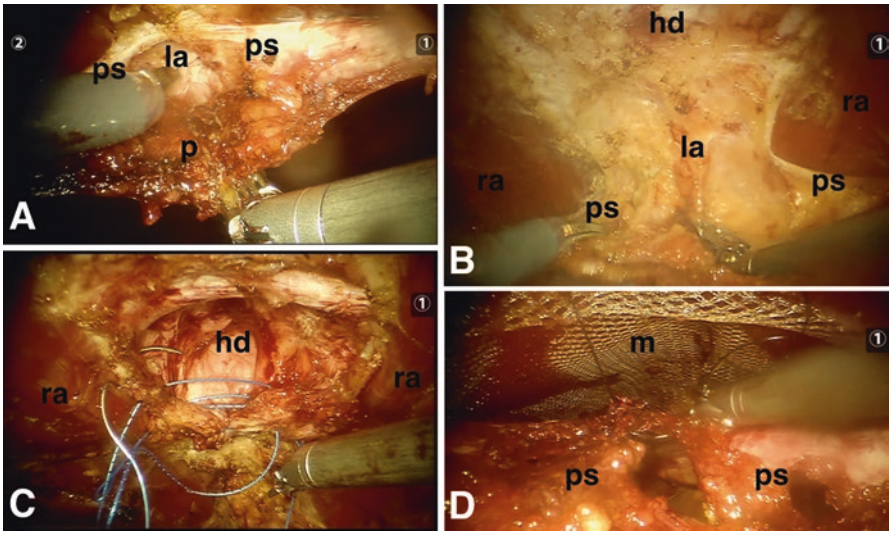

Fig. 4 Operating technique for single-dock robotic repair of upper abdominal wall hernias. (**a**) The midline dissection below the hernia defect, creating the retromuscular space bilaterally and the preperitoneal space at the midline, and dividing the posterior sheath on each side to create a single space; *la* linea alba, *ps* posterior sheath, *p* peritoneum. (**b**) Completion of the retromuscular dissection above the level of the hernia defect, leaving the linea alba intact; *hd* hernia defect, *ra* rectus abdominis muscle. (**c**) Closure of the hernia defect. (**d**) Placement of mesh against the anterior abdominal wall and closure of midline posterior sheath defect at the level of the hernia sac; *m* mesh

Double-Dock Retromuscular Repair

The single-dock approach is limited by the caudal extent of the hernia defect. To allow inferior overlap, dissection should begin at least 5 cm below the defect, and instruments are typically unable to reach the abdominal wall within 5–8 cm of the trocar insertion site. As a general rule, hernias that are less than 3–5 cm above the umbilicus are not suitable for a single-dock robotic repair. In these cases, a double-dock technique is used. The patient is positioned supine, arms out, and with the bed flexed slightly. Trocars are placed along the right lateral abdomen along the anterior to mid-axillary line between the costal margin and iliac crest. The robotic cart should be aligned over the patients' hip, which allows the assistant access to the contralateral upper abdomen for later trocar placement and passage of suture and mesh (Fig. 5). After any necessary adhesiolysis and hernia reduction, the retromuscular dissection is initiated on the left side by incising the posterior sheath just lateral to the linea alba (Fig. 6a). Dissection is continued laterally to the semilunar line, superiorly to the costal margin, and inferiorly at least 5 cm below the hernia defect (Fig. 6b). Beginning just medial to the neurovascular bundles, the TA fascia and muscle are incised to enter the preperitoneal plane, which is extended laterally to approximately the mid-axillary line (Fig. 6c). At this point, three additional mirror image trocars are placed into the dissected preperitoneal space (Fig. 6d). The hernia defect and dissected space are measured in order to size the mesh

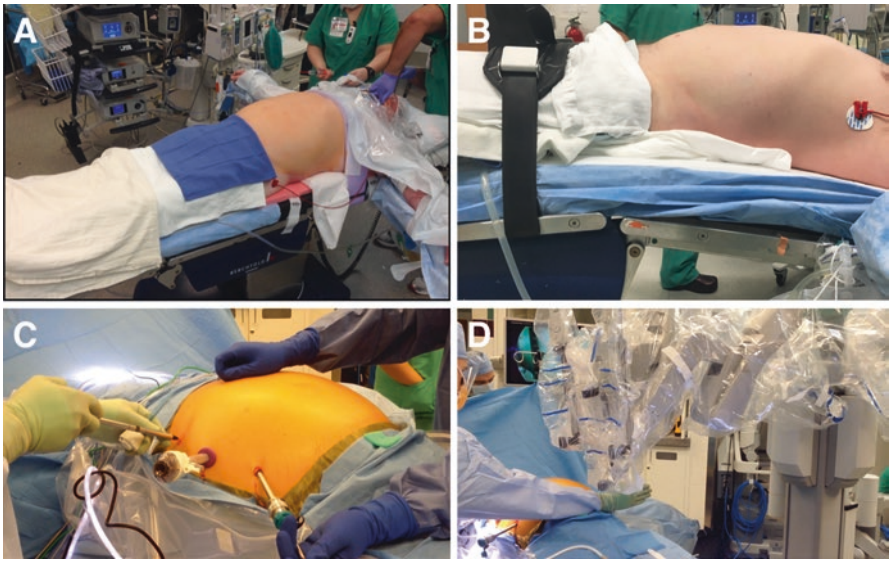

Fig. 5 Positioning for double-dock robotic retromuscular hernia repair. (**a**) Supine with arms extended. (**b**) Bed flexed slightly to open the space between the costal margin and iliac crest. (**c**) Lateral trocar placement, typically between the anterior and mid-axillary line. (**d**) Alignment of the center column of the robotic cart with the hip

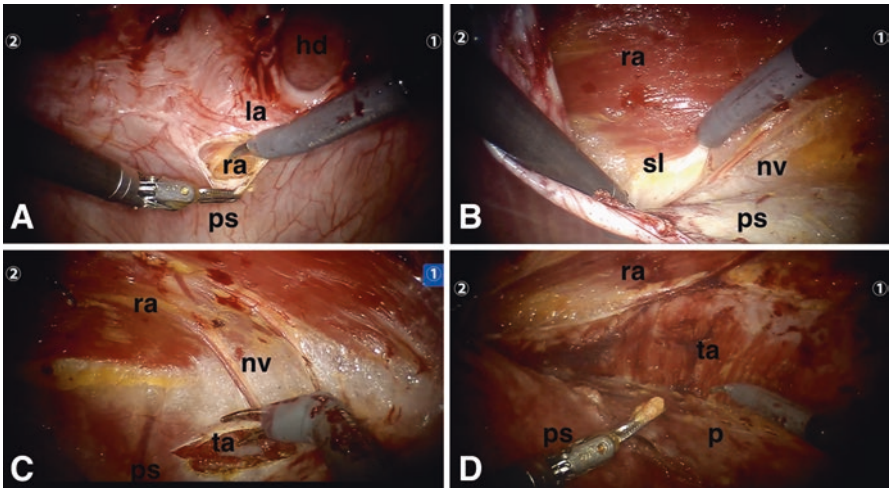

Fig. 6 Double-dock robotic hernia repair. (**a**) Dissection begins just lateral to the linea alba to enter the retromuscular space; *hd* hernia defect, *la* linea alba, *ps* posterior sheath, *ra* rectus abdominis muscle. (**b**) Retromuscular dissection terminates at the semilunar line; *sl* semilunar line, *nv* neurovascular bundles. (**c**) Initiation of transversus abdominis release by division of the transversus abdominis muscle medial to the nv; *ta* transversus abdominis muscle. (**d**) Completed TAR; *p* peritoneum

appropriately. The mesh width is estimated at this point to be double the width of the dissected posterior sheath, and is best measured by passing a spinal needle through the left lateral edge of the hernia defect down to the ruler, which is placed on the posterior sheath inferiorly. The mesh is cut to size, rolled along its vertical axis, and secured to the left lateral abdominal wall with absorbable suture just beyond the left-sided trocars (Fig. 7).

The robot is then redocked on the left side, and an identical retromuscular dissection and TAR are performed on the right, bringing the initially placed

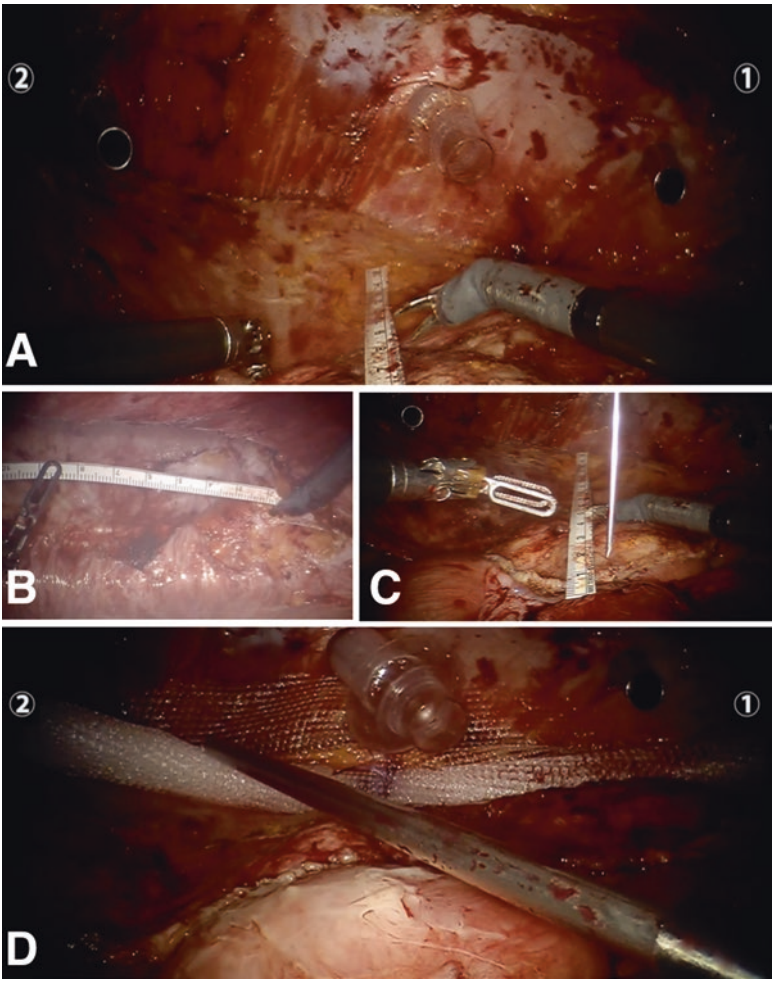

Fig. 7 Double-dock robotic hernia repair (*cont.)*. (**a**) New trocars placed into the dissected preperitoneal space in mirror image to the initially placed trocars. (**b**) Measuring the hernia defect. (**c**) Measuring the posterior sheath to estimate the required mesh width. (**d**) Placement of mesh into the contralateral preperitoneal space lateral to the nascent trocars

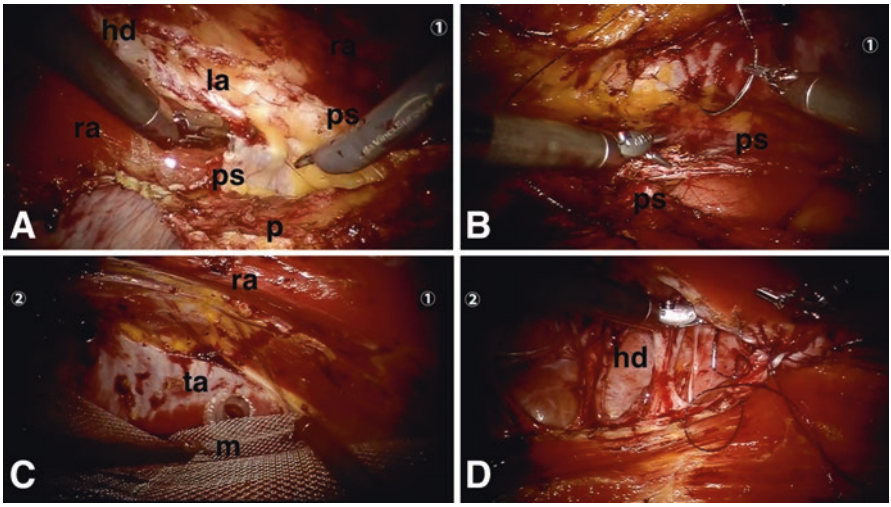

Fig. 8 Double-dock robotic hernia repair (*cont.*). (**a**) Completion of the midline dissection above and below the hernia defect; *hd* hernia defect, *la* linea alba, *ra* rectus abdominis muscle, *ps* posterior sheath, *p* peritoneum. (**b**) Closure of the posterior rectus sheath after completing the contralateral retromuscular dissection and TAR. (**c**) Deployment of the mesh across the closed posterior sheath; *m* mesh. (**d**) Closure of the hernia defect anteriorly

right-sided trocars into the preperitoneal space. Any remaining dissection of the midline above and below the hernia defect is easily accomplished at this time, creating the continuous space for mesh overlap around the defect and maintaining the integrity of the linea alba (Fig. 8a). The posterior sheath on each side is now lying inferiorly over the viscera, below the robotic camera and instruments. The midline posterior sheath is closed using a 2–0 absorbable self-fixating, barbed suture. Once this is completed, the abdominal cavity is closed and the remainder of the case proceeds entirely within the retromuscular space (Fig. 8b). The rolled mesh is retrieved from under the trocars, unfurled over the closed posterior sheath and secured to the right lateral abdominal wall beyond the trocars (Fig. 8c). The hernia defect is then closed using a #1 absorbable, self-fixating, barbed suture (Fig. 8d). Pneumoperitoneum is released and trocars removed, with no need to close the trocar sites, as each is covered by the mesh. The double-dock approach is represented schematically in Fig. 9.

Preperitoneal Repair

Alternatively, repair of upper abdominal hernias can often be completed using a preperitoneal technique similar to the transabdominal preperitoneal repair of inguinal hernias (Fig. 10). This is preferred for small defects when myofascial release is not necessary for defect closure. Operative setup and patient positioning are identical.

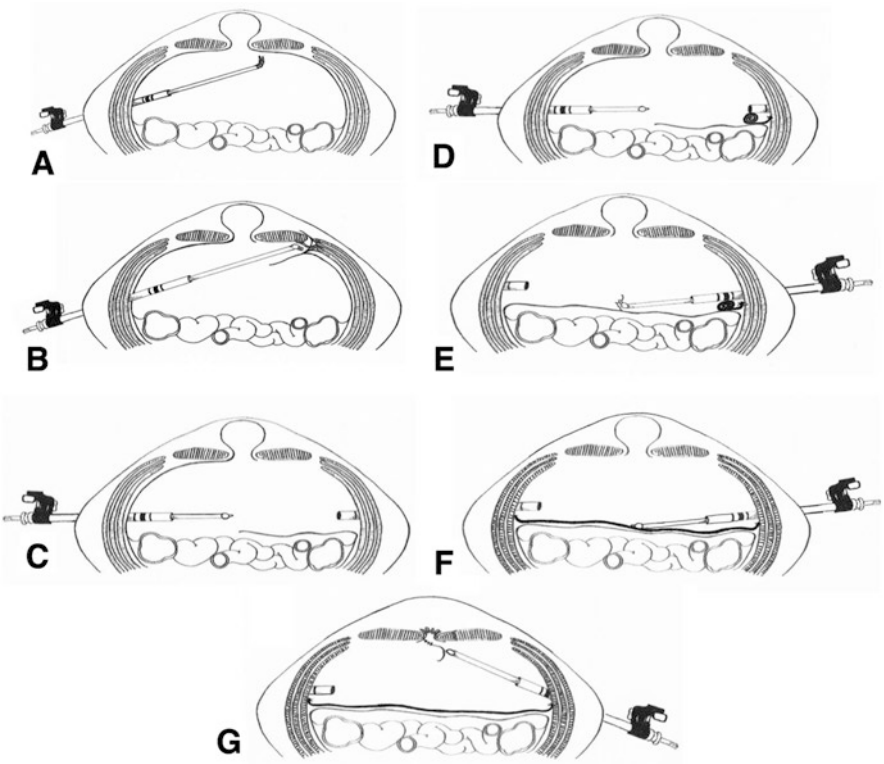

Fig. 9 Schematic representation of the double-dock robotic technique. (**a**) Initiating the retromuscular dissection. (**b**) Retrorectus dissection continued to the semilunar line. TAR is initiated medial to the neurovascular bundles. (**c**) Completion of the TAR with placement of new trocars into the dissected preperitoneal space. (**d**) Placement of mesh into the dissected space lateral to the nascent trocars. (**e**) Completion of the retromuscular and TAR dissection on the contralateral side with closure of the posterior rectus sheath at the midline. (**f**) Deployment of the mesh across the closed posterior sheath. (**g**) Closure of the hernia defect

However, rather than incising the posterior rectus sheath and entering the retrorectus space, only the peritoneum is incised. Again, this should begin at least 5 cm below the hernia, extending at least 5 cm in all directions around the defect to allow adequate mesh overlap. The caudal extent of the falciform ligament is often the easiest location to begin the preperitoneal dissection. As with the retromuscular technique, the hernia sac is dissected free of the subcutaneous tissue, creating a single posterior peritoneal flap. The hernia defect is measured, as is the extent of the dissected preperitoneal pocket. Closure of the hernia defect is performed with a #1 absorbable, self-fixating, barbed suture. A large-pore, midweight polypropylene mesh is cut to fit the dissected space and placed against the anterior abdominal wall. As with the retromuscular approach, minimal fixation is typically needed. Once the mesh is secured, the peritoneal flap is closed with 2–0 absorbable self-fixating, barbed suture.

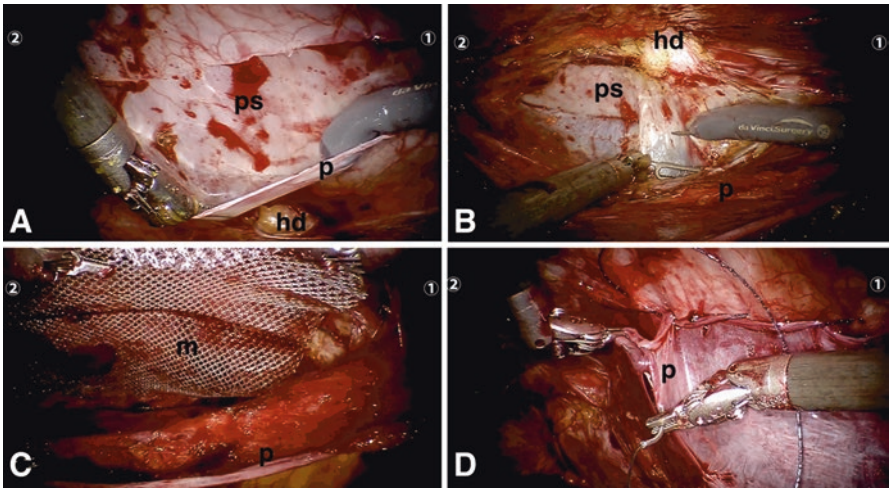

Fig. 10 Robotic preperitoneal hernia repair. (**a**) Peritoneal dissection initiated at least 5 cm from hernia defect to allow adequate mesh overlap; *hd* hernia defect, *p* peritoneum, *ps* posterior sheath. (**b**) Preperitoneal dissection continued beyond the hernia defect, with reduction of the hernia sac whenever possible. (**c**) After closure of the hernia defect, mesh is deployed against the anterior abdominal wall; *m* mesh. (**d**) Peritoneal flap is closed to cover the mesh

Intraperitoneal Repair

In the event that these planes cannot be accessed, a standard intraperitoneal onlay of mesh (IPOM) remains an excellent option. The fascial defect should still be closed whenever possible as described above. A tissue-separating mesh is required for intraperitoneal placement to minimize the risk of adhesions, and should be sized to provide at least 5 cm overlap in all directions. Mesh fixation can be readily accomplished with intracorporeal suture in either an interrupted or running fashion around the circumference of the mesh. We recommend permanent fixation to prevent future mesh migration. Choice of fixation is widely debated, however, and there is no clear evidence, particularly robotically, as to the optimal method of mesh securement.

Summary

Repair of upper abdominal hernias can be challenging. The anatomic boundaries of the abdominal cavity impede standard laparoscopic mesh fixation superiorly and limit the medialization of the musculofascial abdominal wall for defect closure, making an extraperitoneal sublay mesh placement ideal. The robotic platform is ideal for this approach. Dissection of the preperitoneal or retromuscular space, intracorporeal closure of the hernia defect, and fixation of mesh to the abdominal wall are greatly enabled by enhanced 3D visualization and articulating

instruments. Data are currently scant on the outcomes of robotic hernia surgery [10–14], but the ability of this technology to replicate complex open operations using a minimally invasive approach holds great promise for the future of abdominal wall reconstruction.

Concluding Remarks

- The robotic platform facilitates repair of upper abdominal wall hernias, reinforced with mesh in the extraperitoneal position.
- Smaller hernia defects can most often be repaired with preperitoneal mesh placement from a single-dock position.
- Larger defects limited to the supraumbilical abdomen can often be repaired from a single-dock position using a rectus myofascial release and retromuscular mesh reinforcement.
- Defects extending to or below the umbilicus can still be repaired robotically using a double-dock technique and bilateral rectus and transversus abdominis myofascial releases.

Glossary

Rives-Stoppa Technique for ventral hernia repair involving myofascial release of both rectus muscles, mesh reinforcement in the retromuscular space and defect closure over the mesh.

Transversus abdominis release (TAR) A posteriorly oriented component separation by which the transversus abdominis muscle and fascia are divided within the posterior rectus sheath to release the lateral abdominal wall and allow midline fascia closure.

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Robotic Repair of Lower Abdomen Defects

Eduardo ParraDavila, Flavio Malcher, and Carlos Hartmann

Keypoints Summary

- Robotic ventral hernia repair can offer traditional minimally invasive open repair techniques.
- Adhesiolysis is a key point in minimally invasive hernia repair.
- Fascia closure can have many benefits in the hernia repair and robotic technology can facilitate the procedure.
- Circumferential sutures can secure mesh in a better way with less postoperative pain.
- Exploiting the layers of the abdominal wall is made possible by the precision the dV robot affords.

Electronic Supplementary Material: The online version of this chapter (doi:10.1007/978-3-319-55527-0_4) contains supplementary material, which is available to authorized users.

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R.Z. Abdalla, T.N. Costa (eds.), *Robotic Surgery for Abdominal Wall Hernia Repair*, DOI 10.1007/978-3-319-55527-0_4

Introduction

In 2004, at the American Hernia Society, a consensus statement concluded that the Rives-Stoppa repair of ventral hernias was the standard by which all open hernia repairs should be judged [1]. However, laparoscopic ventral hernia repair emerged and resulted in negligible wound complications and low recurrence rates [2–5].

Although laparoscopic repair has been associated with faster recovery, fewer complications, and a lower recurrence rate compared to the open technique, there continues to be a significant incidence of postoperative pain associated with the transabdominal wall sutures. Several authors [5–9] have reported a 2% incidence of significant postoperative pain lasting more than 2–8 weeks after repair.

Traditionally, the steps of laparoscopic ventral hernia repair (LVHR) involve adhesiolysis to isolate the defect, bridging the defect closed with a large overlapping sheet of tissue-separating mesh, and fixating the mesh to the abdominal wall by way of circumferential tacks and full-thickness transfascial sutures. Technically speaking, this approach delineates the three shortcomings of this repair. Adhesiolysis is the Achilles heel of this procedure because of its technical difficulty due to frequent encounters of recurrent hernias with bowel adhering to the previous mesh. Secondly, bridging defects may predispose to migration of the mesh into the defect and seroma formation [10, 11]. Thirdly, the requirement for circumferential tacks and multiple full thickness transfascial sutures to secure the intraperitoneal onlay mesh (IPOM) adequately predispose to both acute and protracted pain [12].

Robotic ventral hernia repair (RVHR) overcomes these shortcomings by allowing the operator to offer traditional open repair techniques through minimal-access incisions. The da Vinci robot (Intuitive Surgical, Sunnyvale, CA, USA) offers numerous advantages, including several degrees of motion, three-dimensional (3D) imaging, and superior ergonomics that enable easy, precise adhesiolysis, and intracorporeal suturing for defect closure and mesh fixation. Previous reports have demonstrated the ease of intracorporeal suturing of the mesh to the abdominal wall [2].

Whereas previous reports have confirmed the need to suture the mesh at 2–5 cm intervals [4, 13, 14] as a means of reducing the recurrence rates associated with laparoscopic hernia repairs, we believe that continuous circumferential suturing applies those principles while evenly distributing the tension throughout the mesh. The entire repair is performed under direct visualization, with precise placement and confirmation of depth into the posterior fascia for all sutures placed.

The fascial sutures encompass 1 cm bites of fascia, minimizing trauma to the abdominal wall. Intracorporeal suturing of the fascia allows the midline to be reapproximated, allowing possible primary repair, more physiologic abdominal wall movement, and greater overlap of the mesh to the defect's fascial edges. Robot-assisted laparoscopic ventral hernia repair offers yet another advantage by providing the suturing option under excellent visualization for the repair of difficult hernias with bony or muscular margins, such as lumbar, suprapubic, and subcostal hernias [15, 16]. Several patients have hernias on or near lateral borders of the abdomen, making mesh fixation with tackers difficult. This allows the surgeon to take precise bites of tissue to anchor the mesh repair. Limitations of this robot-assisted technique

are obvious [17]. Large ventral hernias as they approach the working ports and camera, make this technique technically challenging for the robotic arms to be placed and able to work with the angulations needed.

Techniques

Hernia repair techniques amenable to the robotic approach include: IPOM bridge, IPOM after primary closure of the defect, preperitoneal placement of mesh, or placement of retrorectus mesh with or without posterior component separation. These individual techniques are chosen based on location of the hernia defect, size of the defect, and perhaps most important, surgeon experience. This chapter provides detailed instruction on each individual technique along with author insight where applicable.

Intraperitoneal Onlay Mesh After Primary Closure of the Defect

Patient Positioning, Trocar Placement, and Docking

For the majority of patients with defects in the lower abdomen, supine positioning with the arms tucked is preferred, unless trocar access to the lateral abdomen is obscured by this position. In this situation, the arm is placed on a board set at 90° from the trunk. For lower mid-abdominal hernias, the trocars should be placed at the most cranial possible to be at least 3 cm from the edge of the future mesh that will be used. The position of the trocars should allow for a full range of motion and anterior abdominal wall suturing. The extremes for instrument length must also be considered prior to trocar placement.

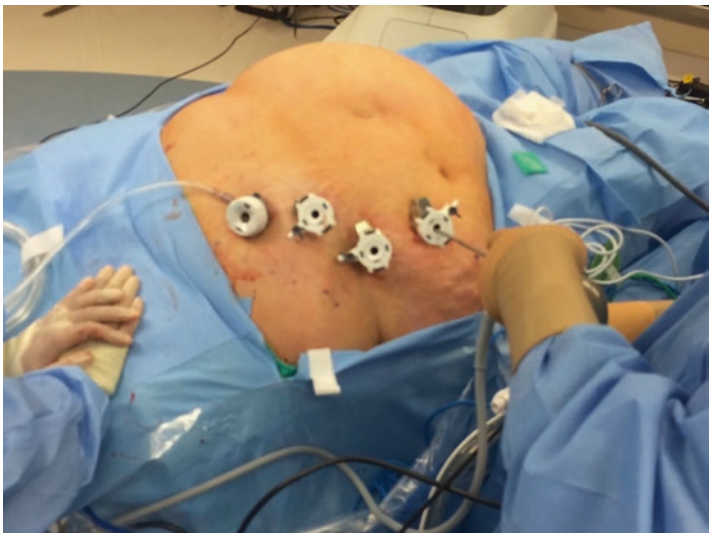
Gaining safe intra-abdominal access remains the first step in minimally invasive surgery [18]. This can be made difficult in the multiply operated abdomen. Sites of previous operative intervention will certainly influence the strategy to gain initial access. Optical entry with a 5 mm trocar with or without initial Veress needle insufflation in the left upper quadrant is generally safe. A 12 or 8 mm trocar for the camera is placed in the abdomen in relationship to the other two or three trocars that will be placed in the upper abdomen and considering three or four equal parts to have the best separation between the trocars and avoid collisions.

For hernias located on the left or right lower quadrants the trocars are placed on the contralateral side of the hernia and the same rules mentioned above are followed to avoid collisions and allow suture fixation of the mesh.

Another consideration is the accessory port. The accessory port is used to aid mesh introduction, suture introduction, removal, and cutting. We found that using the accessory trocar for the larger mesh introduction under direct visualization was safer and more efficient than introducing the mesh and sutures through the 12 mm camera port. The accessory port is less useful for the repair of smaller ventral hernias, where the orientation of the mesh and the retraction of the mesh for exposure in suture

placement are less cumbersome procedures. The accessory port location must also be determined in relationship to the da Vinci arms. It is crucial to place the accessory port as far from the defect as possible to allow for increased range of motion and effectiveness. Generally for mid to lower abdominal hernias a supine position and Trendelenburg are sufficient for these patients but for the hernias located in the lateral area of the lower abdomen rotation of the body to the contralateral side is added to the Trendelenburg. Any patient position manipulation required, however, must be performed prior to docking of the robot. The robotic cart is driven directly over the abdomen and in line with the trocar sites.

Final port position for a LLQ hernia



Instrumentation

For right-handed surgeons, a da Vinci (dV) prograsp (or fenestrated bipolar) is placed in arm #2, 12 mm 30° up camera in the camera port, and the dV monopolar scissors are placed in arm #1.

The dV needle drive is used primarily to close the hernia defect as well as affix the mesh to the abdominal wall.

Essential Steps

Adhesiolysis

The essential steps of robotic hernia repair are analogous to that of conventional laparoscopic repair. Adhesiolysis of the abdominal wall to isolate the hernia defect must be performed meticulously. The dV platform facilitates adhesiolysis through its 3-D visualization, tremorless precision, and superior ergonomics. For direct bowel handling, the dV fenestrated bipolar grasper results in less trauma to serosal tissue. It is important to emphasize the loss of haptic feedback when performing robotic surgery. This drawback is overcome by the improved ability to see individual stretch fibers. Special attention is therefore required to prevent inadvertent bowel injury and excessive bleeding by way of atraumatic handling and judicious use of cautery. Clearing the entire abdominal wall of adhesions is mandatory to ensure complete evaluation. In dense adhesions the robotic harmonic scalpel may facilitate hemostasis.

Primary Closure of the Defect

Successful primary closure of the defect is facilitated by the use of the barbed V-loc suture (Medtronic). The ability primarily to close defects without component separation is based on the principles of Ramirez regarding width and location of the hernia defect. Of course this is based on open technique and not working against the forces of pneumoperitoneum. As a general rule, <10 cm wide defects are amenable to primary closure but also depend on body habits and age, being easier to close larger defects in the older population. Desufflating the abdominal cavity to 6–8 mm Hg pneumoperitoneum is often necessary. The suture is introduced into the intra-abdominal cavity through the 8 mm dV trocar. This is facilitated by skeeting the needle facilitating both introduction and removal.

Mesh Placement and Fixation

A tissue-separating mesh is used when placed in the intraperitoneal onlay position. The size of the mesh upholds the principle of maintaining an at least 5 cm overlap in all directions. For larger defects primarily closed under certain tension, a wider mesh is utilized. The mesh is rolled and introduced through the 12 mm camera trocar site or assistant port if using a 12 mm.

There are myriad options and permutations of the technique to secure the mesh to the abdominal wall including reproducing the standard LVHR technique with a combination of tacks and sutures, or securing the mesh to the abdominal wall with circumferential suture fixation [19].

With the mesh positioned on the abdominal wall by using a scroll technique or the self-expanding mesh device (Echo mesh, Bard/Davol), a full-length nonabsorbable suture (00 or 0 prolene ethicon) is introduced into the intra-abdominal cavity

through the trocar of the needle holder. The external end of the suture situated outside the trocar is secured with a hemostat. This technique avoids excessive suture in the intra-abdominal cavity thereby facilitating fixation. In a running fashion, the suture is then placed around the circumference of the mesh. This may be done with one or two sutures in the larger meshes >30 cm.

Upon completion of mesh fixation, the robot is undocked. Only 10/12 mm trocar fascial sites are closed with a suture passer.

Robotic TAPP Ventral Hernia Repair

Exploiting the layers of the abdominal wall is made possible by the precision the dV robot affords [16]. Although possible to do with conventional laparoscopy, working high on the anterior abdominal wall remains technically demanding and ergonomically challenging [20, 21]. Placing mesh in the preperitoneal space obviates the need for a more costly tissue-separating mesh, allows the mesh to incorporate directly on fascia [22] thereby decreasing the need for sutures or tack fixation that cause postoperative pain, and avoids complications inherent with leaving mesh in the intraperitoneal position, that is, bowel erosion or fistula [23, 24].

The robotic TAPP VHR was developed based on the TAPP inguinal hernia repair and involves dissection of the preperitoneal plane, reduction of the hernia sac, primary closure of the defect, placement of mesh with minimal fixation, and reperitonealization of the mesh.

Essential Steps

Patient positioning, trocar placement, docking, and instrumentation are analogous to the above-described procedure. For larger hernias trocars are placed above the umbilicus.

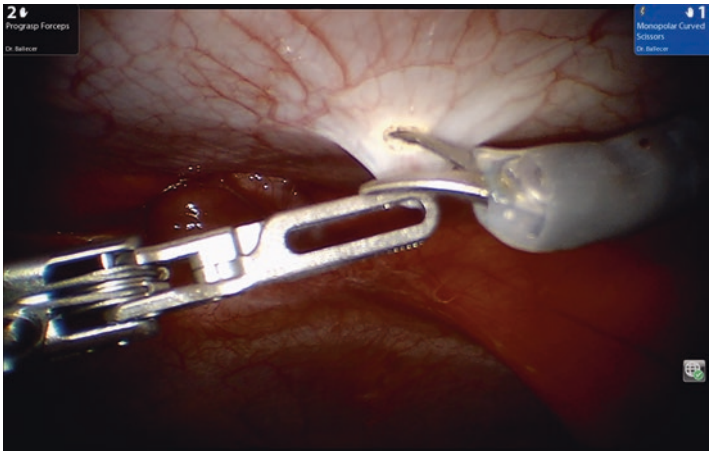
Developing a Preperitoneal Plane

The peritoneum is incised at least 5 cm proximal to the hernia defect. A preperitoneal plane is then developed widely with a combination of blunt and sharp techniques. Care is taken to avoid disrupting the posterior fascia. In the event the posterior fascia is breached and the rectus muscle is visible, it is subsequently closed with suture. The hernia sac is reduced and dissection continues distal to the hernia allowing for placement of an adequately sized mesh. Wide distal dissection allows for the creation of a large flap in which to reperitonealize the mesh completely.

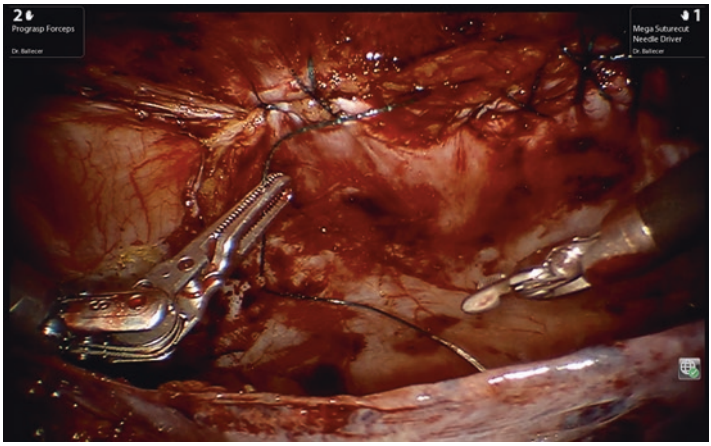
Primary Closure of the Defect

The hernia defect is closed with 0 or 1 V-lock running barbed permanent or long-term absorbable suture (Covidien). Disinflation of the abdominal cavity may need to be employed to facilitate closure.

Peritoneal incision



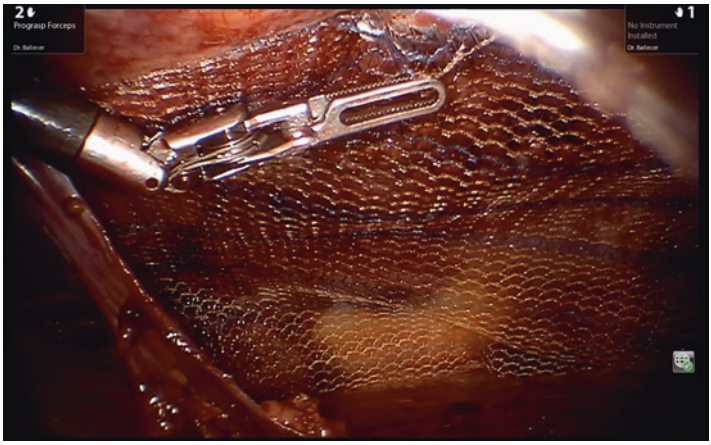
Defect closure after preperitoneal dissection



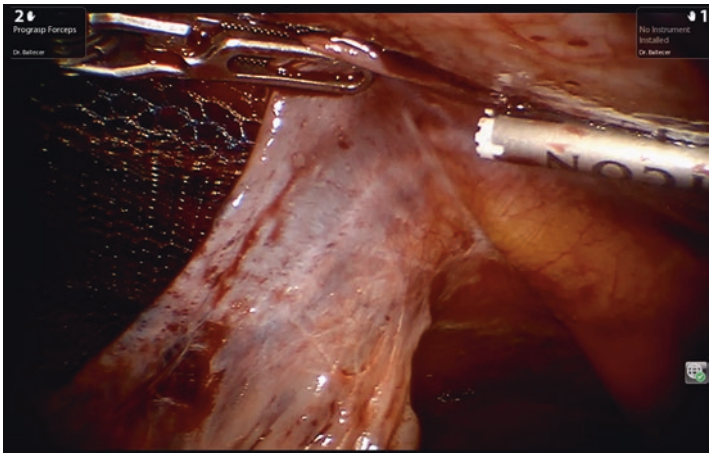
Mesh Placement, Fixation, and Reperitonealization

The mesh is introduced into the intra-abdominal cavity and placed flat on the abdominal wall. A large overlap of the closed defect (5 cm minimum) is ensured. The mesh is secured to the abdominal wall with four absorbable tacks (Securestrap^{tm}, Ethicon) placed at the cardinal points of the mesh or with sutures as per the surgeon's preference. Once adequate fixation and hemostasis are achieved, the peritoneal flap is re-approximated to cover the mesh with a continuous 2–0 PDS running suture.

Mesh fixation in the preperitoneal space



Peritoneal closure with absorbable tacks



Suprapubic Hernias

The challenges of laparoscopic suprapubic hernia repair include the need for mobilization of the bladder, creating a pelvic dissection within the spaces of Bogros and Retzius, and fixating the mesh along the pelvic rim [25]. Robotic preperitoneal repair facilitates bladder mobilization, visualization of the pelvic rim, and creation of a large space to accommodate overlapping mesh that is more evident in recurrent hernias or in patients with previous open prostatectomy.

Patient Positioning, Trocar Placement, and Docking

The patient is placed in a supine lithotomy position. A three-way Foley catheter is placed that is used to distend the bladder for proper identification. The patient is placed in a slight Trendelenburg position.

A 12 mm camera trocar is placed in a supraumbilical location for initial access. The camera port must be at least 15–20 cm from the superior aspect of the hernia defect. Two or three dV 8 mm trocars are placed in line with the camera trocar and the robot is docked in between the legs.

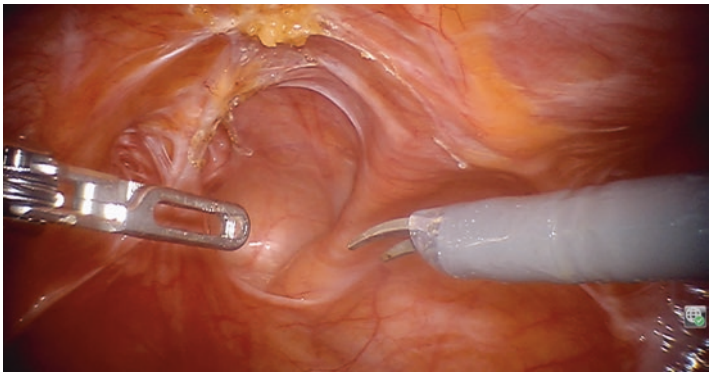
Essential Steps

A preperitoneal plane is incised a minimum of 5 cm cephalad to the superior aspect of the hernia defect. A wide plane of dissection is necessary to accommodate a large sheet of overlapping mesh. The hernia defect is reduced. The superior dome of the bladder may occupy the hernia sac and therefore great care and meticulous dissection is performed to mobilize the bladder safely. This is facilitated by instilling 300 cc of sterile saline into the bladder for easy identification. The retroinguinal space (space of Bogros) is developed bilaterally to expose Cooper's ligament. Caudal mobilization of the bladder reveals the space of Retzius. This space can be dissected inferiorly to ensure adequate overlap of mesh inferior to the caudal aspect of the hernia defect.

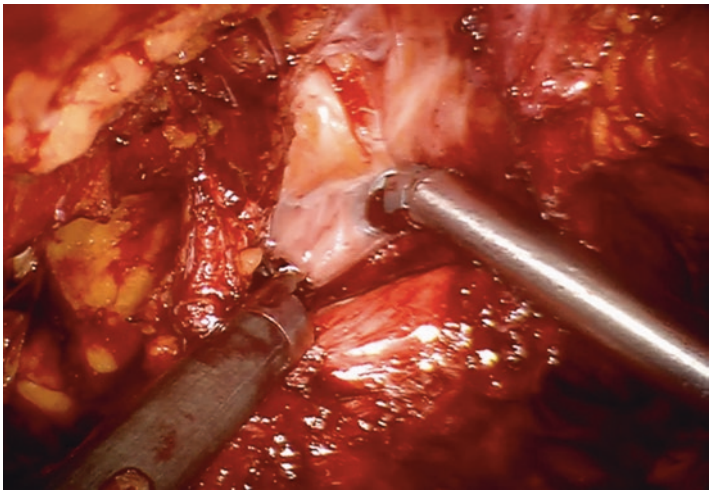
The hernia defect is primarily closed with 0 or 1 V-loc barbed suture (Covidien) as described previously. Partial disinflation of the abdominal cavity may be required to adequately close the defect. The dome of the defect may also be incorporated into the closure in order to obliterate the dead space.

An adequately sized mesh is introduced into the abdominal cavity. Absorbable tacks are placed to secure the mesh to the abdominal wall. 00 or 0 prolene suture is used to secure the mesh to Cooper's ligament bilaterally as well as the symphysis pubis. Upon completion of mesh fixation, the mesh is reperitonealized with 2-0 PDS suture.

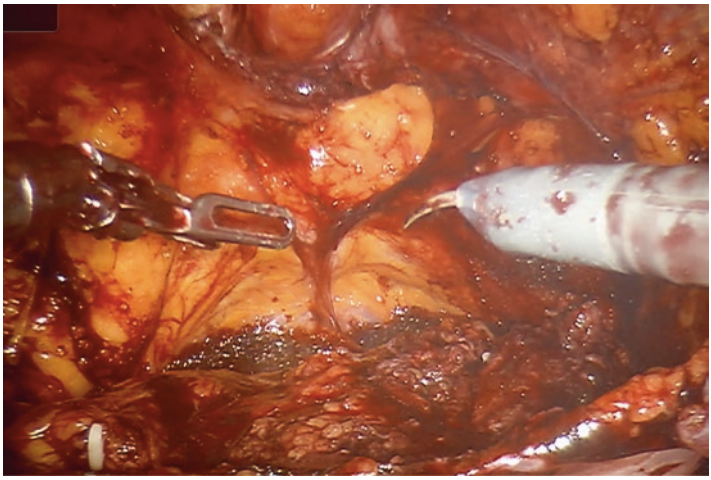
Suprapubic hernia



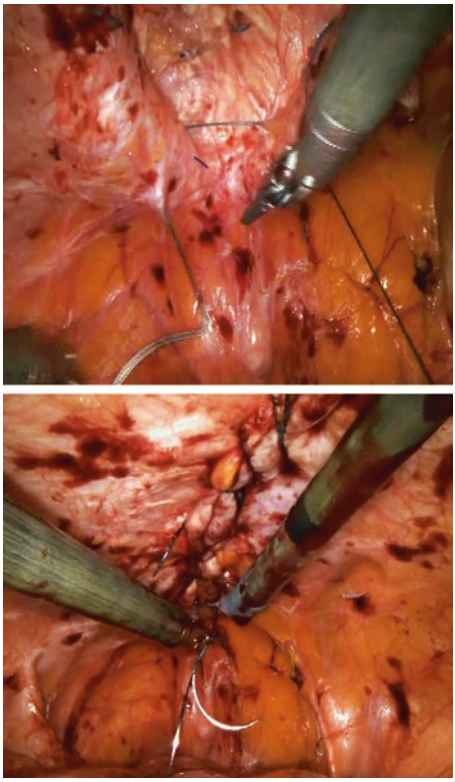
Bladder and inferior margin of hernia defect



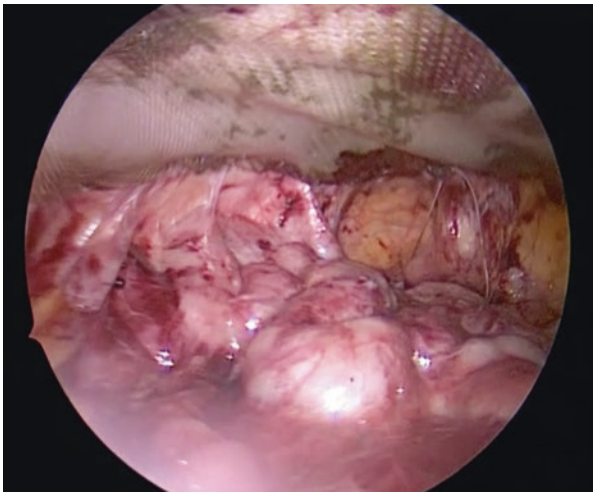
Full dissection of retzius space with bladder mobilization



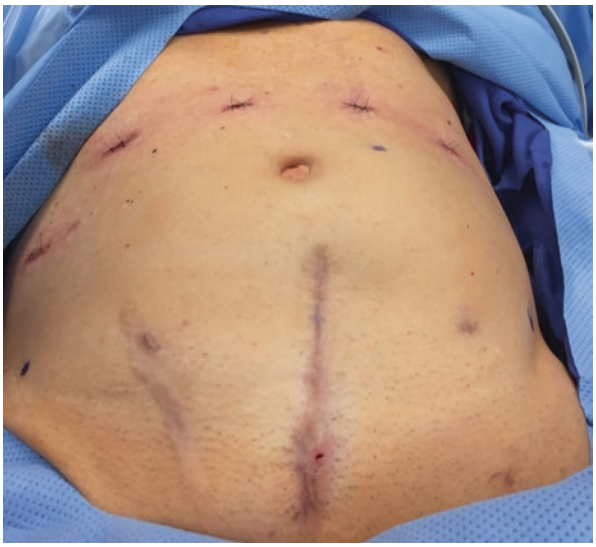
Primary closure of the suprapubic defect



Final aspect of an IPOM mesh in the suprapubic region



Final aspect of closed wounds after a robotic suprapubic hernia repair



Summary

The technique of robot-assisted laparoscopic incisional hernia repair in the lower abdomen with intracorporeal closure of the fascial defect and continuous circumferential suturing for mesh fixation is feasible, reduces wound morbility, allows good mesh overlap and fixation in the retropubic space, and may reduce postoperative pain by eliminating transfascial suture. Further evaluation is needed, and long-term data are lacking to assess the benefit to the patient.

Concluding Remarks

- Clearing the entire abdominal wall of adhesions is mandatory to ensure complete evaluation.
- As a rule, <10 cm wide defects are amenable to primary. Desufflating the abdominal cavity to 6–8 mm Hg pneumoperitoneum is often necessary.
- Placing mesh in the preperitoneal space obviates the need for a more costly tissue-separating mesh, allows the mesh to incorporate directly on fascia, and avoids complications inherent to the method.
- Suprapubic hernias are challenging procedures; robotic repair facilitates mobilization and visualization, and can overcome problems related to recurrence.

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Robotic Ventral Hernia Repair from a Lateral Approach

Conrad Ballecer, Daniela Cocco, and Brian Prebil

Keypoints Summary

- Robotic ventral hernia repair from a lateral approach is suitable for small, medium, and large ventral hernias.
- Robotic transabdominal preperitoneal hernia repair (rTAPP) can be performed from a single-dock lateral approach.
- rTAPP may minimize bowel-associated complications by obviating placement of an intraperitoneal mesh and eliminating the need for full-thickness transfacial suture.
- Robotic transversus abdominis release successfully reproduces a well-established open procedure performed in a minimally invasive fashion.
- Despite the size of the hernia, the success of robotic repair requires adhering to well-established principles of both open and conventional laparoscopic repair.

Introduction

Incisional hernias develop in 2–11% of patients who undergo laparotomy. The incidence of recurrence has been reduced 30–60% after primary repair and 6–10% if prosthetic mesh or patch is used [1]. Despite improvements in recurrence rates, the number of hernia repairs in the United States has increased during the past decade, with an increment of ventral hernia (VH) repairs to 3%/year particularly in the older-adult male population [2, 3].

These numbers parallel the increased interest of surgeons to further the adoption of MIS technique observed in the last decade.

Laparoscopic VH repair (LVHR), compared to an open approach, has been associated with shorter length of stay, earlier return to work, and lower rate of surgical

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R.Z. Abdalla, T.N. Costa (eds.), *Robotic Surgery for Abdominal Wall Hernia Repair*, DOI 10.1007/978-3-319-55527-0_5

site infections with similar recurrence rates and postoperative pain between the two techniques [4].

Robotic hernia repair is an emerging laparoscopic technique born from well-established principles set by open and conventional laparoscopic techniques. Its growing popularity in the United States is often attributed to enhanced 3D visualization, precision, and enhanced surgeon ergonomics. Inherent limitations of conventional "straight-stick" laparoscopy make operating high on the anterior abdominal wall difficult.

The robotic platform also enables exploitation of the individual layers of the abdominal wall. Virtually any well-established surgical plane of the abdominal wall can be exploited and dissected for the subsequent placement of mesh in a preperitoneal, retromuscular, and even onlay position, effectively protected from the visceral cavity by the body's own autologous tissue. Although this approach has been demonstrated with conventional laparoscopy, it remains technically challenging [5].

Recent data [4, 6] showed that when compared with the laparoscopic approach, the robotic retromuscular repair enables true abdominal wall reconstruction and obviates the need of an intraperitoneal mesh (IPOM) that has been associated with serosal adhesions and intestinal erosions that can complicate subsequent abdominal operations [7, 8].

Inspired by the robotic retromuscolar VH repair first described by Adballa et al. [9], in this chapter the authors introduce robotic ventral hernia repair from a lateral approach for both robotic transabdominal preperitoneal (rTAPP) repair and robotic transversus abdominis release (ROBOTAR) as a new armamentarium in the treatment of VHs.

The robotic VH repair from a lateral approach is suitable for small to medium hernias <6 cm wide as well as large hernias with mid-abdominal wall defects measuring between 8 and 15 cm wide. Advantages of the lateral approach include better visualization and access to the entire anterior abdominal wall while maintaining the familiar established technique of the conventional LVHR,

Robotic Transabdominal Preperitoneal (rTAPP) Hernia Repair

Surgical Anatomy

A clear understanding of the layers of the abdominal wall is imperative to execute this technique properly. The basic principles of the rTAPP ventral hernia repair are based on the conventional laparoscopic TAPP technique for inguinal hernias in which (1) the peritoneum is incised and dissected off the transversalis fascia, (2) the hernia sac is reduced, (3) and a mesh is placed within this retroinguinal space. For hernias of the anterior abdominal wall, the peritoneum is dissected from the posterior sheath, the hernia sac is reduced, and a large space is opened to accommodate well-overlapping mesh. The size of the preperitoneal mesh is based on the original size of the defect adhering to well-established principles of maintaining a minimum 4–5 cm overlap in all directions.

This approach is best suited for smaller or medium-size hernias (<5–6 cm) that do not require component separation in order to reconstitute the linea alba. It can also be readily adapted to repair hernias in atypical locations such as flank, suprapubic, retrosternal, and subxiphoid defects.

The authors propose three major advantages to placing mesh in a preperitoneal position:

1. It eliminates the requirement for placing more costly coated intraperitoneal mesh.
2. The mesh incorporates on both sides, eliminating the need for full-thickness transfacial suture fixation which is associated with both acute and chronic postoperative pain [10, 11].
3. It minimizes bowel-associated complications when leaving mesh in an intraperitoneal position, that is, adhesions and bowel fistula.

Preoperative Considerations

A thorough history and physical is mandatory to formulate and execute an effective preoperative plan. Specifically, certain comorbidities, such as diabetes, obesity, smoking, prior abdominal surgeries including hernia repairs, and prior history of abdominal wall infection may critically affect the operative approach as well as the risk/benefit ratio for surgical intervention versus watchful waiting.

Many primary umbilical hernias detected on the physical exam warrant no preoperative further work-up. CT scan of the abdomen and pelvis may be ordered for atypical hernias or small to moderate incisional hernias in order to diagnose and delineate correctly the size, position, and content of the hernia sac.

Patient Prep and Positioning

Standard operative protocols are utilized including SQIP antibiotic dosing, body hair clipping, and placement of sequential compression devices. The patient is positioned supine with arms tucked at the sides. In patients with small torsos, it is helpful to position the patient under the kidney rest at the level of the umbilicus (Fig. 1). The patient is strapped securely to the bed to allow for Trendelenburg tilting and lateral rotation of the table. After obtaining safe intraperitoneal access, the kidney rest is raised which increases the distance between the costal margin and the anterior superior iliac spine. This allows for port placement with adequate separation to prevent robotic arm collision. Patient positioning should be finalized prior to docking of the robot. Foley catheterization is not generally required unless the surgeon expects a prolonged case or the hernia defect extends to the lower abdomen.

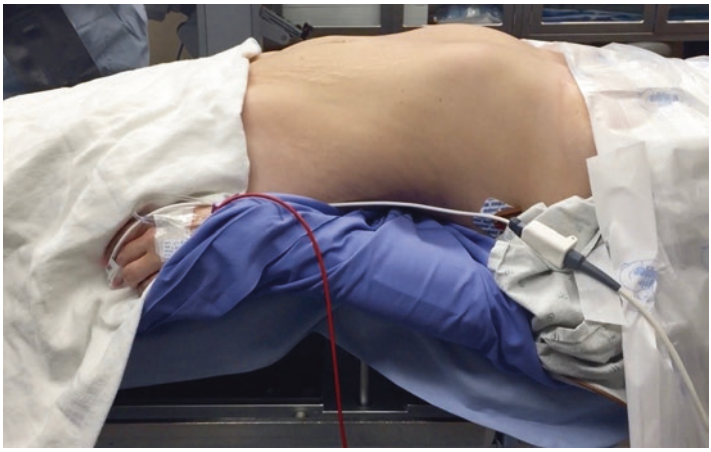

Fig. 1 Kidney rest positioning

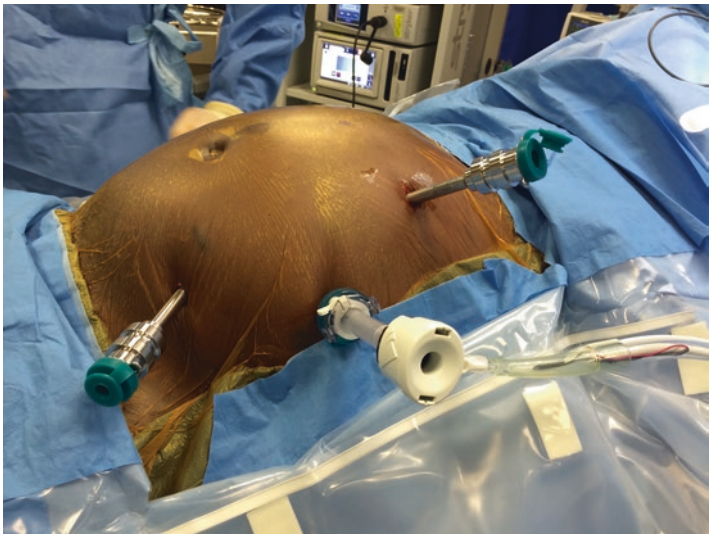

Fig. 2 rTAPP port position

Port Positioning, Docking, and Instrumentation

The ports are positioned with the established principles of triangulation similar to conventional LVHR (Fig. 2). It is important to place the trocars as far from the defect as possible without sacrificing range of motion based on potential collisions with the upper and lower extremities.

As in any minimally invasive surgery, the first step is to gain safe intra-abdominal access which may be difficult in the reoperative abdomen. Sites of previous

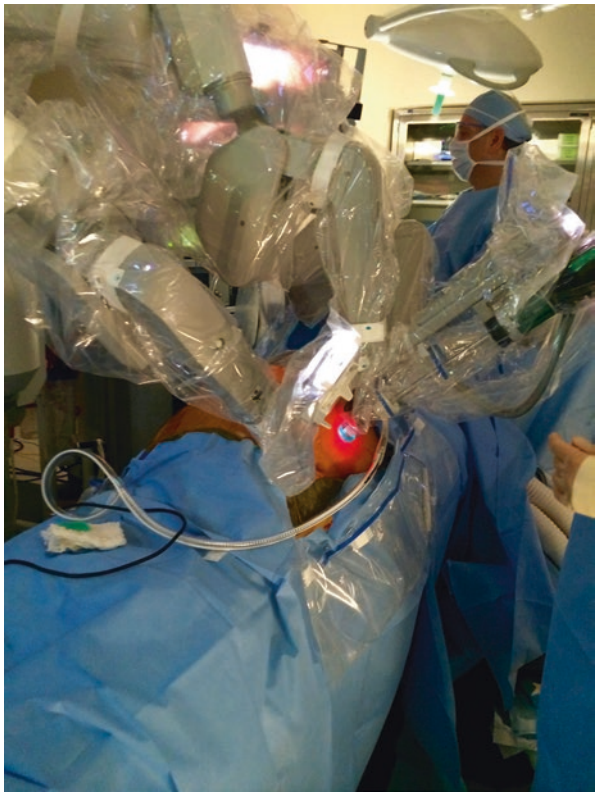

Fig. 3 rTAPP docking for midline abdominal wall hernias

operative intervention will certainly influence the strategy. Optical entry with a 5 mm trocar at Palmer's point with or without initial Veress needle insufflation in the left upper quadrant is generally safe.

A 12 or 8 mm trocar for the camera is placed as far lateral to the ipsilateral edge of the defect. As a general rule we place the camera trocar a minimum of 15 cm away from the ipsilateral edge of the hernia defect. This allows for visualization, dissection, and instrumentation on the side closest to the ports. An 8 mm robotic trocar is placed in the lower lateral abdomen and the initial 5 mm optical trocar is then replaced with an 8 mm trocar. Final configuration of the trocars for an SI robot are typically in a V configuration (Fig. 2). Additional trocars on the contralateral abdomen or an assist trocar are typically unnecessary, but this may vary depending on surgeon comfort.

Following port placement and satisfactory patient positioning, the robot is docked directly over the lateral abdomen and in line with the trocar sites (Fig. 3). Instrumentation includes a grasper, monopolar scissors, and a needle driver. A 30° up scope is used to begin the case and may need to be switched to a 0 or 30° down when progressing to the contralateral abdomen.

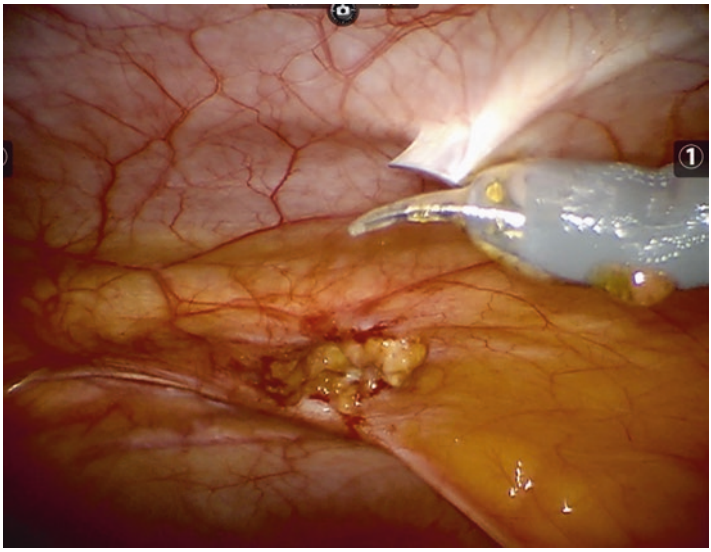

Fig. 4 Peritoneal incision

Adhesiolysis and Developing a Preperitoneal Plane

As with conventional laparoscopy, the anterior abdominal wall is meticulously cleared of all adhesions to delineate the full extent of the defect as well as uncover any other sites of herniation. Care must be taken to avoid not only injury to intraperitoneal viscera, but also to avoid injury to the peritoneum which may complicate preperitoneal dissection. If bowel manipulation is required, a lower grip strength grasper is utilized to avoid iatrogenic serosal injury.

Starting a minimum of 5 cm from the edge of the defect, the peritoneum is incised using scissors (Fig. 4). This will allow for the placement of mesh with a minimum of 5 cm overlap on the side ipsilateral to the working ports. Ideally, the incision is often made within the visible preperitoneal fat that underlies the rectus muscle. The plane of dissection is more readily entered in this manner without causing disruption of the overlying posterior sheath. The preperitoneal plane is developed widely in a cephalad to caudad direction with a combination of meticulous blunt and sharp dissection. Sweeping with the blunt edge of the scissors is an effective technique to separate the peritoneum from the posterior sheath. Cautery is sparingly applied to avoid thermal injury that may result in peritoneal defects. The hernia sac is reduced and further dissection continues laterally (Fig. 5). Wide preperitoneal dissection is performed to allow for the placement of a large mesh based on the original size of the defect (Fig. 6a, b). If the preperitoneal space is deemed inaccessible, the procedure may be converted to placement of an intraperitoneal coated mesh subsequent to primary closure of the defect.

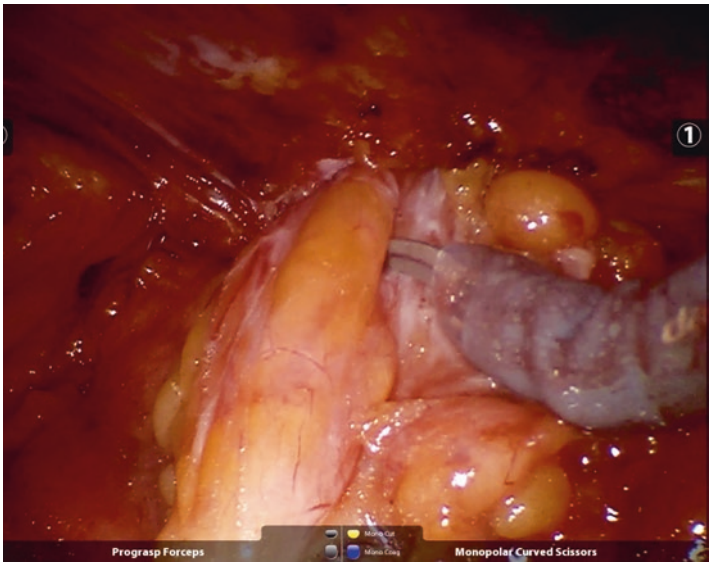

Fig. 5 Reducing the hernia sac

Primary Closure of Defect

After the preperitoneal space is widely dissected, the hernia defect is primarily closed with absorbable suture (Fig. 7a, b). In order to minimize operative time, the author prefers to use knotless barbed suture in a running fashion. The subcutaneous tissue situated at the dome of the defect is incorporated within the primary closure. This effectively obliterates the anterior dead space minimizing the risk of seroma formation. This technique also minimizes the risk of postoperative skin bulging. Desufflation of the abdominal cavity to a pressure of 6–8 mm Hg may facilitate primary closure and linea alba restoration.

Mesh Placement, Fixation, and Reperitonealization

An appropriately sized uncoated mesh is introduced into the abdominal cavity via the 8 mm trocar. The mesh is placed flat against the abdominal wall and fixated with either tacks or sutures placed at cardinal points (Fig. 8a, b). A minimum of fixation points is used to accomplish flush approximation of mesh against the abdominal wall.

Following adequate fixation, the peritoneum is reapproximated to cover the mesh completely with either running suture or tacks (Fig. 9a, b). Peritoneal rents should be repaired to prevent bare mesh exposure to the visceral content. The fasciae for all 10 mm or greater trocar sites are closed with absorbable suture under direct vision.

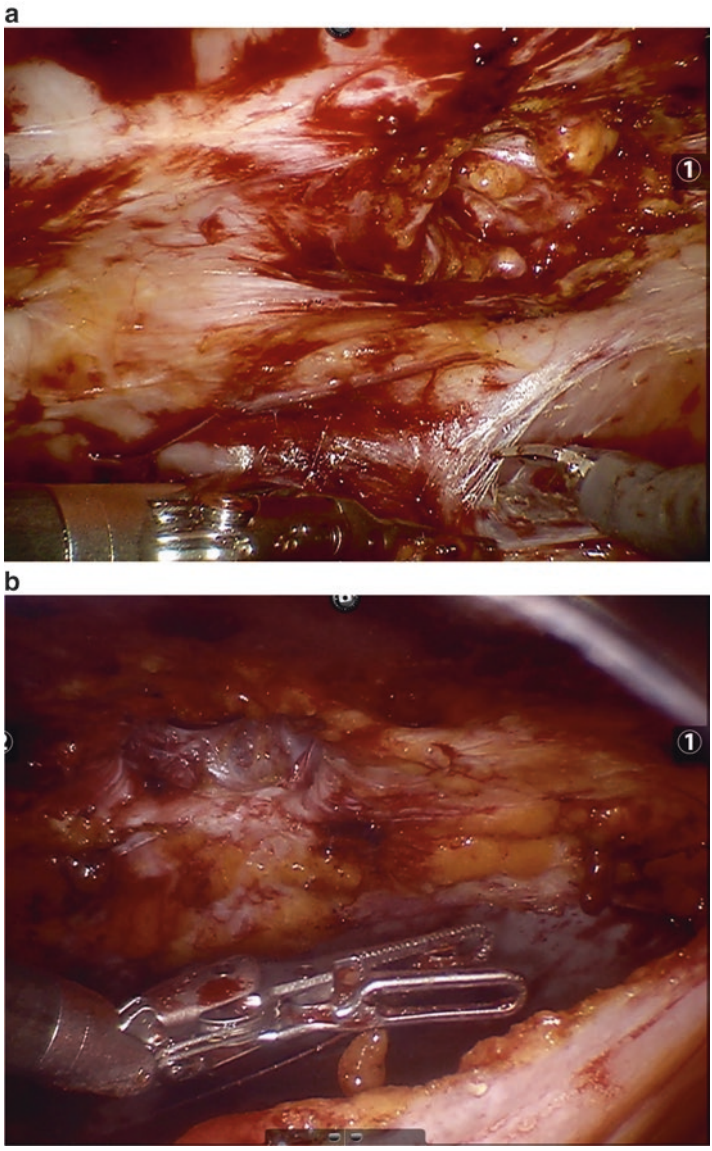

Fig. 6 (**a**, **b**) Preperitoneal dissection

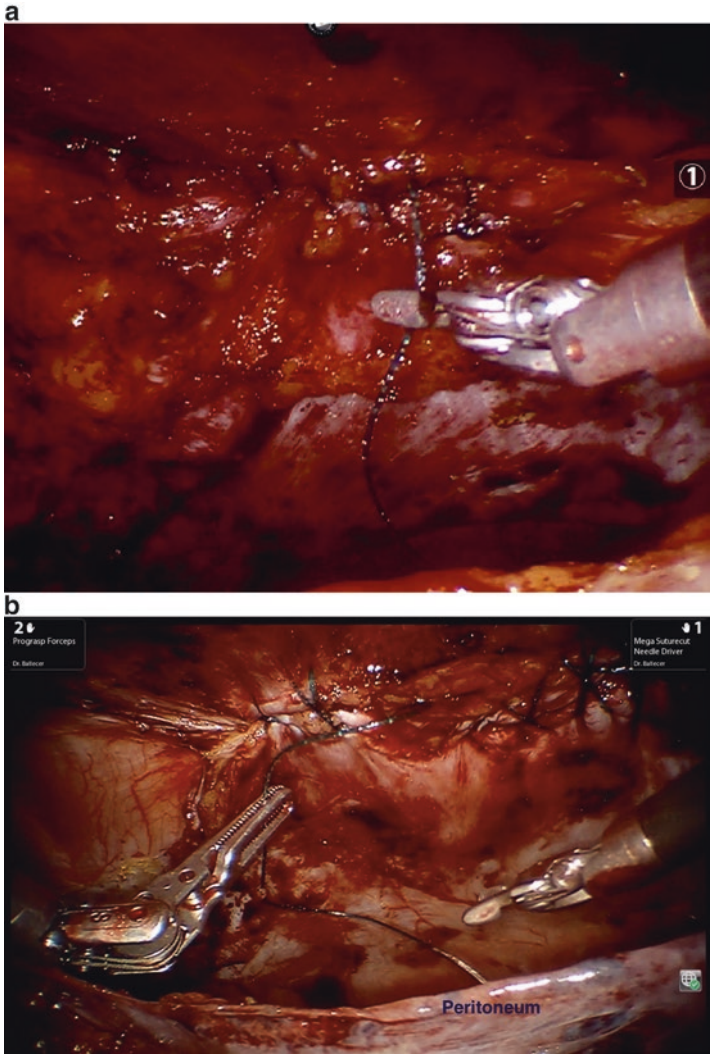

Fig. 7 (**a**, **b**) Primary defect closure

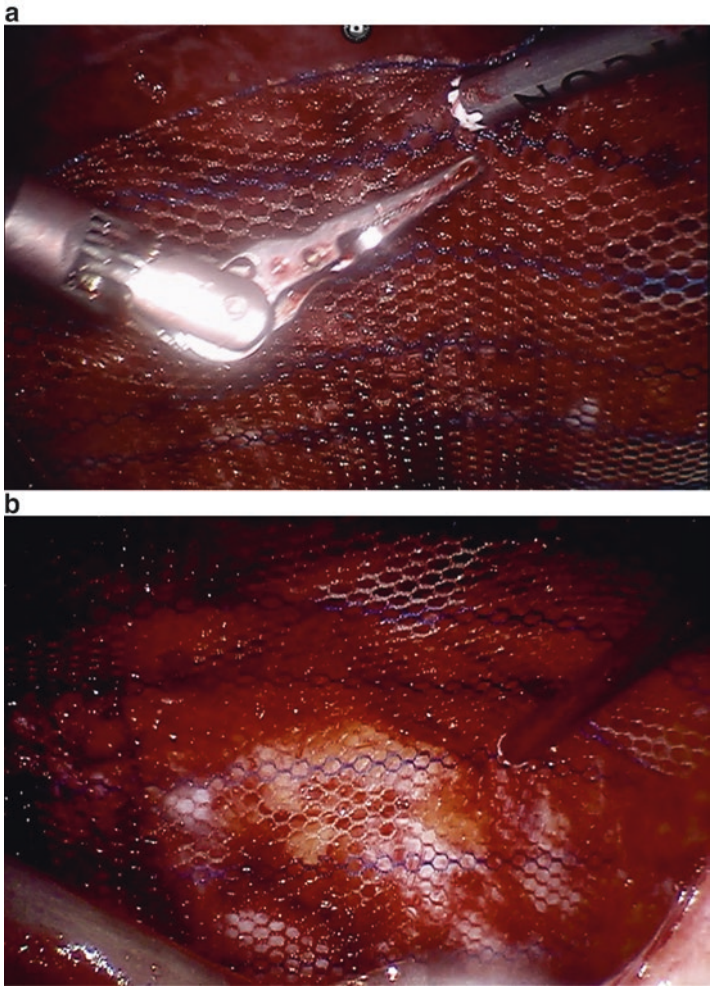

Fig. 8 (**a**, **b**) Mesh placement and fixation

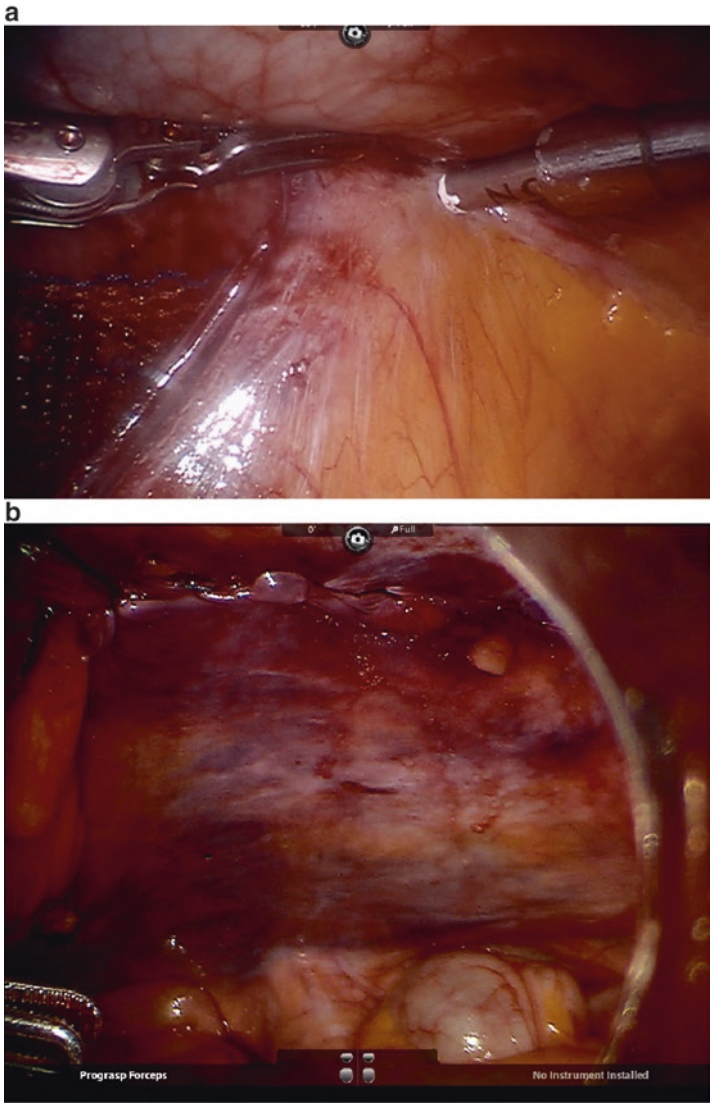

Fig. 9 (**a**) Tack reperitonealization of mesh; (**b**) suture reperitonealization of mesh

Robotic Transversus Abdominis Release (ROBOTAR)

Preoperative Considerations

Robotic retromuscular hernia repair employing the transversus abdominis release for posterior component separation requires an extensive knowledge of the individual layers of the abdominal wall. Hernia repair by way of abdominal wall reconstruction and component separation should be highly regarded as the ultimate

definitive repair for large hernias. Therefore, it is mandatory that surgeons performing ROBOTAR are not only experienced in the open counterpart, but also well experienced on the robotic platform.

Benefits of MIS TAR include:

1. Posterior component separation technique without creation of large lipocutaneous flaps.
2. Significant myofascial release to restore the linea alba.
3. Creation of a large space unencumbered by the linea semilunaris for a giant prosthetic reinforcement of the visceral sac (GPRVS).
4. Patients may experience the benefits of MIS including decreased length of stay and postoperative pain, and earlier return to work.

Obtaining a thorough history and physical is mandatory to coordinate an operative plan. Specifically, comorbidities such as diabetes, obesity, smoking, and collagen vascular disease may critically affect the operative plan. A CT scan of the abdomen and pelvis is critical to preoperative planning. This imaging modality can delineate the size and location of the hernia defect, the content of the hernia sac, and possibly the position of previously placed mesh. The most suitable candidates for ROBOTAR include patients with mid-abdominal wall defects measuring between 8 and 15 cm wide. Factors such as body habitus and abdominal wall compliance must be taken into account during preoperative evaluation. Indications for ROBOTAR also include patients with lateral defects such as ostomy site hernias which require overlap beyond the level of the linea semilunaris.

Factors that preclude ROBOTAR include hernias with associated loss of abdominal wall domain, defects that extend from flank to flank, and significant dystrophic or ulcerated skin requiring excision.

Patient Positioning, Trocar Placement, and Docking

For the majority of patients with large defects in the midline, supine positioning with the arms tucked is preferred, unless trocar access to the lateral abdomen is obscured in which case the arms are situated at a 90° angle relative to the trunk. Trocars are placed in the lateral abdomen similar to conventional laparoscopic repair. The robot is docked over the contralateral abdomen (Fig. 10).

Posterior Sheath Mobilization

After safe adhesiolysis the extent of the hernia defect is evaluated and the rectus abdominis muscle is identified. It is generally not necessary to dissect the hernia sac unless this tissue will be necessary to augment closure of the posterior sheath. The retromuscular space is accessed by incision and subsequent mobilization of the posterior sheath from the overlying rectus abdominis muscle (Fig. 11). Below the

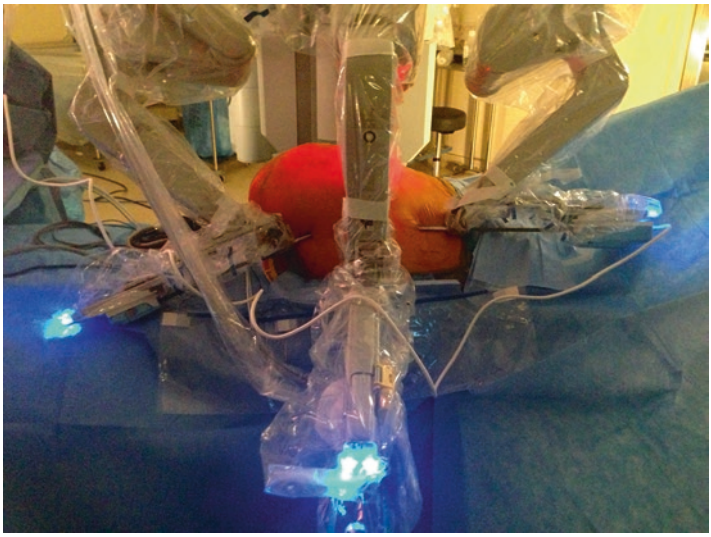

Fig. 10 TAR docking

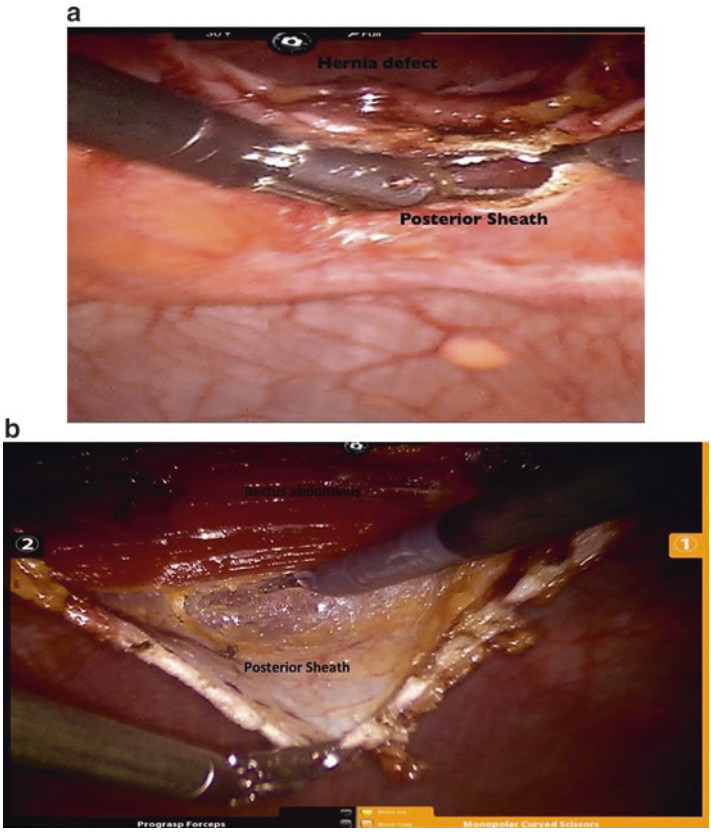

Fig. 11 (**a**) Incision of posterior sheath, (**b**) Mobilization of posterior sheath

arcuate line, the peritoneum and transversalis fascia are mobilized in a similar fashion. The degree of cranial-caudal dissection is based on the size of the defect, assuring a bare minimum of 5 cm overlap. It is important to note the degree of cranial-caudal dissection is based on the extent of the previous midline incision that is completely reinforced often mandating inferior dissection into the space of Retzius and superior dissection to the level of the central tendon of the diaphragm.

Transversus Abdominis Release

Posterior sheath dissection is carried out laterally to the level of the linea semilunaris. The neurovascular bundles serving the rectus abdominis muscle are exposed and preserved (Fig. 12). In the upper third of the abdomen, the posterior lamella of the internal oblique is incised thereby exposing the medial insertion of the transversus abdominis muscle on the posterior sheath (Fig. 13). The transversus abdominis muscle is then divided along the cephalo-caudal extent of posterior sheath mobilization (Fig. 14a, b). In the lower abdomen the transversus muscle is replaced by fascia which is divided, accordingly. Meticulous division of the transversus muscle will expose the transversalis/peritoneal layers which are dissected and mobilized off the abdominal wall. Adequate dissection is achieved when the posterior sheath lays flat over the visceral content (Fig. 15). Peritoneal defects are closed with absorbable suture.

Initial Deployment and Fixation of Mesh, Placement of Trocars on the Contralateral Abdomen, and Redocking

The cranio-caudal extent of dissection is measured as is the distance between the extent of flank dissection to the midline. These measurements are utilized to choose an appropriately sized mesh that is deployed into the retromuscular space (Fig. 16a, b). The scrolled mesh is then fixated with sutures or tacks along the posterolateral abdominal wall.

The robot is undocked and under direct vision, mirror image trocars are placed on the contralateral abdomen (Fig. 17). The trocars are placed above the posterior sheath as well as the mesh. The patient is rotated and the robot is redocked. The daVinci Xi has the ability to rotate around a vertical axis, thereby eliminating the requirement of rotating the patient.

Contralateral Dissection

Contralateral dissection and symmetrical TAR dissection is performed as described. The initial trocars placed ultimately reside in the retromuscular space. Retroxiphoidal or retropubic dissection is performed as indicated to achieve sufficient overlap of the hernia defect and any previous midline incision (Fig. 18a, b). Completion of adequate TAR dissection is confirmed when the two leaves of the posterior sheath rest flat against the abdominal viscera and can be reapproximated without undue tension (Fig. 19).

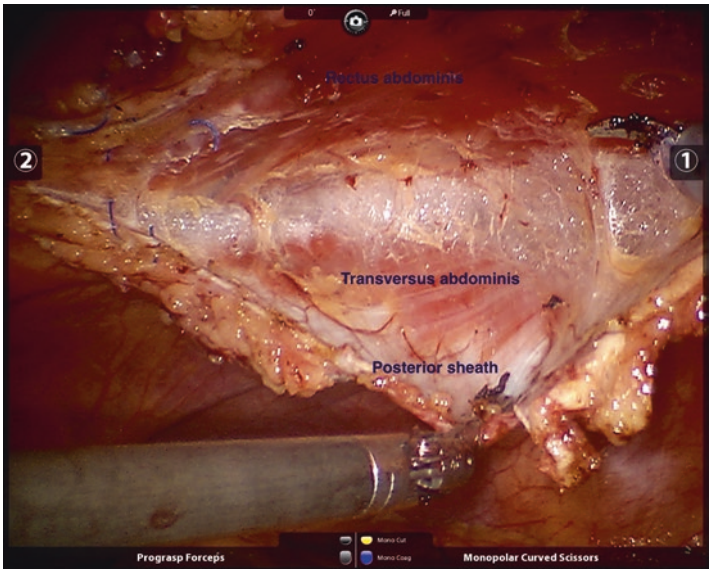

Fig. 12 Exposure and preservation of the neurovascular bundles

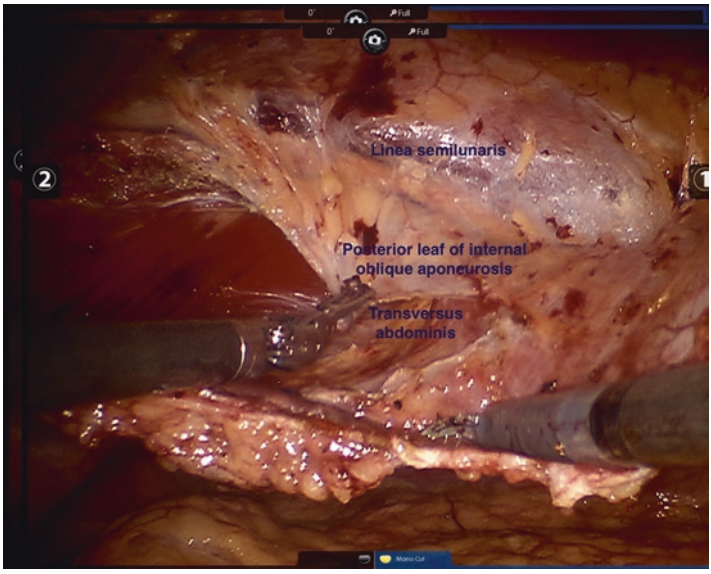

Fig. 13 Exposure of transversus abdominis

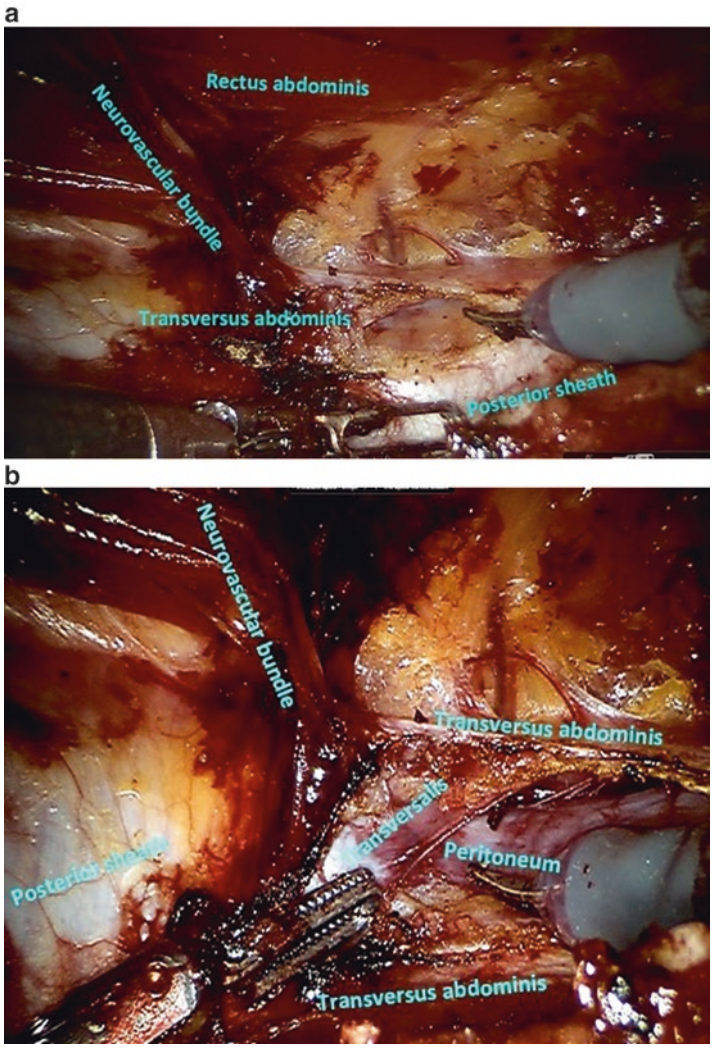

Fig. 14 (**a**) Division of the transversus abdominis, (**b**) division of the transversus

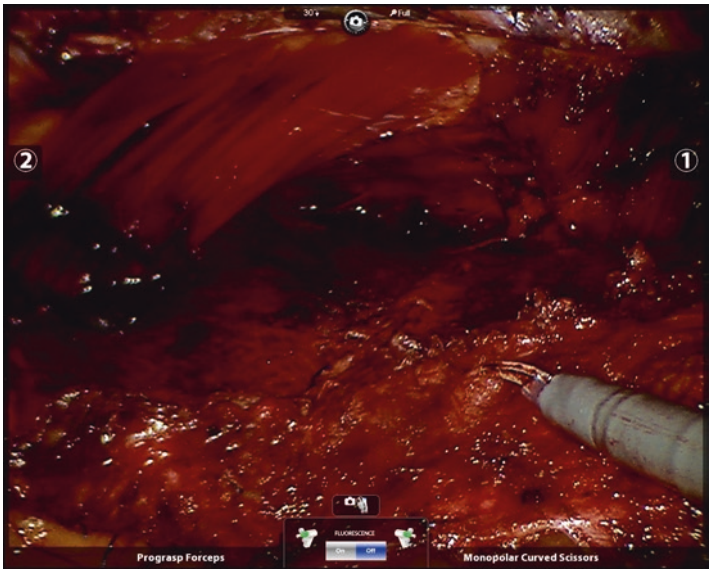

Fig. 15 (**a**, **b**) Final posterior sheath mobilization

Closure of the Posterior Sheath, Final Deployment of Mesh, and Restoration of the Linea Alba

Running suture is used to reapproximate the posterior sheath. Utilization of barbed suture may facilitate reapproximation (Fig. 19a, b). Any peritoneal defects are closed with absorbable suture. The previously placed mesh is unscrolled and secured to the abdominal wall using tacks or sutures (Fig. 20). The anterior fascia is reapproximated with barbed suture (Fig. 21a, b). Closure is facilitated by reducing the level of pneumoperitoneum to between 6 and 8 mm Hg. After the linea alba is restored and the rectus is returned to the midline, retromuscular drains are placed under direct vision through one of the available ports. All 10–12 mm trocar sites are closed with suture.

Concluding Remarks

- The robotic platform offers many options to provide a minimally invasive hernia repair for their patients.
- The learning curve of robotic ventral hernia repair must be respected, however. Surgeons should not be under the illusion that the robot will enable them to perform complex abdominal wall hernia repairs without being facile on the robotic platform as well as experienced with the open equivalent.

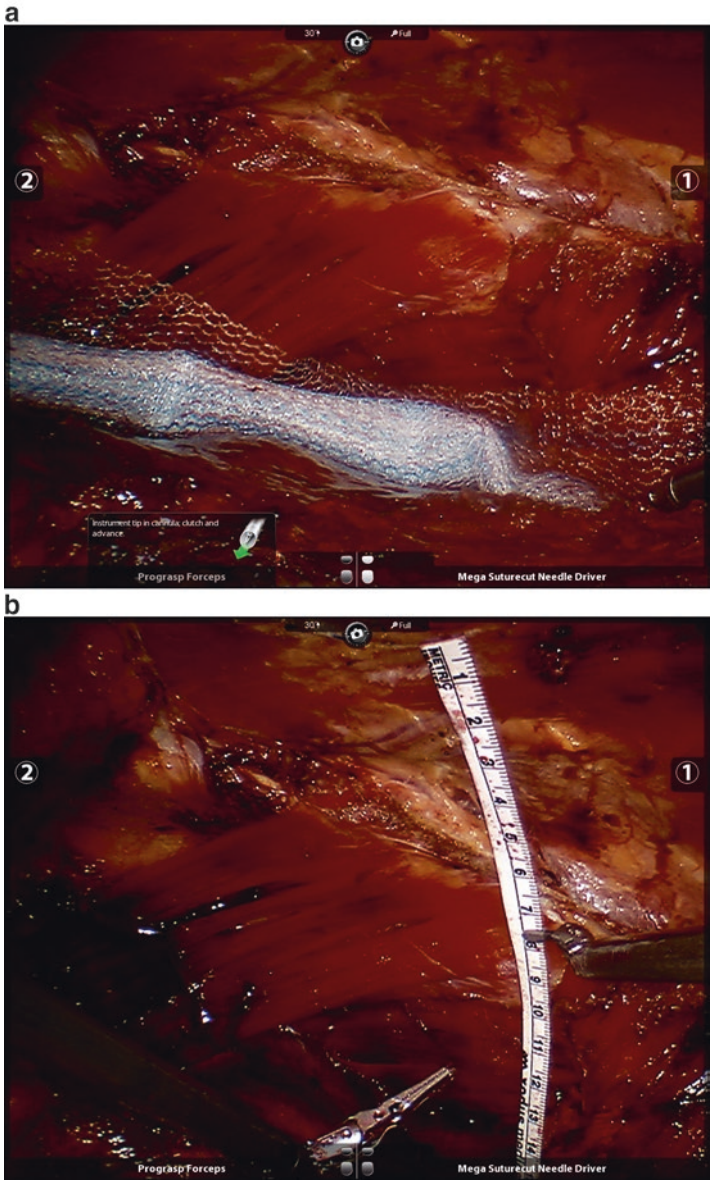

Fig. 16 (**a**, **b**) Measurement and initial deployment of mesh

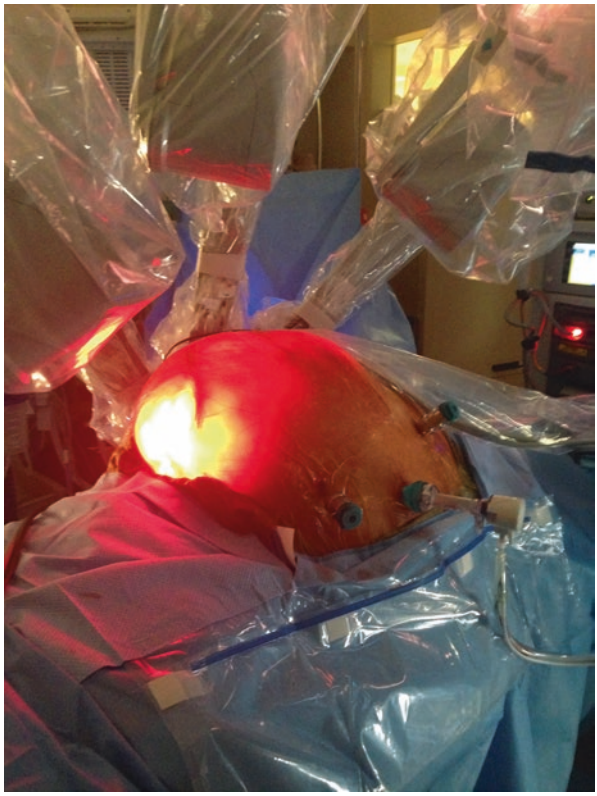

Fig. 17 Redocking with contralateral trocars

- The technical success of robotic ventral hernia repair is dependent upon adhering to well-established principles of both open and conventional laparoscopic repair. This includes but is not limited to careful lysis of adhesions, primary closure of defects without undue tension, and sufficient overlap of reinforcing mesh.
- Mesh size is chosen based on the original size of the defect including adequate 5 cm minimum overlap of the patient's previous incision.

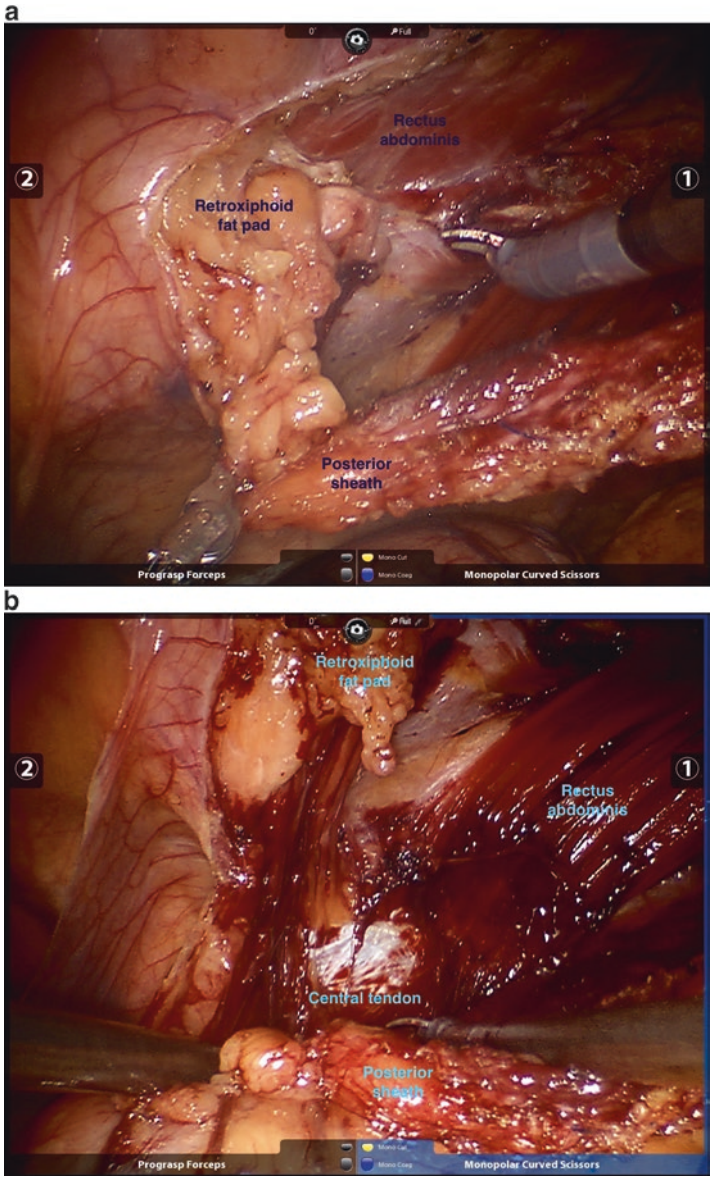

Fig. 18 (**a**, **b**) Retroxiphoidal dissection

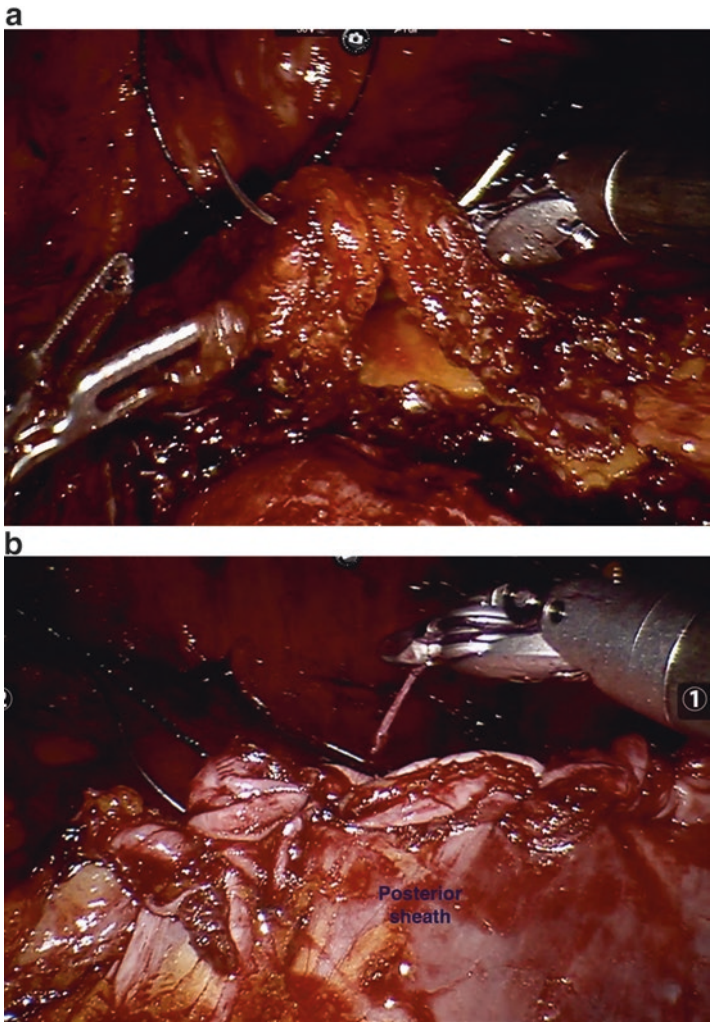

Fig. 19 (**a**, **b**) Closure of the posterior sheath

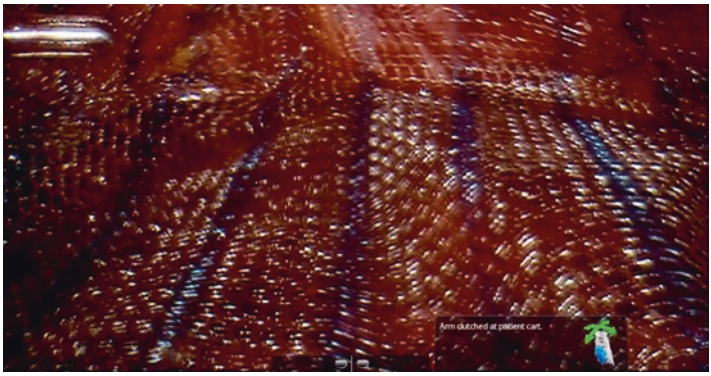

Fig. 20 Final mesh placement

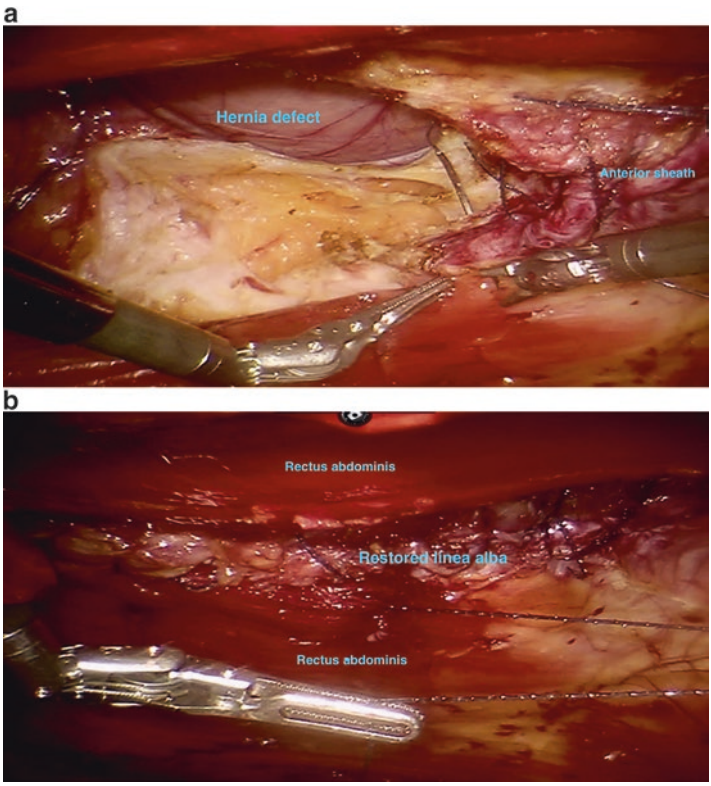

Fig. 21 (**a**, **b**) Closure of the anterior sheath

Glossary

Robotic transabdominal preperitoneal (rTAPP) hernia repair Robotic intraperitoneal approach by which the peritoneum is dissected from the posterior sheath, the hernia sac is reduced, and a large space is opened to accommodate well-overlapping (4–5 cm) mesh

Robotic transversus abdominis release (ROBOTAR) A posterior component separation technique by which the transversus abdominis muscle and fascia are divided within the posterior rectus sheath to release the lateral abdominal wall and allow midline fascia closure as well as placement of a large prosthetic unencumbered by the linea semilunaris

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Parastomal and Lateral Defects

Ricardo Z. Abdalla, Thiago Nogueira Costa,
and Cassio Eduardo Silva Gontijo

Keypoints Summary

- Robotic-assisted video surgical hernia repair in cancer patients post cancer procedure is feasible and safe.
- Cancer patients after cancer treatment with hernia and pain can control the last two through robotic-assisted video surgery.
- Robotic-assisted video surgery minimizes complications on adhesiolysis.
- Recovery after minimal invasive hernia surgery is faster and easier in cancer patients after cancer treatment.
- Despite classification and localization of abdominal wall hernia, including diaphragm and perineal, robotic-assisted video surgery can bring technical facilities never considered before in this kind of disease.

Introduction

Hernia repair (herniorraphies) were performed by open surgery and simple suture in the past, presenting recurrence rates out of 46–100% [11], depending on different situations [12]. The prostheses' arrival in this field took the recurrence down to 7% and 18% [13].

Electronic Supplementary Material: The online version of this chapter (doi:10.1007/978-3-319-55527-0_6) contains supplementary material, which is available to authorized users.

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R.Z. Abdalla, T.N. Costa (eds.), *Robotic Surgery for Abdominal Wall Hernia Repair*, DOI 10.1007/978-3-319-55527-0_6

LeBlanc and Booth described a novel technique with the laparoscope using mesh bridging the defect with good results [14, 15]. The laparoscopic technique has several advantages over traditional open surgery, such as shorter hospital stay, significant wound complication reduction, less surgical site infection, less normal tissue dissection, and sometimes a better defect understanding. Laparoscopic small incisions, robotic-assisted or not, are well accepted to have less possibility to develop new incisional hernias. Usually they are three in number but could be more depending on the defect and reconstruction.

Lateral defects must be studied before the procedure, when a stoma is presented or not. Tomography is very important to preview anatomy and anticipate the surgical method [16, 17]. A laparoscopic view is new and powerful information to see the defect from its origin, from the inside, and repair it in a better way.

Parastomal hernias are normally combined with other defects, around the stoma, or in the midline, between partially disrupted flat muscles, and they can have attached small bowel that is difficult to recognize or differentiate from adhesions [11]. Technical principles begin with completed adhesiolysis all around or between bowels. It should have the left colon isolated in the stoma and it should be parietalized, to push it against the anterior/lateral wall. A big piece of intraperitoneal mesh is left over this bowel covering the whole area regarding all weaknesses and defects around the ending of the stoma. The mesh must be anchored by sutures or double crown staples [18].

Problem Evaluation

The patient evaluation must consider a wound ostomy care nurse to significantly benefit before reconstruction. These common issues are not always brought to the attention of the surgeon, and patients suffer without proper guidance or access to readily available resources [19].

Considering the combination between bowel and abdominal wall functionality, the robotic laparoscopic arms can perform better. The preparation of the abdominal wall must be broad, regarding preoperative muscle relaxation [20–23]; eventually new marks for stoma repositioning and total abdomen computed tomography [24] are necessary for anatomical study and surgery success. Thus, maximizing the time before surgery for patient education and preparation becomes more crucial. An intensive protocol with multidisciplinary staff beyond the conventional methods, preoperative abdominal wall preparation, and robotic-assisted minimal invasive surgery can improve patient and abdomen physiology recovery.

Material and Methods

Operative Room and Team Setup

The patient is positioned over the table with the complete abdomen well exposed. He should be in a horizontal position, with both arms alongside. The surgeon stays

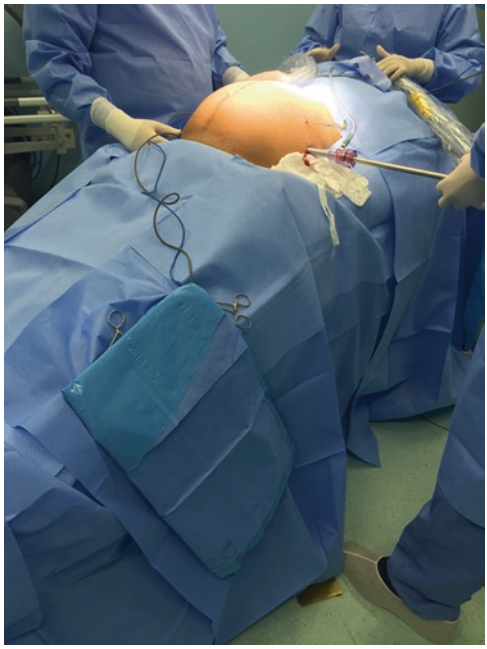

Fig. 1 Patient's positioning and wide exposition of the abdominal wall

on the opposite side of the ostomy or the lateral hernia and the first assistant stays behind the surgeon's left or right depending on the necessity of holding the robot camera at the beginning of the procedure. The monitors in the room must cover all around the patient—cephalad, feet, left and right areas—because of this first understanding where to enter with the arms, in order to stay far from all possible or obvious adhesion areas. At this time the surgeon can change positions to work comfortably, facing the monitors for other trocar planning positions. Bladder catheterization is important before the procedure begins, for trocar placement or for further inguinal or retropubic dissection. The table has a small 15° Trendelenburg, with slide contralateral turn from the ostomy/lateral hernia, towards the surgeon. The patient must be well stabilized and secured, fixed on the table with appropriate techniques from the beginning (Fig. 1).

Operative Technique

Parastomal

The same operative steps as incisional laparoscopic hernia already described are carried out, but with some differences regarding extreme care in the presence of the exteriorized bowel well fixed in abdominal wall layers. Sometimes it is difficult to differentiate what is adhesion and what is the correct bowel to be left in place. Some bowel lesions could occur close to the ostomy, at this time.

Abdominal gas insufflation should follow the Palmer's point needle entry, as described in other chapters [25, 26]. The blind insertion of a Veress needle must be

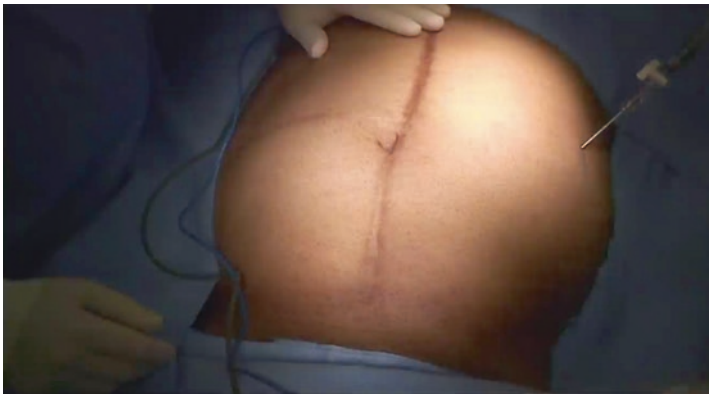

Fig. 2 Pneumoperitoneum by the Veress needle

preferred at this point, right subcostal, 2 cm below the costal margin, to create the pneumoperitoneum (Fig. 2). No specific technique has been shown to be superior in preventing vascular and visceral complications [27]. Optical trocars combine the advantages of the different entry techniques. An optical trocar provides a safe and feasible primary insertion method for laparoscopy in patients prone to access injuries. This is not always possible because of the size of the trocar and the robotic optics and a spare video set is necessary for that procedure. The optics' camera is attached to the optical trocar to allow the view of every layer's progress during this first insertion. This entrance should be at least 20 cm far from the stoma in a straight line with the surgeon's position. Two other 8 mm robotic trocars are located at each side of the camera trocar, respecting the necessary distances from each other. Some situations require other new 5 or 10 mm punctures to complete adhesiolysis and/or dissection or suturing for safety and efficacy, depending on the case complexity. As a bowel opening can occur, the surgeon must be prepared to suture any bowel wall lesion immediately and if no contamination or small leakage is found, the procedure can continue as well.

Adhesiolysis

The object is to get an open wide space from the border of the defect for a safety mesh fixation from 5 to 8 cm depending on its diameter. Parastomal hernia contents must be freely dissected, reallocated to the peritoneal cavity with meticulous care and patience, leaving the bowel that goes to the stoma isolated and intact. The robot assistance allows stability and safety at this dissection time, bostering the surgeon's confidence. Sometimes it is very difficult to recognize the difference between small bowel seromuscular wall surface and the abdominal wall peritoneum (Fig. 3). During the console surgeon time, first assistant, by the patient side, is very important to push the external hernia bulge in and out as the dissection goes on. The hernia size is measured from all limits of the defect including the edge where the fixed

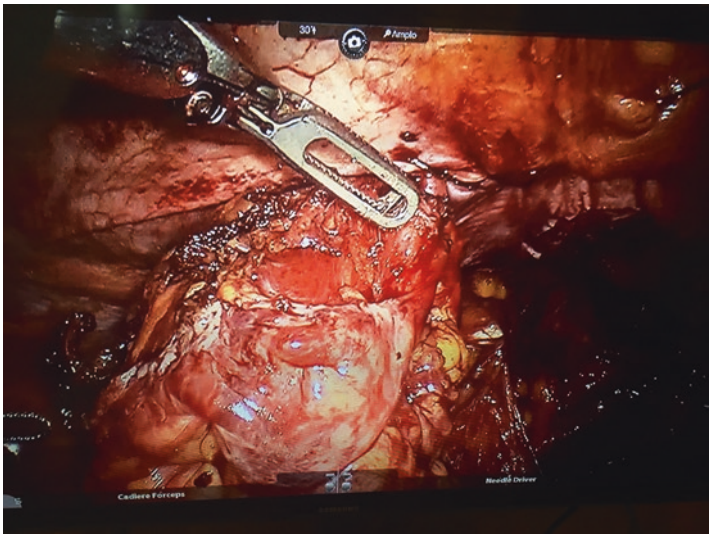

Fig. 3 Dissection of the stoma from the abdominal wall

bowel is hiding it. The mesh is big enough to cover the entire defect going at least 5–8 cm from any direction of these diameter limits. The distance increases with a larger defect, a minimum of 5–8 cm as necessary.

Mesh Repair

The dissection leaves the bowel that goes to the surface like a pipe. This must be positioned against the lateral wall, with two opposite folds for good accommodation. There is no more content around the extremity of this pipe and any space must be attempted to be sutured with the help of the mechanical arm. Remember that the majority of the hernia contents goes to the anterior abdominal wall as a unique mass and we need to cover our reconstruction with a mesh between this mass and the wall. The abdominal wall is reinforced by mesh, holding the "pipe" in place behind it, leaving the bowel lateral and parietal, preventing recurrence and complications. This parietalization is comparable to the parietalization of the spermatic cord of the inguinal laparoscopic hernioplasty. The ostomy bowel remains against the lateral cranial abdominal wall, from proximal to distal finishing at the stoma. When the stoma is too low, under the arcuade line of the posterior rectus sheath, the peritoneal opening is facilitated and muscle fiber exposition is clearer and could allow placing the mesh in a retromuscular layer totally preperitoneal, covered by the lower abdomen peritoneal sac, which is better for fixation of the mesh and decreases postsurgery recovery time and pain (Fig. 4).

Fluoride material of the mesh, combined or pure, seems to be better tolerated by patients (PTFEe or PVDF) [28–30]. Double crown fixation appears to be more stable and is the recommendation in these patients. Robotic suture is another option for being superficial to avoid vascular injuries [31].

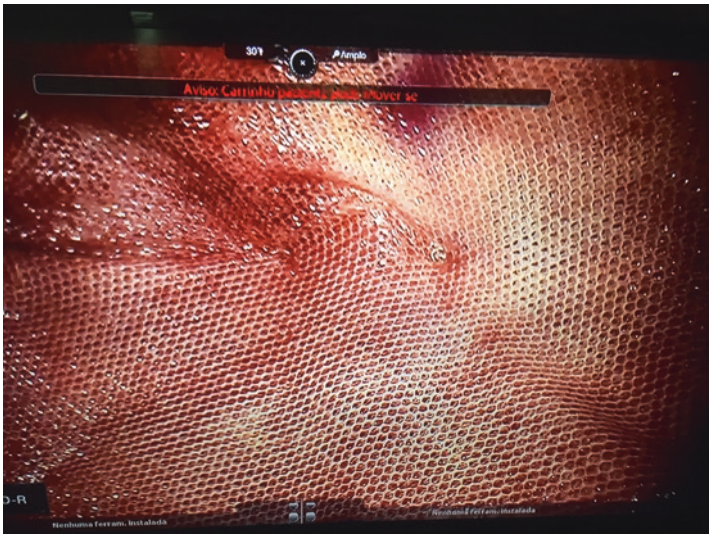

Fig. 4 Mesh placed in the parastomal repair

Lateral Defects

Lateral hernias comprehend a variety of diseases located far from the midline, usually in the lateral muscles. Different from the parastomal, these types of hernias do not have a bowel or colon passing through the defect. However, they tend to be hard to repair because of the lateral muscle hypotrophy [32] and difficult places to work on, such as subcostal or close to the iliac bone.

The abdominal gas insufflation as shown before follows Palmer's point needle entry [25, 26]. The blind insertion of a Veress needle must be preferred at this point, left subcostal, 2 cm below the costal margin, to create the pneumoperitoneum. Care must be taken to avoid adhesions. The entrance of the camera port should be at least 20 cm away from the defect, as proposed by the da Vinci rules. The other trocars are placed following the same rule, forming a semicircle opposed to the defect. Some situations require an assistant port to help in the adhesiolysis and mesh placement. After completing that it is time to dock the robot and proceed with the surgery.

Adhesiolysis

The main objective of the minimally invasive hernia repair is to get the entire abdominal wall in which the defect is located free from adhesion. A wide space must be cleared to place a mesh at least 5–8 cm wider than the primary defect. At this time the robot confers stability and safety to the dissection; sometimes it is hard to reach the correct spot when working with standard laparoscopic instruments (Fig. 5).

During the procedure the assistant, by the patient's side, is very important, pushing the external hernia bulge in and out as the dissection goes on and correctly

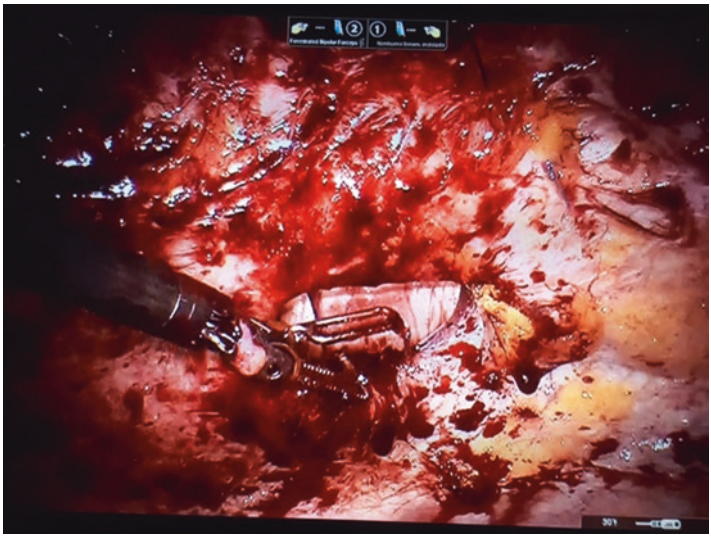

Fig. 5 Dissection of lateral hernia

measuring the defect and mesh to put in. She can also prepare the mesh to be inserted and make marks in it to facilitate its handling inside the patient's cavity. The hernia size is measured from all limits of the defect including the edge where the fixed bowel is hiding it. In the sequence it is time to repair the defect.

Mesh Repair

After the completion of the adhesiolysis a wide space is now seen by the surgeon. With the benefit of the robotic 3D view the lateral muscular planes can be well delineated, helping the surgeon achieve the correct closure of the hernia. Many studies show the benefits of the closure of the defect and in this particular case it can be done in a more proper way [33, 34] (Fig. 6a, b).

A mesh is then inserted inside the peritoneal cavity and fixed with a minimal distance of 5–8 cm wider than the previous defect. Although tackers may be applied, using robotic technology, as discussed in the chapter, "Lower Abdomen Midline Defects," the mesh can be fixed by sutures reducing the rate of complications [31]. The mesh used has to be composed in order not to have problems regarding adhesions or bowel injuries. Double crown fixation seems to be more stable and is the recommendation in these patients (Fig. 7).

Summary

These are challenging patients and the chosen method does not have to be more complicated than the disease. Lateral and parastomal hernias are growing in number and complexity. Their diagnostics are more available to the general surgeon because

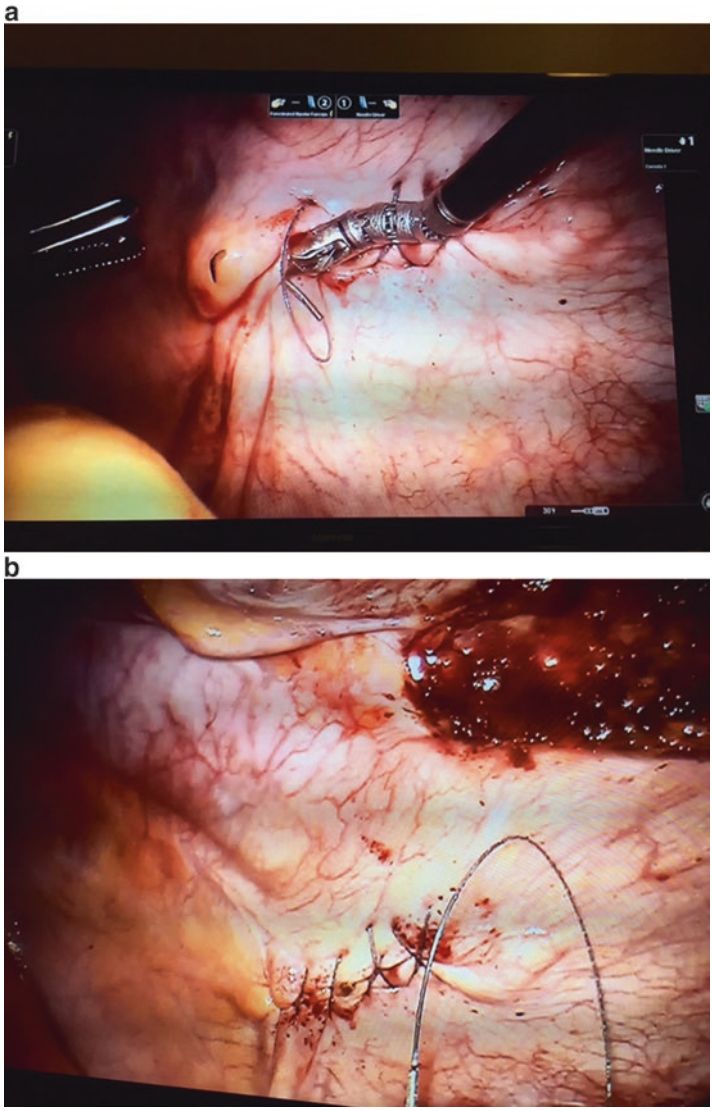

Fig. 6 (**a**, **b**) Closure of the lateral defect

of new solutions, meshes, methods, video surgery, and even robotics, solutions that weren't options in the past. This growth is happening in patients over 60 years, with other risk factors such as obesity, diabetes, and cardiorespiratory problems.

Surgical parastomal hernioplasties remain associated with high levels of recurrence, but each patient must be individualized and treated separately, considering the synthetic mesh procedure, combined, structured, or chosen at the surgical planning strategy with previous tomographic anatomical study. Suturing, approximating muscles, and wall tissues should be followed as much as possible, but single suture must be discontinued.

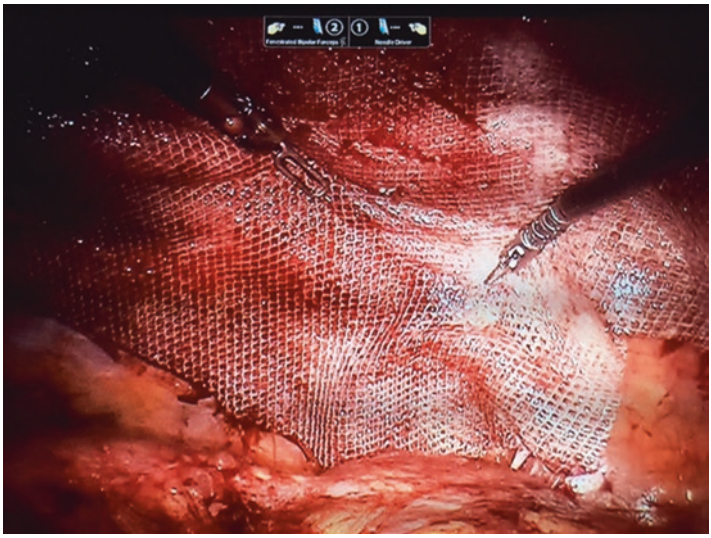

Fig. 7 Mesh placed in the lateral hernia

It is possible to study and program abdominal wall reconstruction in patients who underwent definitive stoma technique and developed parastomal or lateral complex hernias. Some are compromised in bowel function or social living because of their hernia, but the disease is ongoing because of the difficulty of treatment. Robotic-assisted video surgery is a good option to go further in these procedures. The results, in turn, are satisfactory and showed that patients, in general, were satisfied with the procedure.

Concluding Remarks

- Lateral and parastomal hernias are growing in number and also in complexity.
- The surgeon has to anticipate possible adhesion sites in order to place the trocars far away from them.
- Lateral or combined approach to parastomal and lateral hernias is preferable, keeping an adequate distance from the target.
- High recurrence rate is still a concern in the parastomal and complex lateral hernias repair.

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Pelvic Defects

Thiago Nogueira Costa and Ricardo Z. Abdalla

Key Points Summary

- Perineal hernias have a rare presentation and high recurrence rate, up to 16%.
- There are a large number of techniques without any standardization.
- Robotic view and articulated movements could overcome problems related to the depth and difficulty of the dissection.
- Good equipment and a well-trained team are needed for the treatment of pelvic hernias.

Introduction

The pelvic defects comprise some hernia types, such as obturator, sciatic and perineal hernias. The first are rare entities, mostly primary hernias [1]. The second, perineal hernias, are incisional hernias following protectomy or abdominal perineal resection (APE). They account for 1–7% of the incisional hernias with a rare incidence [2]. APE is the surgical treatment for patients with distal rectal cancer in whom an anterior resection with anastomosis (AR) cannot be performed, leaving them with a terminal colostomy. Even though it is a radical procedure, it has a high incidence of local recurrence due to the extended invasion those types of cancer have [3]. Therefore other techniques were created to try to get better oncologic results. This was how the extra elevator abdominal perineal excision (ELAPE) was created with a larger margin resection in the attempt to have better oncologic outcomes. However, with the increased resection, the incidence of perineal hernia became higher, leading to the discussion of prevention and possible treatments of this disease [4].

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R.Z. Abdalla, T.N. Costa (eds.), *Robotic Surgery for Abdominal Wall Hernia Repair*, DOI 10.1007/978-3-319-55527-0_7

The main risk factors of developing a perineal hernia, in addition to the type of surgery done, are: female gender, neoadjuvant chemoradiation (very common in this type of disease), poor nutrition, use of tobacco, wound infection, and the failure to close the perineal defect [5]. Other factors such as obesity and age have a lower impact in the hernia formation [3, 4].

Symptoms range from bowel obstruction, skin erosion, to a slight bulging in the regions. The patients can show urinary problems, perineal pain, or other types of skin lesions [3, 6].

There are no classifications regarding perineal or sciatic hernias, because they are rare and their main treatment is not well standardized nowadays. Regarding perineal hernias, the first attempt to correct them was made by Yeoman et al. in 1939 [1]. Since then various types of procedures have been tried in the setting of this type of disease. Most of them are open procedures either done by the perineum with muscle flap rotations, primary closure, or from the abdomen with the placement of a prosthesis. Even though there are many procedures, the recurrence rate can be as high as 16% [7].

The perineum approach is often done by plastic surgeons, who try to close the pelvic defect using muscles from the leg or the back [8]. The other one, repair from the abdomen, has the advantage of dealing with the bowel and hernia sac, with the possibility of doing the adhesiolysis and treating the hernia sac adequately [9]. In respect to sciatic hernia, the surgery can be done by the local approach (inguinal/femoral) or from the abdominal cavity.

When minimally invasive surgery began, hernia surgeons saw the opportunity to treat incisional and primary hernias using that technology [10]. Video surgery has modified dissection and anatomy preparation of surgical diseases. This approach allied with the advantages of the repair coming from the abdomen led surgeons to try to use laparoscopy in the treatment of perineal hernias. In this way, many case reports showed techniques to repair those types of hernias, mostly utilizing a mesh placed in the defect without tension [11–13].

However, the benefit of this method in the abdominal wall has been delayed due to the lack of development of technologies and articulated movements, demanding the need for investments and time for solidification. With the advent of robotic surgery, problems such as the depth of the dissection, hard 2D view, and difficulties in placing the mesh could be solved [14].

Thus, we present in this chapter the robotic treatment of pelvic hernias based on the experience of a hernia service centered in minimally invasive surgery and cancer.

Preoperative Workup

Before starting the procedure the patient has to be evaluated and prepared. First of all, a good history of symptoms and other comorbidities has to be taken from the patient. It is very important to have the oncologic status of the patient. After that a physical examination is done with the patient in different positions (Fig. 1).

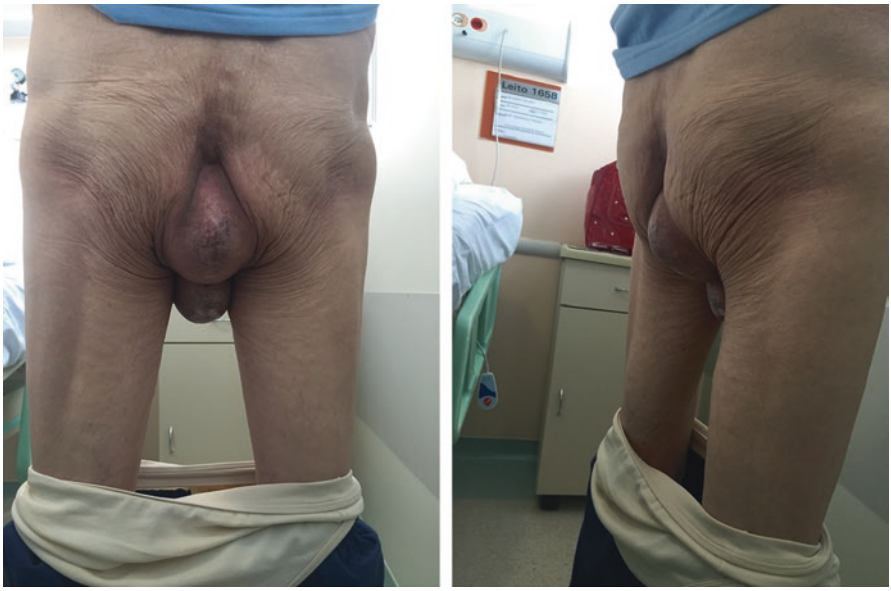

Fig. 1 (**a**, **b**) Physical exam

In order to achieve the diagnosis a computed tomography (CT) scan of the abdomen and pelvis can be done as shown in Fig. 2.

When the diagnosis is made the patient has to be evaluated as to the possible treatment, in this case, surgery. He has to be fit for surgery and a consultation with the clinician and anesthesiologist is necessary.

Patient Preparation and Positioning

The patient is hospitalized on the same day of the surgery, at least 2 h before the scheduled procedure. In the majority of cases, there is no need for bowel preparation. Then, he is taken to the operating room (OR) and the preparations can be seen in Table 1.

He is placed on the surgical table with both arms and legs closed. Sometimes the legs can be opened in order to dock the robotic cart between them. General anesthesia is applied with orotracheal intubation. After that, the patient receives prophylactic antibiotics, urinary catheter and the peripheral lines are placed. The patient is always secured on the table with fixation straps and well protected with a chest protector and a head/eye protector. A heater device is used, placed on the chest of the client.

The asepsis is done using chlorexidine and the surgical drapes are placed exposing the entire abdominal area. The colostomy is closed using a separated sterile surgical drape.

After all that is done, cannulas, energy cables, and other parts of the OR patient safety components and accessories are secured so as not to cause any problems during surgery.

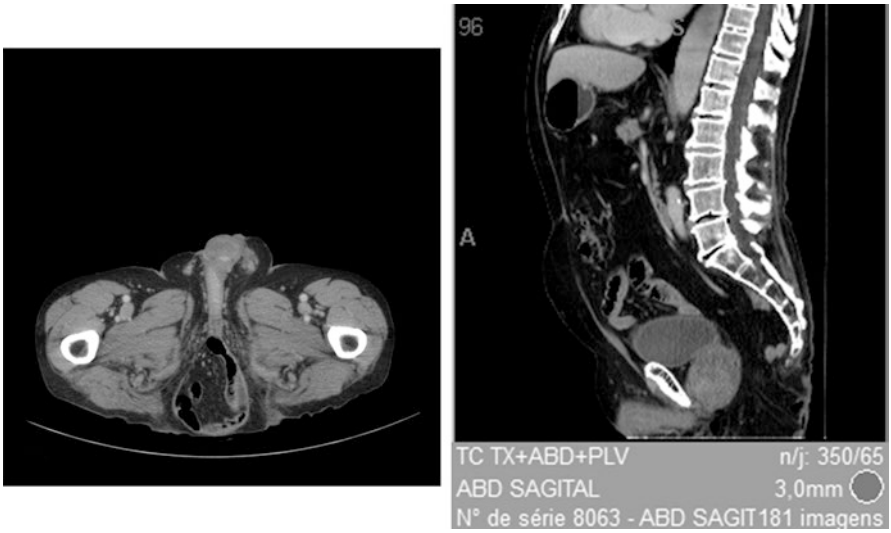

Fig. 2 (**a**, **b**) Computed tomography showing perineal hernia (axial and sagittal)

Table 1 Patient's preparation

Antibiotics
Urinary catheter
Peripheral lines
Fixation strap
Chest protector
Head/eye protector
Endotracheal cannula
Anesthesia cannulas
Energy cables
Colostomy closure (sterile drape)
Surgical drapes
Sterile film
Heater device

Getting Started

The surgery can then start after all the preparations described are done. The pneumoperitoneum is made at the left upper quadrant using a Veress needle with the pressure of 12 mm of Hg. Using a sterile pen the ports are programmed using the perineal area as the target. The first cannula to be placed is the optical one, 12 mm, positioned at 2 cm above the umbilicus and 2 cm to its right side, respecting the distance of minimum 20 cm from the target and aligned with the robotic arm cart that will come from the left thight or between legs, depending on the "size" of the pelvis. Technology development is decreasing and changing this distances, time after time.

When the optic is inserted, a first evaluation of the abdominal cavity is done, looking at the entire cavity, searching for adhesions, understanding the main hernia, and diagnosing other possible defects such as inguinal hernias, paracolostomic, or incisional/ventral. We can change trocars positions depending on multiple defects, but perineal problems are the main goal to be done.

The other 8 mm cannulas are placed following the rule of 10 cm distance from each other to avoid collision during the procedure. Number 1 is placed in the left flank, number 2 between the camera and number one, and number 3 in the right iliac fossa. A fourth cannula for the assistant is placed in the upper right quadrant or any strategic place behind the camera and arm 3 with space for support from the auxiliary. Figure 3 shows the positioning of the cannulas. Caution must be taken to avoid lesions to the colostomy when it exists.

In other cases, such as combined hernias the optical cannula can be placed 4–5 cm above the umbilicus. In this setup arm 1 can be placed at the left upper quadrant, arm 2 in the right upper quadrant, and arm 3 in the right flank. The assistant port can be between arms 2 and 3 at the right side of the patient. In these types of hernias there is no need to worry about the colostomy, and most patients do not have previous surgeries.

Docking

When the cannulas are placed and checked for positioning it is time to dock the robot. Using the pelvic defect as the target the robot can come from many areas, but mainly from the legs.

Figure 4 shows the possible dockings that can be done in the pelvic hernia repair.

The robot can come from the left side, with the legs closed: this type of docking is used to treat left anterior pelvic hernias and perineal hernias in order to protect the colostomy and treat possible paracolostomic defects, often present in patients that have undergone APE or ELAPE (Fig. 4a).

In the case of a right anterior pelvic hernia the robot can come from the right with the legs closed (Fig. 4b).

The third option is the docking between the legs, as used in prostatectomies (Fig. 4c).

In case of emergency, the assistant must be ready to undock the robot and take whatever action is necessary to solve the problem that appeared.

Surgical Technique

The surgical technique can be divided into parts for better understanding of the procedure. Hence, it is separated in: dissection/adhesiolysis, closure of the defect, mesh placement, and fixation.

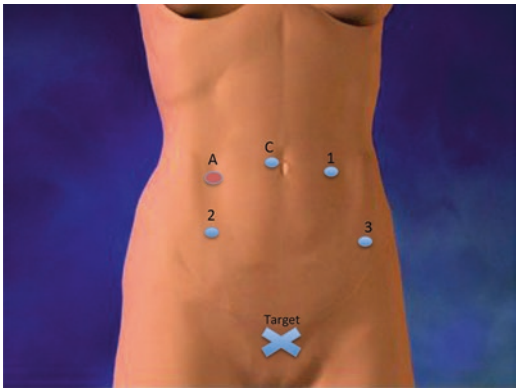

Fig. 3 Cannula placement

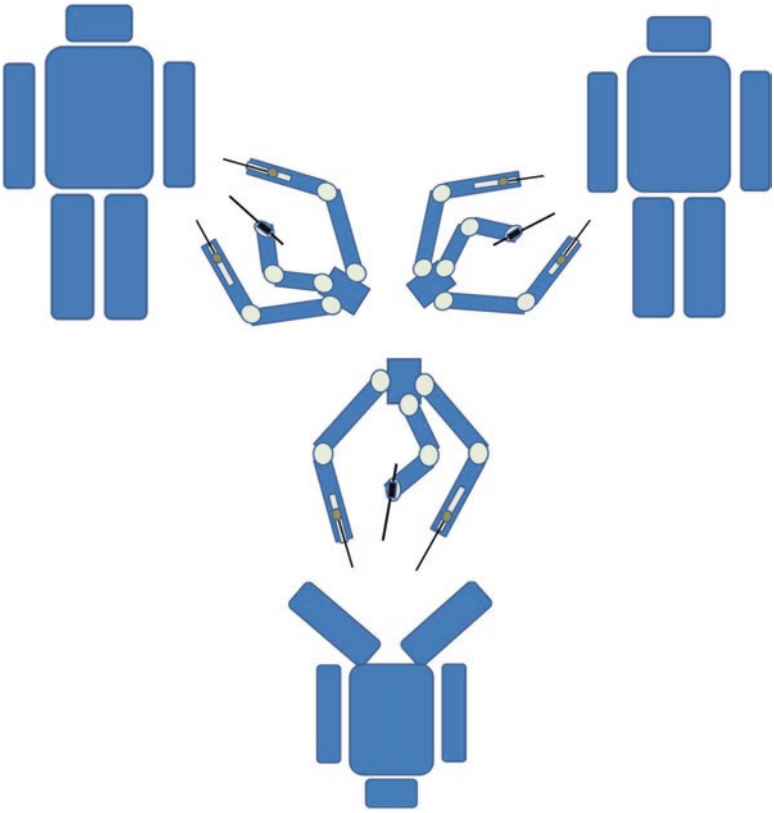

Fig. 4 (**a**–**c**) Robotic docking

Dissection/Adhesiolysis

One of the most important parts of the dissection is the identification of the structures to be separated. Because one of the major complications of the perineal hernia repair is bowel injury, the adhesiolysis becomes even more important. The perineal defects are often accompanied by strong, firm adhesions, mainly in the pelvic area, but the entire abdominal cavity can present them. The robotic instruments with wrist movements along with the 3D view can facilitate management of these adhesions, as the penetration of CO_2 between the conjuntive tissue, lowering the incidence of lesions and making the process faster. The instruments used are (Fig. 5):

- Monopolar scissors
- Maryland bipolar
- Cadiére bipolar
- Double fenestrated
- Needle driver

All the dissection is made using cautery when safe, blunt dissection, or cold scissors, depending on the adhesion. In the perineal area sometimes it is difficult to have the right angle to work on, but with robotic technology the instrument's wrists can overcome this problem and the surgeon can dissect deeper in the pelvis and obturatory space. Another important part about the perineal hernias is that these patients can have concomitant hernias, such as paracolostomic or inguinal, so caution must be taken not to have injuries and mistakes regarding them.

After dissecting and taking down all the adhesions the defect can be seen (Fig. 6). At this time it is important to have a good description of the hernia, with accurate measurement and correct vision of the edges, anatomical references in order to choose the correct type of repair and fixation.

Closure of the Defect

There is a big discussion regarding whether to close the defects in different types of hernia (ventral, inguinal). In recent years the majority of papers tend to favor the closure of the hernia, mainly in ventral hernias. In the perineal and obturatory defects this could be challenging inasmuch as there is little tissue to try to approximate and close.

Sometimes, in small defects, using robotic instruments such as the needle driver, the surgeon can approximate the edges of the defect in an attempt to have the least tension possible.

But the majority of cases reported in the literature regarding pelvic hernias have not closed the defect. In our experience the defect is only closed when we can have almost no tension.

Fig. 5 Instruments used

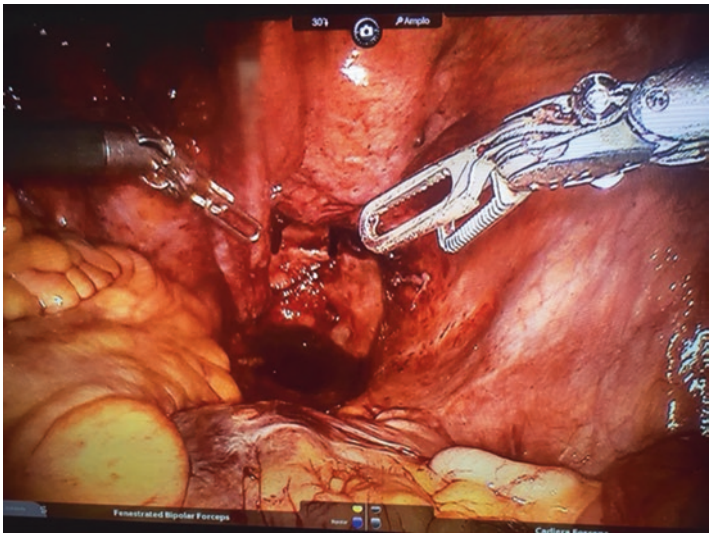

Fig. 6 Perineal defect (internal view)

Mesh Placement and Fixation

After dissecting and exposing the defect it has to be repaired. There are surgical groups that repair these types of hernia from the perineum using surgical flaps without any meshes. But when we come from the abdominal cavity it is recommended to use a mesh, because most times the defect can't even be closed.

The preferred types of mesh are coated mesh or double layer, because there is no tissue or peritoneum to cover the mesh and they can be exposed to the bowel. The mesh has to be 3–5 cm wider than the original defect, with or without closing it. Big pelvic diameter requires bigger mesh length further than 5 cm, considering 8 cm wider than defect.

Fixation can be done by hernia stapler (tacks) or by suture. There are few studies comparing the type of fixation in other types of hernias such as inguinal and ventral. In these papers they compare tackers, glue, and stitches (transfacial or intra-abdominal) and they don't show a big difference in terms of recurrence or major complications. In the perineal hernia repair, the authors prefer to use tackers with good results. The tackers are applied at the peripheral part of the defect and 5 cm wider in a double crown technique (Fig. 7).

Complications

All types of surgery have their complications. In hernia surgery, those complications can affect the treatment, return to normal activities, and recurrence [10, 15].

One of the most common complications in laparoscopic and robotic hernia repair is the seroma. This is caused by a fluid collection localized mainly between the repair (mesh or closure) and the skin/hernia sac. In the perineal area this is very common due to the space and size of the hernia sac. Most of the seromas are treated without any intervention [12, 13].

Another major complication is bowel injuries. This type of problem can lead to reoperations and even death. The patients we are dealing with are overtreated because of cancer disease and they do not heal well to fistulas and avoidable complications. In the pelvic area it is important to do the adhesiolysis carefully not to have any bowel lesions.

Clinical complications such as pulmonary infections and embolism have to be remembered and care must be taken with prophylaxis.

Other complications such as infection, bleeding, and adinamic ileus are difficult to see. The main complications are shown in Table 2.

Results and Perspectives

There has been little evidence until now regarding the minimally invasive treatment of pelvic hernias, mainly robotic-assisted repair. However, there are a small number of cases reported with what is seen as a low recurrence rate, with good clinical results regarding time of hospital stay, pain, and other complications [14].

When we talk about the surgical outcomes we can see shorter operative time, less dissection, and scars.

However, it continues to be costly per procedure done. But with major clinical trials comparing the robotic approach to pelvic hernias with the traditional surgeries (open repair) we can see that the total costs can be lowered if the outcomes seen in the first cases are proved to be true. It looks like robotic surgery is good for complex cases.

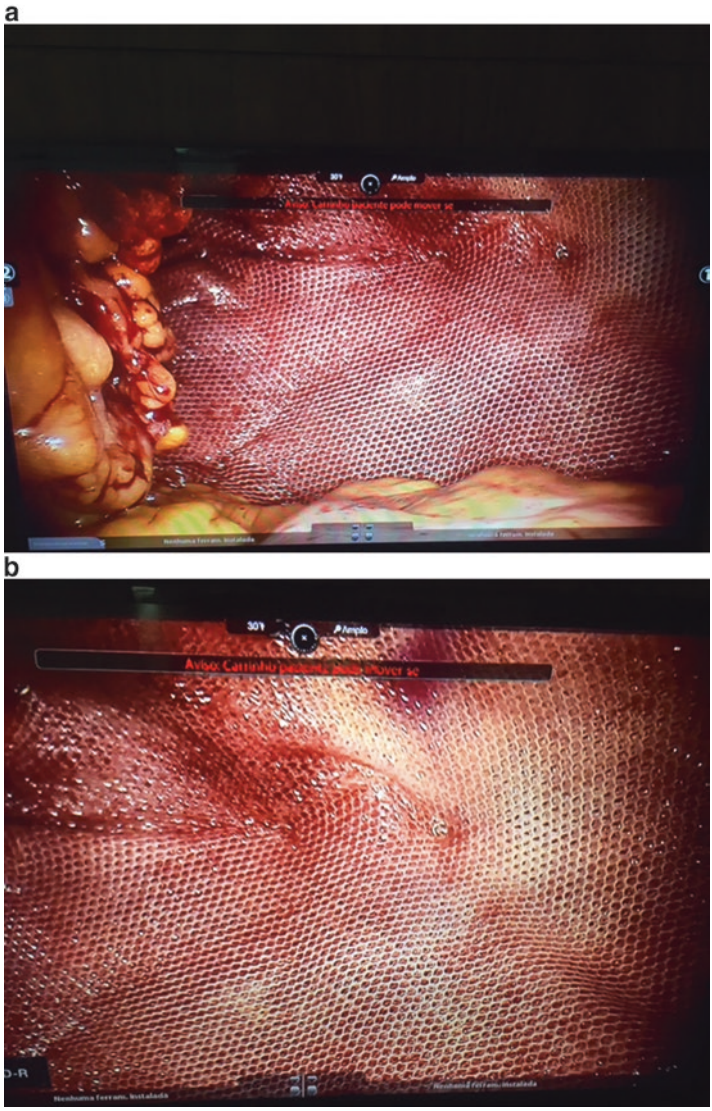

Fig. 7 Final view of the repair, with the mesh placed. (**a**) Internal view with colostomy. (**b**) Close internal view

Table 2 Surgical complications

Seroma
Infection
Mesh migration
Bleeding
Adinamic ileus
Bowel lesions
Care with colostomy
Clinical complications—pulmonary and urinary

Summary

Perineal/pelvic hernias have a rare incidence, achieving from 1% to 3% of the surgeries done in the perineum [2, 3]. With the development of larger techniques to try to treat the distal rectal cancer, such as ELAPE, the incidence of that type of hernia is increasing.

There are different types of surgical procedures to repair the perineal hernia, but they are not standardized and can be done either from the perineum or from the abdominal cavity [10, 16, 17]. With the advent of minimally invasive surgery (MIS) hernia repair could be taken to another level, with the understanding of anatomy and better ways to dissect the adhesions. However, limitations such as 2D view and lack of articulated movements have led laparoscopic repair to only a few case reports.

Thus, by using robotic technology those problems can be overcome and better results can be achieved in the treatment of perineal hernias. But caution and care must be taken to prepare the patient and the equipment to be used in these procedures.

Concluding Remarks

- Pelvic hernias have a rare presentation and high recurrence rate.
- Patients' preparation before and during the surgery is important in the surgical setup.
- Robotic arms and 3D view can improve the technique and surgical outcomes.
- Caution must be taken regarding early and late surgical complications.

Glossary

Abdominoperineal excision (APE) Surgical procedure to treat distal rectal and anal carcinoma, in which an anastomosis cannot be done

Extralevator APE (ELAPE) Surgical procedure proposed by Holms et al. to improve local tumor control and with the aim to reduce local recurrence

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Postoperative Pain

Pedro Paulo Kimachi and Elaine Gomes Martins

Keypoints Summary

- There are several types of pain associated with robotic surgery: incisional port site pain, pain from the peritoneum being distended with carbon dioxide, visceral pain, and shoulder tip pain.
- Low-pressure pneumoperitoneum with deep neuromuscular block is worth considering for patients undergoing laparoscopic surgery. Patients reported a significantly lower intensity of postoperative abdominal pain with this procedure.
- Use of multimodal analgesia has shown improved recovery, less nausea and vomiting, and fewer opiate side effects; these can culminate in shorter hospital stays, less morbidity, and increased patient satisfaction.
- Regional anesthesia given during robotic surgery significantly decreases both short-term postoperative opioid use and pain experienced by patients.
- Two procedures have an important role in the postoperative analgesia of patients undergoing robotic surgery: TAP block and quadratus lumborum block.
- Postoperative patient care is an essential part of making this technique both safe and successful.

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Introduction

Minimally invasive surgery, including robotic and laparoscopic surgery, has become the standard of care for treatment of most intra-abdominal conditions. Robotic-assisted surgery has evolved over the past two decades, with constantly improving technology that assists surgeons in multiple subspecialty disciplines. Currently, the main focus is on the operative technique; however, postoperative patient care is an essential part of making this technique both safe and successful. Many surgeries that were previously performed using large open incisions can now be done with as few as three 5 mm or 8 mm incisions. Minimally invasive surgery has been shown to reduce postoperative pain, decrease the duration of hospitalization, shorten recovery time, and improve the appearance of scars [1]. However, strategies for postoperative pain management after laparoscopic surgery are mainly derived from concepts that have been established for open surgical procedures.

Previous studies have suggested that decreasing pain levels can decrease both recovery time [2] and costs [3]. Any available technology, such as robotic surgery, that has the ability to remove barriers to treatment and increase patient quality of life should be considered. However, no procedure is pain free, and there are different challenges in treating this specific type of pain.

There are multiple analgesic techniques available to both prevent and treat pain caused by this kind of surgery. This chapter explains the mechanism of pain involved in laparoscopic procedures and reviews current evidence pertaining to systemic and especially regional analgesia methods, which are both promising and effective treatments for robotic surgery.

Literature searches, specifically those conducted on analgesia for any specific robotic surgery, were carried out and yielded few results; due to a lack of evidence on techniques, further studies are needed in this area [4]. However, searches for laparoscopic procedures can be extrapolated and used to mount evidence to establish best practices.

Postoperative Pain

There are several types of pain associated with robotic surgery: incisional port site pain, pain from the peritoneum being distended with carbon dioxide, visceral pain, and shoulder tip pain. The etiology of postlaparoscopic pain can be classified into at least three categories: visceral, incisional, and shoulder tip pain [6].

Pneumoperitoneum

Laparoscopic surgery generally involves the insufflation of carbon dioxide (CO_2) into the peritoneal cavity, producing a pneumoperitoneum that causes an increase in the intra-abdominal pressure (IAP). However, CO_2 absorption and elevated IAP during pneumoperitoneum can cause specific pathophysiological effects, such as

cardiovascular, pulmonary, and splanchnic perfusion changes [5]. Thus far, several studies have been conducted in an effort to reduce CO_2 pressure and minimize the adverse effects of pneumoperitoneum, and they have reported postoperative pain relief after low-pressure pneumoperitoneum [7].

One international guideline recommended use of "the lowest intra-abdominal pressure allowing adequate exposure of the operative field, rather than using a routine pressure" [8]. However, the authors of a recent systematic review concluded that "the recommendation to use low-pressure pneumoperitoneum during laparoscopy is weak" [9]. The most important benefit of low-pressure pneumoperitoneum reported in the researched studies was decreased postoperative pain intensity, especially shoulder tip pain.

There is a correlation between the amount of residual intraperitoneal gas and pain scores postoperatively. Therefore, using lower abdominal pressures when insufflating and aspirating residual gas at the end of the procedure reduces postoperative pain [10].

Deep Neuromuscular Block

The surgical requirements of lithotomy and steep Trendelenburg positions, the creation of pneumoperitoneum, and the lack of direct access to the patient all present management challenges in this surgery. Patient positioning requirements can have significant physiological effects and can result in many complications. In addition to the repercussions of the pneumoperitoneum already described, muscle relaxation becomes a crucial point in these surgeries.

It has been hypothesized that providing deep neuromuscular block (NMB) (a posttetanic count of one or more but a train-of-four [TOF] count of zero) when compared with moderate block (TOF counts of one to three) for laparoscopic surgery would allow for the use of lower inflation pressures while both optimizing surgical space and enhancing patient safety. There is some evidence that maintaining low inflation pressures during intra-abdominal laparoscopic surgery may reduce postoperative pain.

Maintenance of a deep block for the duration of the pneumoperitoneum presents a problem for clinicians who do not have access to sugammadex. Reversal of the block with neostigmine at a time when no response to TOF stimulation can be elicited is slow, incomplete, and increases the potential for postoperative residual neuromuscular block. The obligatory addition of sugammadex to any anesthetic protocol, based on the continuous maintenance of a deep block, is not without associated problems. Firstly, monitoring of neuromuscular function is still essential. Secondly, antagonism of a deep block necessitates doses of sugammadex of $\geq$4.0 mg/kg. Thus, maintenance of a deep block has substantial economic repercussions [11].

A prospective randomized trial conducted by Kim et al. [12] suggested that deep NMB has benefits over conventional moderate NMB in laparoscopic surgery, including a greater intra-abdominal pressure lowering effect, maintenance of

surgical conditions, less severe postoperative pain, and faster bowel function recovery. In addition, patients in the deep NMB group reported a significantly lower intensity of postoperative abdominal pain at all periods within 48 h postoperatively and a lower intensity of shoulder tip pain within 6 h postoperatively [12]. Therefore, low-pressure pneumoperitoneum with deep NMB is worth considering for patients undergoing laparoscopic surgery.

Chronic Pain

Chronic postoperative pain has been a significant problem in hernia repair. Severe chronic pain has been reported in 3% of cases [13, 14]. Given the large numbers of patients undergoing hernia surgery, it is not surprising that a number of studies have looked at both intraoperative and postoperative factors that relate to the development of chronic pain. Those intraoperative factors, especially the laparoscopic approach, have been shown to be associated with a lower incidence of nondisabling, mild, and moderate chronic pain [15]. Postoperatively, the severity of pain at 1 and 4 weeks has also been shown to be a predictive factor for pain at 1 year. Therefore, we can highlight two important points here: robotic surgeries may decrease the chance of patients developing chronic pain, and adequate control of postoperative pain is important to avoid postoperative chronic pain.

Postoperative Management in Robotic Surgery

Robotic laparoscopic procedures are relatively new, hence, there is a paucity of data regarding the most suitable analgesia for these procedures. Studies are too few in number and lack power; they are also too heterogeneous to enable statistical analysis. There is a need for good quality, high-powered, randomized controlled trials.

Although operative time was once longer in robotic surgery, Shashoua et al. [16] reported that a longer operative time did not result in higher narcotic use in the postoperative period. Notably, operative time has decreased significantly for robotic procedures in tandem with increased experience.

Treatment

We would like to emphasize the use of multimodal and regional analgesia.

Multimodal Analgesia

Multimodal analgesia involves the use of different classes of analgesics and different sites of analgesic administration to provide superior dynamic pain relief with reduced opioid analgesia-related side effects. This important concept employs the

theory that agents with different mechanisms of analgesia may have synergistic effects in either preventing or treating acute pain when used in combination. Those undergoing multimodal analgesia have shown improved recovery, less nausea and vomiting, and fewer opiate side effects; these can culminate in shorter hospital stays, less morbidity, and increased patient satisfaction. Multimodal analgesia should utilize nonopiate systemic analgesics in addition to regional techniques [4].

As treatment options, we can describe the use of acetaminophen, nonsteroidal anti-inflammatory drugs (NSAIDS), anticonvulsants, NMDA receptor antagonists, and alfa 2 agonists.

NSAIDs (diclofenac, parecoxib, etoricoxib, calecoxib) and Cox-2 inhibitors showed promising results and benefits from their administration and demonstrated a good side-effect profile. Steroids (dexamethasone and methylprednisolone) have been shown to reduce postoperative nausea and vomiting and postoperative pain relief, both of which improve patient well-being and encourage earlier discharge. A meta-analysis of colorectal laparoscopic procedures conducted by Joshi et al. [17] showed that dexamethasone improved postoperative pain relief as well as nausea and vomiting. They also recommended infiltration of surgical incisions with local anesthetic.

Another widely used drug—Paracetamol—has been shown to be effective and should be used in combination with other analgesics; notably, it cannot be used in isolation.

In recent years, the use of systemic lidocaine as a coanalgesic has gained increasing interest for the treatment of acute postoperative pain. Lidocaine is a local anesthetic amide with analgesic, antihyperalgesic, and anti-inflammatory properties. In abdominal surgery, lidocaine has been demonstrated to result in lower postoperative pain scores and a significantly reduced use of both anesthetics and postoperative analgesics [18].

Regional Anesthesia

Although minimally invasive procedures are less painful, there are more adverse effects than benefits associated with epidural analgesia in laparoscopic surgery [4]. Epidural analgesia provides excellent analgesia; however, it is not the best choice because it can be associated with numerous complications. Therefore, the risks must be carefully considered when using a neuroaxial blockade.

Notably, other regional anesthesia procedures have become promising, showing excellent results in robotic surgery. Minor postoperative pain scores, early recovery, and decreased opioid consumption are important advantages in the use of this anesthetic technique [19]. We consider it important to describe the two procedures that would have important roles in the postoperative analgesia of patients undergoing robotic surgery: TAP block and quadratus lumborum block.

The key to understanding abdominal wall nerve blocks is an understanding of the anatomy. The skin and fascia of the anterior abdominal wall overlie the muscles that help support the abdominal contents and the trunk. There are three lateral

muscle layers within the abdominal wall, each with an associated fascial sheath. From superficial to deep, these are the external oblique, internal oblique, and transversus abdominis. Beneath the muscles lie extraperitoneal fat and then the parietal peritoneum.

The abdominal wall is supplied by intercostal nerves T7–T11 (the thoracoabdominal nerves) and by the subcostal, iliohypogastric, and ilioinguinal nerves. The iliohypogastric nerve originates from the L1 nerve root and supplies the sensory innervations to the skin over the inguinal region. The ilioinguinal nerve also originates from the L1 nerve root. Between the internal oblique and transversus abdominis muscles lies a plane that corresponds to a similar plane in the intercostal spaces. This plane contains the anterior rami of the lower six thoracic nerves (T7–T12) and first lumbar nerve (L1), supplying the skin, muscles, and parietal peritoneum.

TAP Block

Hernia repair is associated with considerable postoperative pain. Transversus abdominis plane (TAP) blocks have proven effective in controlling postoperative pain in a variety of laparoscopic abdominal operations [19]. The TAP block is a relatively new regional anesthesia technique that provides analgesia to the parietal peritoneum, the anterior abdominal wall, and the skin.

As discussed previously, in addition to reducing postoperative pain, muscle relaxation is necessary for better visualization of structures when using a lower intra-abdominal pressure during robotic surgery. Use of the TAP block showed consistent and significant muscle-relaxation effects of the abdominal wall in volunteers [20]. This finding was supported by an anatomical study of the innervation of the lateral abdominal wall in cadavers, which demonstrated that branches from T9 and L1 primarily innervate the three lateral muscle layers. The clinical effect of this relaxation is still unknown; however, muscle relaxation may be part of the pain-relieving effects reported in clinical studies. Future studies should investigate whether the TAP block can be used as a muscle relaxant to improve surgical conditions, thereby limiting the use of neuromuscular-blocking drugs during abdominal surgery.

Quality improvement requires the implementation of new tools to improve both patient and financial outcomes. An article presented at the 2014 Society of American Gastrointestinal and Endoscopic Surgeons conference discussed the benefits of TAP blocks on patient outcomes [21]. Adding TAP blocks to an enhanced recovery protocol facilitated shorter lengths of stay with both low readmission and reoperation rates when compared to previously published series. The effect appeared durable and consistent in a large case series. Transversus abdominis plane blocks may be an efficient, cost-effective method for improving laparoscopic results [21].

Approach Considerations

The use of ultrasound (US) in regional anesthesia has led to an increase in the number of block descriptions. TAP is the most studied of all those procedures. With the patient in the supine position, the ultrasound probe is placed in a transverse plane between the lower costal margin and the iliac crest in the mid-axillary line (Figs. 1a, b and 2).

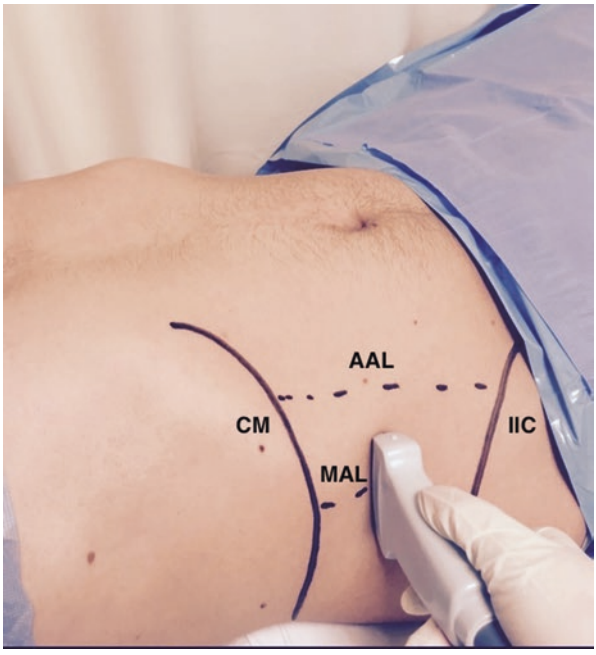

Fig. 1 Photographs demonstrating siting of the TAP block. The US transducer is placed in the transverse plane between the twelfth rib or costal margin and the iliac crest. *CM* indicates costal margin, *IIC* iliac crest, *AAL* anterior axillary line, *MAL* medial axillary line

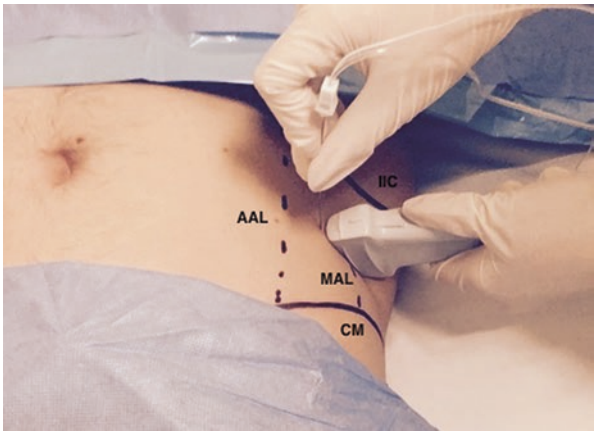

Fig. 2 Photographs demonstrating siting of the TAP block. (*Cranial view*) The US transducer is placed in the transverse plane between the twelfth rib or costal margin and the iliac crest. *CM* indicates costal margin, *IIC* iliac crest, *AAL* anterior axillary line, *MAL* medial axillary line

The needle is advanced using the in-plane technique with an anterior to posterior direction. Local anesthetic is then injected between the internal oblique and transverse abdominis muscles just deep the fascial plane in-between, which is the plane through which the sensory nerves pass.

Requirements for Performing the Ultrasound-Guided Block

- Ultrasound machine with a high-frequency probe (10–5 MHz)
- Ultrasound probe cover
- Antiseptic for skin disinfection
- Sterile ultrasound gel
- 100 mm needle
- 20 ml syringe
- 20–30 ml local anesthetic this block relies on local anesthetic spread rather than concentration, and this is volume-dependent (Fig. 3)

Quadratus Lumborum Block

The use of the quadratus lumborum block (QLB) resulted in an increased sensory block (T6-L1) compared to the TAP block when performed using a similar volume of local anesthetic [22]. For this reason, QLB is very interesting for upper abdomen

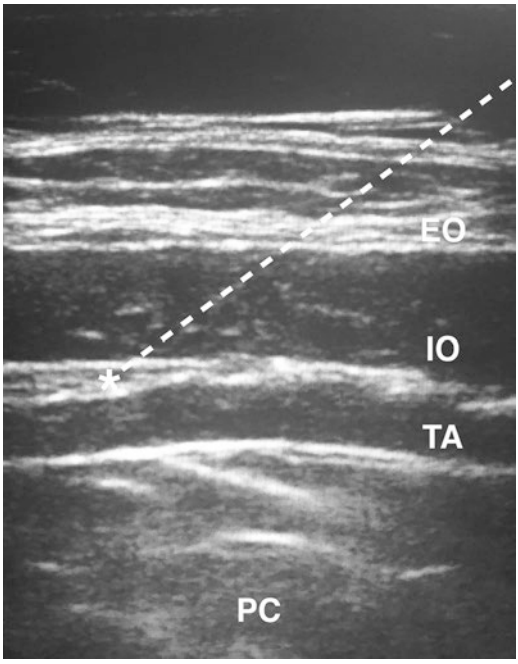

Fig. 3 Ultrasonographic images demonstrating siting of the TAP block, before injection of LA. The right side of the image is oriented medially, and the skin is at the *top* of the images. The needle is marked as a *dashed line*. *PC* indicates peritoneal cavity, *EO* external oblique muscles, *IO* internal oblique muscles, *TA* transversus abdominis muscles

midline defects. We can use the same principle of TAP block to understand the application of this technique in video-laparoscopic surgeries when adding analgesia to higher regions of the abdomen.

The QLB is a superficial fascial block between the posterior abdominal wall muscles and is not technically difficult to perform. This technique has three different approaches. We suggest the use of type 2 because it is safe and easy to perform. Although it can be performed with the patient supine, the lateral decubitus position is preferred for two reasons: stability in handling the ultrasound probe and needle, and increased patient comfort (Figs. 4 and 5).

Requirements for Performing the Ultrasound-Guided QL Block

- Ultrasound machine with a high-frequency probe (10–5 MHz)
- Ultrasound probe cover
- Antiseptic for skin disinfection
- Sterile ultrasound gel
- 100 mm needle
- 20 ml syringe
- 20–30 ml local anesthetic

The probe is placed in the anterior axillary line to visualize the typical triple abdominal layers. Then the probe is placed in the mid-axillary line. At this juncture,

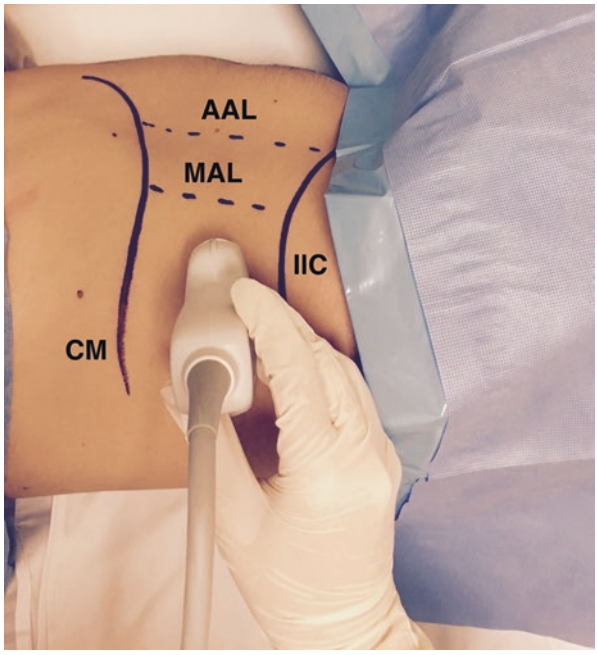

Fig. 4 Photographs demonstrating siting of the QL block. The US transducer is placed in the transverse plane between the twelfth rib or costal margin and the iliac crest; the patient is in a *lateral* position. *CM* indicates costal margin, *IIC* iliac crest, *AAL* anterior axillary line, *MAL* medial axillary line

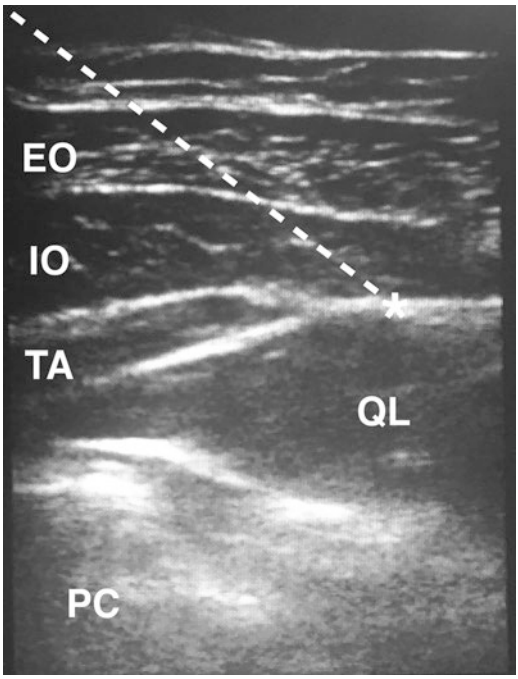

Fig. 5 Ultrasonographic images demonstrating siting of the QL block, before injection of LA. The *left* side of the image is oriented medially, and the skin is at the *top* of the images. The needle is marked as a *dashed line*. *PC* indicates peritoneal cavity, *EO* external oblique muscles, *IO* internal oblique muscles, *TA* transversus abdominis muscles, *QL* Quadratus lumborum muscle

the abdominal layers start to taper. When the probe is placed in the posterior axillary line, sonoanatomy first shows the transversus abdominis disappearing followed by both the internal and external obliques, which form an aponeurosis. Finally, the appearance of QL is noticed. At the junction of the tapered ends of abdominal muscles and the QL, a needle is inserted in the plane.

Dose and Volume of Local Anesthetic

Because this is a fascial plane block, it requires a large volume of local anesthetic to obtain a reliable block similar to other blocks of its kind. Volumes of 20–30 mL are usually recommended. The block onset time depends on a number of factors, including but not limited to vascularity of the area, the exact tissue plane where the local anesthetic was injected, as well as type and concentration of local anesthetic used.

In summary, QLB produces more prolonged analgesia than the TAP block. Adopting the QLB as the default technique can decrease postoperative pain after robotic surgery, especially for upper abdomen midline defects.

Concluding Remarks

- The etiology of postlaparoscopic pain can be classified into at least three categories: visceral, incisional, and shoulder tip pain.

- Regional anesthesia, especially procedures that promote abdominal wall analgesia, plays an important role in the effective management of postoperative pain.
- Further studies should be performed to improve postoperative pain outcomes in patients undergoing robotic surgeries.

Glossary

IAP Intra-abdominal pressure is the steady-state pressure concealed within the abdominal cavity.

NMDA The NDMA antagonist is a receptor for the excitatory neurotransmitter glutamate, which is released with noxious peripheral stimuli. Therefore, NMDA antagonists may play a role in these areas of pain management. There are several NMDA receptor antagonists available, including ketamine, methadone, and memantine.

NSAIDS Nonsteroidal anti-inflammatory drugs block the Cox enzymes and reduce prostaglandins throughout the body. As a consequence, ongoing inflammation, pain, and fever are reduced.

QLB The quadratus lumborum block is a postoperative analgesic method used following abdominal surgery.

Shoulder tip pain Pain in the shoulder tip and rib cage. This is due to small amounts of gas remaining under the diaphragm postoperatively.

TAP The transversus abdominis plane is the plane between the internal oblique and transversus abdominis muscles. There are spinal nerve branches in this area.

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Quality of Life

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and Alessandro Gonçalves Campolina

Key Points Summary

- Quality of life (QoL) assessment is a tool that measures the patient's feeling of well-being using subjective parameters.
- Health-related quality of life (HRQoL) can be defined as: "The extent to which one's usual or expected physical, emotional, and social well-being are affected by a medical condition or its treatment."
- Multidimensionality is an important component of HRQoL and it has many applications.
- In selecting a HRQoL questionnaire, it is important to identify the most relevant areas of health on which to focus.

Introduction

Quality of life (QoL) assessment is a tool that measures the patient's feeling of well-being using subjective parameters including good health, adequate housing, employment, personal and family safety, interrelationships, education, and leisure pursuits [1].

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R.Z. Abdalla, T.N. Costa (eds.), *Robotic Surgery for Abdominal Wall Hernia Repair*, DOI 10.1007/978-3-319-55527-0_9

Increasing interest in the systematic assessment of QoL in the past decades has become an important focus of benefit for health care, influenced by the definition of health offered by the World Health Organization: "A state of complete physical, mental and social well-being, and not merely the absence of disease and infirmity" [2].

The concept of "health-related quality of life" (HRQoL) emerged from the broader concept of general QOL, and is, by definition, more focused on aspects of life that are influenced by or that can influence one's health status directly [3]. Important HRQoL measures may vary among studies attempting to elucidate the impact of a disease process or medical condition. These impacts can include general health, physical functioning, social functioning, role functioning, emotional functioning, cognitive functioning, vision, hearing, pain, and so on. Measures focused on health are useful when assessing the impact of conditions/interventions that are directly related to health but may be less sensitive when assessing public health or social care interventions that do not necessarily fall within medical interventions [4, 5]. HRQoL outcomes have become an essential principle in determining evidence-based guidelines.

Historically, HRQoL has been a fundamental concern of oncologic practice since 1949, when Karnofsky and Burchenal developed a clinical scale to quantify the functional performance of cancer patients [2, 6, 7]. Although length of survival was previously considered the most important among these, the impact of illness on QoL has received increasing recognition. For more than 30 years, improvement in HRQoL is one of two potential benefits that are considered by the US Food and Drug Administration (FDA) as a basis for full approval of new anticancer drugs [8].

Definition of Health-Related Quality of Life

HRQoL can be defined as: "The extent to which one's usual or expected physical, emotional and social well-being are affected by a medical condition or its treatment" [9]. This definition incorporates the two widely accepted aspects of quality of life: subjectivity and multidimensionality [10].

Health measures can be objective (based on clinical outcomes such as blood pressure) or subjective (based on the patient's report of how they are feeling, such as the level of pain). Objective outcomes are dependent on the presence or absence of externally verifiable effects of poor health. They can help to establish the cause of symptoms which is important when identifying appropriate treatment. However, not every condition can be identified objectively and patients will often seek health care when they have specific symptoms that affect their daily activities, such as fatigue, but which cannot be verified objectively. Subjective measures allow us to assess these type of symptoms as well as what is important to patients. HRQoL represents a subjective appraisal of the impact of illness or its treatment; individual patients with the same objective health status can report dissimilar HRQoL due to unique differences in expectations and coping abilities [1]. As a result, HRQoL must be measured from the individual's viewpoint rather than that of outside observers (i.e., caregivers or health care professionals). The importance of obtaining HRQoL reports from patients

themselves is highlighted by a substantial literature documenting disparate estimates of symptoms and HRQoL between patients and their physicians [11].

Multidimensionality is the other important component of HRQoL. This aspect suggests that although health can be about specific symptoms such as our ability to move around or to be free from pain, it extends to all areas of our lives (domains) and will include things such as socializing with friends and how we feel [1, 12].

Applications of Health-Related Quality of Life Measures

1. Capturing changes in clinical status during treatment—The opportunity to utilize patient-reported quality of life to guide individual clinical care is increasingly important to clinicians [5]. For instance, a brief multidimensional HRQoL instrument might be administered at every chemotherapy visit. The treating nurse or physician can then review the current HRQoL for indications of problems and compare it with the HRQoL from the previous visit. Significant changes can be flagged for follow-up by the physician or nurse. This may be of significant benefit in busy practices where there is not always sufficient time to ask the questions one would like. A quick glance at a standardized computer-generated printout of HRQoL scores and changes from the last visit's scores could catch a problem that might otherwise be missed [13]. With increasing interest in HRQoL assessment in routine care, several centers have initiatives across conditions and technologies [14–16].
2. Predicting treatment response—HRQoL data can also be used to predict the outcome of treatment. As an example, in patients with metastatic lung cancer, pretreatment HRQL predicted the likelihood of an objective response to chemotherapy treatment, and the change in HRQoL between baseline and 6 weeks after treatment initiation also predicted survival [17, 18]. The importance of this type of information for stratification of patients during random treatment assignment is obvious [18].
3. Planning tools for future clinical care—Because HRQoL information can provide a detailed assessment of disease and treatment effects, and their global impact on the individual's daily life, it can be used as a planning tool for assessing the need for further treatment, rehabilitation, or palliative care [4]. In particular, HRQoL assessment may reveal anxiety or depressive symptoms, or a complaint of pain or dyspnea that may initiate patient–physician communication about medical, psychological, or social interventions to improve the patient's well-being [19, 20].
4. Treatment decision-making—HRQoL is a particularly important issue for patients who are in the advanced stages of a serious life-threatening illness [4]. Prolongation of life, without regard for the quality of that life, is not a universally desired goal. When considering aggressive, life-prolonging treatments and end-of-life decisions, it is necessary to consider each individual's assessment of what makes life worth living [21]. An NIH-sponsored cooperative research group has been founded to study treatment-related issues that are specific to the setting of palliative and end-of-life care [22, 23]. This group has made tremendous

progress in its first few years of operation, uniting and organizing collaborators in palliative care, and launching its first completed clinical trial, showing that stopping statin therapy in terminally ill patients is not only safe but may improve quality of life and reduce cost [24].

5. Evaluation of quality of health care—The evaluation of health care quality to date has largely utilized measures that assess the process of care [4, 5]. These performance measures can include assessments such as the proportion of providers that conduct a foot exam in diabetic patients, or recommend or prescribe an indicated treatment for a specific condition. Increasingly, payers and providers are interested in additionally utilizing HRQoL measures that capture outcomes of care. The methodological issues related to the selection, administration, and use of PRO-PMs are beginning to be better understood [25, 26].
6. Clinical trials—Clinical trials that compare two (or more) treatments often include a HRQoL analysis as one means of determining overall clinical benefit, particularly when treatment-related side effects are considerable [27]. Compared with the control therapy, the alternative treatment option may be associated with a variety of combinations of relative survival benefit and HRQoL. Improvement in HRQoL as an endpoint in clinical research requires recruitment of sufficient numbers of subjects for a trial to have adequate power. Instruments measuring HRQoL with a limited coefficient of variation can decrease the size of a trial needed and offer an important advantage in this regard [28].
7. Health economics—HRQoL measures are useful in particular contexts when considering the resource allocation questions that health care decision makers face. In cost-utility analysis (CUA), the measure of clinical effects is adjusted to reflect the HRQL of the outcome. This is widely associated with the technique of calculating quality-adjusted life years (QALYs), where quality of life seems to provide a single standard means of expressing the results of health care interventions [29].

Selecting and Developing a Health-Related Quality of Life Questionnaire

Measuring HRQoL is about identifying and systematically quantifying symptoms and functioning that may be affected by a condition and/or a health care intervention [1, 27]. This can be done by using a questionnaire, where patients answer questions about aspects of their lives and their health.

In selecting a HRQoL questionnaire, it is important to identify the most relevant areas of health on which to focus. If a questionnaire includes everything then it may be very long and have irrelevant questions. This would take time for a patient to complete and some patients may have conditions that affect their ability to do this. It could also lead to missing data as patients could opt to skip irrelevant questions. On the other hand, if the focus is too narrow then we may fail to assess the full impact of a condition [30]. A vast array of validated and reliable questionnaires is available for assessment of HRQoL [31]. They include generic measures, specific measures, and combined instruments.

Generic measures—Generic health status questionnaires are applicable to all populations and can be completed by individuals both with and without medical illness [32, 33]. These questionnaires typically assess the individual's perception of the functional impact of the illness or disability and can be used to compare different illnesses, levels of disease severity, or types of interventions. Thus, to compare outcomes across different conditions, for example, to compare treatments for asthma and diabetes, a generic measure is needed that will focus on broader outcomes. Such cross-disease comparisons are increasingly important in the allocation of limited health care resources [32]. Examples include the Nottingham Health Profile (NHP) [34] and the Short Form-36 (SF-36) from the Medical Outcomes Study [35, 36], the Sickness Impact Profile (SIP) [37], and the Functional Assessment of Chronic Illness Therapy (FACIT) [38].

Specific measures—A condition-specific measure is useful for comparing outcomes within a condition, for example, to compare different drugs for depression, as the measure will focus on the specific symptoms associated with that condition [32, 33]. Disease-specific measures are designed to assess the HRQL of individuals with specific illnesses (e.g., cancer, diabetes), specific types of treatment (e.g., chemotherapy, lung transplant, palliative care), or specific symptoms (e.g., nausea, urinary incontinence). Compared with other types of instruments, these measures provide a more detailed assessment for specific diseases and are also likely to be more sensitive to specific treatment-related changes in HRQoL. Examples include the Diabetes Quality of Life instrument (DQOL) [39], the Functional Living Index—Cancer (FLIC) [40], the Functional Assessment of Cancer Therapy-General-7 (FACT-G7), and the European Organization for Research and Treatment of Cancer Quality of Life Core 15-Palliative Care (EORTC QLQ-C15-PAL) [41–44].

Combined instruments—One trend in HRQoL research is to combine generic and disease-specific instruments, in order to cover important areas fully that may have an impact on HRQoL. As an example, in one report of patients undergoing knee replacement surgery, the generic illness instrument was more sensitive to general health status and the presence of comorbidity, whereas the disease-specific measure was more sensitive to the degree of knee disability [45]. This approach is reflected in the work of the Patient-Reported Outcomes Measurement Information System (PROMIS) Cooperative Group, an NIH-funded national effort that has produced a comprehensive conceptual framework of self-reported health for adults and children [46, 47]. Developed with the input of hundreds of people with a wide variety of medical conditions, PROMIS instruments are applicable across chronic illness populations in addition to having cancer-specific instruments [48].

Therefore the issue of how to decide which questionnaire to use is often dictated by what we intend to measure, considering the advantages and disadvantages of generic and specific measures [1, 30] (Table 1). For example, in a clinical trial to assess a new drug for depression, we may be interested in how well the drug controls depression-related symptoms and thus can only rely on patient reports of relevant symptoms. Assessing a new type of knee replacement surgery may involve assessing the walking speed of a group that receives standard care versus a group that receives the new treatment. A patient may be concerned about the effect of his

Table 1 Advantages and disadvantages of generic and specific measures of health-related quality of life (HRQoL)

Type of HRQoL Measure	Advantages	Disadvantages
Generic measures	1. Generic measures cover important health-related quality of life domains. Outcomes can therefore be compared within and between conditions	1. Generic measures cover broad areas of health which may not be sensitive to specific symptoms. This may be because they are missing specific domains of health
	2. As generic measures cover several health domains, they can help identify which are the key domains affected by different conditions and/or interventions	2. Generic measures may not be useful to clinicians who are treating specific symptoms and are interested in whether certain symptoms have changed
	3. In some populations comorbidities are common and generic measures allow the assessment of the impact of more than one condition at a time	3. They may also not be acceptable to patients who may question the value of answering questions that are not related to their condition
	4. When assessing new interventions, generic measures can capture other additional benefits or adverse effects, which can be important as differences in choice of interventions may be due to fewer adverse effects caused by a new intervention	4. There are many generic measures available each with different domains and different scoring systems that make it difficult to compare across them
Specific measures	1. Condition-specific measures have the advantage of being specific and more sensitive to conditions which makes them more acceptable to patients and clinicians	1. Specific measures increase the lack of comparability across measures
	2. They are therefore useful in assessing the impact of a single condition or intervention(s) relating to that condition	2. They may exclude the impact of comorbidities and side effects

loss of hearing on his overall quality of life such as its impact on social functioning, role functioning (e.g., work), and feelings of anxiety. The government may be interested in assessing different interventions across different conditions in order to identify the ones that have the greatest impact on health-related quality of life and how society values this impact.

It's also important to consider that populations exist where self-reporting may not be appropriate or applicable [49]. These include the pediatric population and the elderly where proxy reporting may be used. However, the appropriateness of parental or proxy reporting has been questioned. This is because many HRQoL instruments include questions about emotional status or functioning, and it is not possible to state that what is experienced or felt by the patient is the same as what is perceived by the adult or proxy. The proxy can only make a judgment, and this judgment may be influenced by how important they judge the item to be. Differences between self- and proxy-reporting of health are widely recognized, and measures specifically for proxy report (in contrast to measures developed for patients but completed by proxies on the patient's behalf) have been developed [49–51].

Sometimes health professionals might be interested in developing a generic or specific HRQoL instrument once it has been determined that there is no available questionnaire for the evaluation purpose. Key considerations for developing a HRQL measure are:

1. Literature review—Developers should always review the literature first to see whether a HRQoL questionnaire already exists in the area they are interested in and if not, whether similar instruments exist that they could learn from or take items from for consideration. Even if there are no questionnaires in their area of interest, they could still obtain valuable data by conducting a literature review; for example, there may be a study that investigated quality of life in their population of interest but was not turned into a questionnaire [52].
2. Interviewing—Obtaining data directly from the population of interest is a valuable method of generating items for inclusion. The developer may wish to talk to patients, relatives, carers, doctors, nurses, or other health care professionals and could interview all of these, a mixture, or just one group. Once they have decided who to interview, they then need to decide how to interview. One-to-one interviews could be undertaken (e.g., face to face or over the telephone) or a focus group could be held: (1) one-to-one interviews can be useful in situations where the topic material might be more sensitive as patients are more likely to feel comfortable sharing experiences and views with one interviewer rather than in a larger group; (2) a focus group could contain a mixture of people, for example, patients, carers, and nurses, or just one group, for example, a group of patients. In a focus group, two researchers are generally needed to facilitate the group, with one taking responsibility for the discussions and one taking notes [52].
3. Selecting a response scale—HRQoL measures can differ in their response scale options. They may be based upon severity (how "bad" something is), frequency (how often something happens), or the level of agreement with something (strongly agree, strongly disagree). Response choices for each item may be: yes/no responses; a scale/range of responses, for example, "all of the time," "most of the time," "some of the time," "a little of the time," "none of the time"; rating on a numerical scale, such as 0–100. Response scale options are often arbitrary and chosen for their simplicity. They should be as relevant and refined as possible. Some HRQL measures keep the same response scales for every item in the instrument, whereas others vary [1].
4. Psychometric validation—A draft HRQoL measure can undergo preliminary testing to determine whether the items are relevant and whether any are redundant. This can be undertaken using a range of techniques including quantitative techniques such as factor analysis or perhaps further qualitative work with patients. Following this, it is important that the validity of the instrument is examined and its properties explored. This ensures that the measure assesses what it is intended to assess, and increases confidence in any results generated. This involves assessing the instrument for practicality, acceptability, reliability, and validity through a series of defined tests on the population group for whom the instrument is intended [1, 2, 27].

It is important to note that there is no gold standard methodology for the development of HRQoL questionnaires (although recently guidelines for the development and assessment of measures have been developed). There is also no gold standard for the psychometric testing of measures, either in terms of the tests used, or the measure or indicator that is used to assess other instruments against [1, 2, 27].

Another key issue is the translation and cultural adaptation of HRQoL instruments so that the measures can be used in cross-cultural settings [30]. It is important that the concept of each item is translated (rather than a direct linguistic translation), and both forward and backward translations are usually carried out by multiple translators. The translation is then assessed using a process known as "linguistic validation" that assesses the validity and conceptual equivalence of the HRQoL questionnaire among the target population (including clinicians working in the area), and subsequently allows for changes to be made to the translation if necessary.

Robotic Surgery for Abdominal Wall Hernia Repair: Immediate Results on Quality of Life

Abdominal wall hernia repair (AHR) is a common procedure, and it can be associated with significant complications, ranging from 10% to 60%, including surgical site infections, seromas, locoregional pain, bowel perforations, hernia recurrence, and some of them require reoperations [53–56]. These mediate and late complications may interfere with the quality of life of these patients [57].

Moreover, ventral hernia remains a wavering surgical problem from the defect severity and size, hernia type (primary vs. secondary), operative technical options (robotic, laparoscopy, open, reconstructive), mesh fixation methods (tacker, absorbable suture, fibrin sealant), mesh location (preperitoneal, interposition, onlay), and mesh type (lightweight vs. medium or heavy, biologic vs. synthetic) making investigations of general health-related quality of life measures difficult to assess and interpret across studies [54, 57–59]. For instance, some authors have found that in addition to an increased risk of seroma formation, longer operative time, and length of stay (LOS), patients with large hernia defects have more early postoperative pain and activity limitation than those with smaller hernia defects [60, 61].

The open AHR, with a simple suture closure, has been associated with a high rate of wound complications secondary to large flaps in the abdominal wall layers, as well as elevated recurrence rates between 25 and 63%. The open ventral hernia repair with mesh using a tension-free technique has decreased the recurrence rate from 40 to 10%, but it also increased the incidence of significant wound complications, including mesh infections [62]. Laparoscopic repair of abdominal hernia was introduced in 1992 by LeBlanc and Booth in order to improve recovery time, hospital stay, complication rates, and costs [61]. Published recurrence rates have been reduced from 9% to 0%. These recurrences have been attributed primarily to improper positioning of the mesh and to the use of tacking or stapling devices for fixation rather than abdominal wall suturing [60, 61].

The primary complications of laparoscopic ventral hernia repair, similarly to the open technique are seroma formation, wound infection, ileus, and hematoma. Although laparoscopic repair has been associated with faster recovery, fewer complications, and a lower recurrence rate compared to the open technique, there continues to be a significant incidence of postoperative pain associated with the transabdominal wall sutures or other fixative materials. Several authors have reported a 2% incidence of significant postoperative pain lasting more than 2–8 weeks after repair. Significant postoperative pain has also been described in association with helicoid staples tackers. Additionally, a randomized controlled study showed a significantly higher pain level with suture placement compared to tackers for mesh fixation [60–62].

The da Vinci robot (Intuitive Surgical, Sunnyvale, CA, USA) offers numerous advantages, including six degrees of motion, three-dimensional (3D) imaging, and superior ergonomics that enable easy and precise intracorporeal suturing. Previous reports have demonstrated the ease of intracorporeal suturing of the mesh to the abdominal wall. Possibly, patients with massive ventral hernias who should have increased rates of surgical complexity, higher rates of perioperative complications and recurrence, and reduced QoL postoperatively, may be the ones who would benefit the most from robotic surgery [63–66].

Up to now, there has been no study regarding QoL utilizing questionnaires after robotic surgery for AHR. Immediate and delayed postoperative complications such as seroma formation, infection, fistula formation, small bowel obstruction, and pain remain the focus of surgical outcomes following hernia repair, and affect the general QoL [53, 56]. Although these parameters are relevant in defining successful outcomes in AHR, patient-reported outcome as well as length of hospital stay and length of the operative time are also becoming equally relevant. Consequently, patient interpretation of improved HRQoL processes is becoming increasingly important in defining successful outcomes. Increasing emphasis is being placed on patient-reported HRQoL outcomes in decision making, clinical research, clinical practice, and policy. A shift towards HRQoL measures in calculating cost-utility analysis and healthcare reimbursements has brought these measures to the forefront of medicine [57].

New data in AHR are emerging in the current literature related to surgical outcomes [67], using HRQoL measures such as: SF-36, SF-12, SF-8 forms, visual analogue score (VAS; another psychometric assessment scale that uses different subjective characteristics that can be measured directly), HerQLes, EuraHS-QoL, Inguinal Pain Questionnaire, Ventral Hernia Pain Questionnaire or Carolinas Comfort Scale (CCS) [58, 62, 68–73] (Table 2).

The SF-36 survey is divided into eight measured scales that assess vitality, physical functioning, bodily pain, general health perceptions, physical role functioning, emotional role functioning, social role functioning, and mental health. The short-form surveys are criticized for their purpose of assessing QoL in patients with chronic diseases rather than those afflicted with acute disease processes such as illnesses requiring surgical intervention. Particularly in ventral hernias, criticism of the SF-36 has resulted in the development of other QoL assessment tools tailored for abdominal disorders such as the Gastrointestinal Quality of Life Index and the CCS for patients with abdominal mesh [62, 74].

Table 2 Comparative review of generic and specific health-related quality of life (HRQoL) questionnaires for abdominal wall hernia repairs

Instrument	Location	Classification	Questions	Use
SF36 [35]	All types of hernias	Generic	36-question	To assess the functional health states of large populations over time. Useful to compare outcomes across different populations and interventions, including cost-effectiveness studies
HerQLes [70]	Ventral hernias	Specific	12-question	To assess the impact of ventral hernia repair. Focus on abdominal wall function.
EuraHS-QoL [71]	Inguinal hernias	Specific	9-question	To assess patients before and after inguinal hernia repair. Needs further investigation as a tool in ventral or incisional hernia
Carolina Confort Scale [58]	Ventral/inguinal hernias	Specific	23-question	To evaluate QoL related to mesh after hernia repair. Cannot be administered preoperatively in the absence of mesh
Inguinal pain questionnaire [72]	Inguinal hernias	Specific	18-question	To evaluate pain and difficulties in performing activities after inguinal hernia repair
Ventral hernia pain questionnaire [73]	Ventral hernias	Specific	20-question	To evaluate QoL after ventral hernia repair

Given the increased focus on patient-measured satisfaction and QoL in health care and medical research, the CCS has been used to measure hernia-specific preoperative and postoperative QoL [69]. The CCS was first developed and validated in 2008 and has been shown to be superior to the short form 36 in measuring short- and long-term QoL. Since its inception, the CCS has been used in numerous peer-reviewed studies and is now the official metric for postoperative hernia QoL measurement by the governments of France and England. The CCS questionnaire is completed by patients before surgery to establish a baseline preoperative score and after surgery at 1-, 6-, 12-, and 24-month follow-up times to obtain short- and long-term QoL. The questionnaire addresses three primary areas of symptoms: pain, mesh sensation, and activity limitation. This is evaluated by answering seven

questions about activities of daily living on a 6-point Likert scale. Zero corresponds to no symptoms and 5 to disabling symptoms. Scores of 0–1 (mild but not bothersome) are classified as asymptomatic, whereas 2 (mild and bothersome) to 5 are classified as symptomatic. In addition, the patient QoL questionnaires are answered outside the office without the presence of the physician or office staff and returned with guaranteed anonymity to prevent expectation bias and reporter bias. Along with QoL, the questionnaire asked for symptoms of recurrence [67, 75].

Colavita et al. [68] found that, on the whole, when comparing laparoscopic to open AHR, early QoL (at 1 month) was worse in the laparoscopic group. In the open AHR cohort massive status resulted in a worse early QoL at 1 month for postoperative pain and activity limitation. Measure of QoL at the extended time points in these domains was not different according to the size of the repair, and, indeed, they continued to decrease as the follow-up periods extended to 2 years. Mesh sensation in the open group was no different at any time during the follow-up despite the meshes averaging 340 cm^2 larger in the massive hernia repair patients. Closure of the abdominal wall, which was achieved in 97.5% of open operations, may have impacted the patients' perception of the mesh in their abdomens. On multivariate regression controlling for age, gender, country, BMI, smoking, recurrent hernia, and preoperative pain, QoL at the same follow-up periods for both the laparoscopic and open cohorts remained significant. When comparing the massive versus the regular-sized hernias within the laparoscopic cohort, repair of massive hernias was more likely to impact QoL negatively compared to the laparoscopic repair of regular-sized hernias; this was true for pain and activity limitations up to 1 year and mesh sensation for the full length of the study [68].

Generally, the width/length ratio did a poor job in predicting postoperative complications, likely because small ovoid hernias may present with few complications, and can have the same ratio as massive ovoid hernias with many complications. The ratio cut points, however, did discriminate in early postoperative QoL, in particular a width/length ratio of 5 or more in open AHR predicted early symptomatic postoperative pain, activity limitation, and mesh sensation. Greater than 15-cm hernia defect in both dimensions result in the worst early postoperative QoL whether VHR is performed laparoscopic or open. Indeed, a massively wide and long hernia defect repaired laparoscopically has a 100% chance of resulting in symptomatic postoperative pain and activity limitation at 1 month [55].

Although laparoscopic surgery has been advocated to decrease hospital stay, decrease postoperative pain, and reduce incision size, the gold standard for repairing a ventral hernia remains controversial [61, 63]. The efficiency and efficacy of robotic versus laparoscopic repair compared to the open technique is lacking [60, 61]. It is still unclear if one method of repair is superior to the other, and it is unknown if one repair method is more appropriate to certain types of hernia in comparison to the other, regarding QoL evaluation. The clinical guidelines of the Society for Surgery of The Alimentary Tract (SSAT 2005) showed that a hernia of less than 3 cm can be repaired primarily without the use of the prosthetic mesh, and any hernia where extensive tissue dissection is required such as in component separation technique is then qualified for open repair, yet any other hernia types that do not fall

in the above category can be considered where possible for laparoscopic repair [69]. Hence, the success of the repair needs to address the guidelines, taking into consideration the individual circumstances of each hernia, and to plan in advance the best method of repair. Additionally, the current evidence available looks at the best method of repair with various outcomes including recurrence rate, the costs involved, postoperative complications, and long-term results [62, 69, 76].

Results showed less wound infection rate, less hemorrhage, and earlier return to work by almost 50%, but the laparoscopic repair carries a higher rate of bowel injury with 2.9% compared to only 0.9% in the open group [60, 61]. Therefore, the study concluded that laparoscopic repair is still as safe as the open conventional repair and open repair has rather significant advantages of less small bowel injury and seroma formation. Furthermore, recent researchers have shown that laparoscopic incisional hernia repair is far better than open hernia repair in the short-term outcomes such as blood loss, surgical site infection, and hospital stay, with earlier return to work [60, 61].

These data might be extrapolated to robot-assisted surgery because compared to traditional laparoscopy, the addition of robotic technology allows for six degrees of motion, three-dimensional imaging, and superior operator ergonomics [63, 64]. These features enable the ability to perform intracorporeal suturing easily. When applied to AHR, use of the robot allows for the ability to suture mesh to the anterior abdominal wall, a task very demanding with laparoscopy alone [63, 64]. There is less abdominal wall trauma and postoperative pain at the working trocars ports as the fulcrum is not entirely at the abdominal wall but the endowrist of the instruments. Intracorporeal suturing of the fascia allows the midline to be approximated, allowing possible primary repair, more physiological abdominal wall movement, and greater overlap of the mesh to the defect's fascial edges. Robot-assisted laparoscopic AHR offers yet another advantage by providing the suturing option under excellent visualization for the repair of difficult hernias with bony or muscular margins, such as lumbar, suprapubic, and subcostal hernias. Several of our patients had hernias on or near lateral borders of the abdomen, making mesh fixation with tackers difficult. This allows the surgeon to take precise bites of tissue to anchor the mesh properly [76, 77].

Limitations of this robot-assisted technique are noticeable. Large ventral hernias as they approach the working ports and camera make this technique technically challenging. In addition, obese patients pose a challenge preoperatively because it may be difficult to determine the ideal trocar placement [76].

As we have mentioned, there is a paucity of QoL studies in the literature regarding robotic treatment of AHR. In one study, 72 patients were identified during the study period. Thirty-nine patients underwent robot-assisted repair, compared to 33 patients who underwent laparoscopic repair. Of the robot-assisted patients, 21 patients presented with umbilical hernias, 14 with epigastric, and 4 with incisional. Of the laparoscopic repairs, 27 patients presented with umbilical hernias and 6 with epigastric. There was no significant difference in patients requiring postoperative admission between the two groups (robot 14 vs. laparoscopic 7). Of the patients who required admission, there was no significant difference in mean length of stay

[robot: 0.49 days (0–3 days), laparoscopic 0.21 days (0–1 days)]. There was also no significant difference in the overall postoperative complication rate between the two groups (robot: 7.7%, laparoscopic 9.1%). Overall, three patients developed postoperative urinary retention: two in the robot group and one in the laparoscopic group. One patient in each group developed a clinically significant hematoma. One patient in the laparoscopic group developed a clinically significant wound infection. No recurrences have been reported, although the mean duration of follow-up was only 47 days [65].

In one multi-institutional case series, medical records of consecutive patients (including surgeon's learning curve cases) who underwent ventral or incisional hernia repair utilizing the da Vinci Surgical System (Intuitive Surgical Inc., Sunnyvale CA) were retrospectively reviewed. Data collected included preoperative history and perioperative outcomes. Data for a total of 368 patients from four institutions involving five surgeons were analyzed. They were predominantly females (60.3%), and the mean age was 51 years. The majority of the patients were obese or morbidly obese (47.8% and 20.9%), and 83.2% of the patients had a history of prior abdominal operation. Conversion rate was 0.8%, and mean length of stay was 1 day. Total postoperative complications rate up to 30 days was 8.4%, of which incidence of paralytic ileus was 2.4%. This large case series of 368 patients demonstrates reproducibility of safety and performance associated with robotic-assisted ventral hernia repairs performed by five surgeons at four institutions. In addition, the results of short-term perioperative outcomes for surgeons during their early experience for robotic-assisted cases are in the range of what is reported in the existing published data on laparoscopic and open ventral hernia repairs [64].

Conclusions

Several factors may influence QoL after AHR including pain, mobility impairment, cosmetics, and length of convalescence. In addition, patient-reported outcome results are not only important to the patient, but also a factor highly relevant in the ongoing cost-effectiveness debate.

There are several standardized methods for examining QoL after incisional hernia repair, both generic and disease specific. Presently, however, little consensus on either the optimal method or timing of the measurement exists, calling for international guidelines on this topic, to enable comparison across the different studies [78, 79].

Robotics has a significant potential to enhance the overall capacity and efficiency of AHR. Robots can help surgeons perform better quality operations, leading to reductions in the hospitalization time and in the impact of surgery on their postoperative QoL. However, the investigators will have to show an improvement by robotic AHR, for example, lower recurrence rate or less pain to justify such expensive procedures. In addition, the robot could provide the surgeon with increased comfort, better posture, and decreased cognitive and/or physical stress.

Although current robots have known disadvantages—notably the visualization of large areas and working in different abdominal regions is still difficult, both of which are required for laparoscopic AHR—robots will improve significantly by introducing novel technologies to enable the surgeon to benefit from their advantages and potentially allow their widespread use for AHR [63].

Further comparative evidence initiatives have to be pursued to determine the benefits of robotic-assisted techniques and technology in the short and long term, and patient-reported outcomes in AHR.

Additionally, we have to remember that the robot is merely an advanced instrument, but the surgeon's judgment and technique are ultimately responsible for the outcome of the operation and for the QoL of the patient.

Concluding Remarks

- Abdominal wall hernia repair (AHR) is a common procedure and several factors may influence the QoL.
- There are many standardized methods for examining QoL after incisional hernia repair and little consensus on either the method or timing of the measurement.
- Robotics has a significant potential to enhance the overall capacity and efficiency of AHR.
- Further comparative evidence initiatives have to be pursued to determine the benefits of robotic-assisted hernia repair.
- The robot is merely an advanced instrument, but the surgeon is ultimately responsible for the outcome of the operation and QoL.

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Anatomical Dissection for Adhesions

Ricardo Z. Abdalla and Danniel Frade Said

Key Points Summary

- Cell–cell adhesion and communication
- Adhesion concept: normal, expected, and nonphysiological
- Prevention and complications in surgery
- How to treat, treatment options, and instrument facilitator
- Laparoscopic adhesiolysis; laparoscopic robot-assisted adhesiolysis

Introduction

Adhesion of like cells is a primary feature of the architecture of many tissues [1]. The tissue adhesion mechanisms involve not only cell-to-cell interactions but also cell–matrix interactions. Most structures are surrounded or underlain by an extracellular matrix of collagen fiber, glycoproteins, and multiadhesive matrix proteins [2]. The functionality of these structures organizes functions, interactions, tissue pathways for cell growth, proliferation, and gene expression [3]. Some of these adhesions become particularly strong or even weak and won't work for the benefit nor jeopardy to the body. There are many factors influencing these cell adhesion molecules. These cells are activated by various inflammatory signals released by

Electronic Supplementary Material: The online version of this chapter (doi:10.1007/978-3-319-55527-0_10) contains supplementary material, which is available to authorized users.

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R.Z. Abdalla, T.N. Costa (eds.), *Robotic Surgery for Abdominal Wall Hernia Repair*, DOI 10.1007/978-3-319-55527-0_10

surrounding cells in areas of infection or inflammation after surgical trauma and stress [4, 5].

Intra-abdominal adhesions after surgery may occur as normal recovery or can lead to complications as obstruction, pain, emergency, or anatomical limits for normal life [6]. Although the exact pathological mechanisms have not been fully elucidated, surgical trauma, infection, tissue ischemia, and foreign bodies are some of the reasons to induce fibrin deposition. Some experimental laboratory models suggested acute peritoneal inflammation after CO_2 pneumoperitoneum depending on the insufflation pressure and surgery duration [7, 8]. The peritoneum suffers an imbalance between fibrin forming and fibrin dissolving, which results in the postsurgical adhesions [9]. To avoid this formation as much as possible surgical prevention is an important rule [10, 11]. Adhesions were found in 28% of cadavers with no preceding abdominal surgery, and in those that had had abdominal surgery 67% had adhesions. Laparotomy is the standard access for obstructive acute abdomen with suspicious small bowel adhesion [12]. Adhesional small bowel obstruction is an emergency condition that has high-risk distention to get into during a laparoscopy and/or robot-assisted procedures [13–15]. Adhesions related to prior hernia surgery account for 10% of small bowel obstruction and are often associated with strangulation. Despite laparoscopic adhesiolysis not being recommended (evidence level 4) as an alternative to the laparotomic approach for small bowel obstruction (recommendation C grade), several studies have demonstrated laparoscopic surgery is a safe and acceptable alternative even for more complex small bowel obstruction [16].

Adhesion per se is a nonemergency condition [17]. The intra-abdominal contents are adhered but well compensated. The bowel is working and despite adhesions, bowel propulsion (intestinal transit) is normal. Considering getting into this abdomen requires patience and strategy to stay away from the previous surgical area. One can choose laparoscopy and/or a robot-assisted approach for adhesiolysis with hernioplasty treatment [18]. Laparoscopic pneumo dissection is a facilitator and efficacious technique for rapid blunt and scissors-cut tissue dissection. CO_2 pneumoperitoneum needs to be slow and progressively obtained, though. Technical tips are provided by commonly encountered adhesions during other routine laparoscopic procedures in nonemergency patients. Benefits are earlier return of bowel function, better respiratory postoperative recovery, respecting the integrity of the abdominal wall, avoiding further defects, and a shorter hospital stay [19].

Surgical Technique

The proposal is to achieve pneumoperitoneum with a Veress needle puncture on the left upper quadrant (LUQ, Palmer's), 2 cm below the left costal margin at an imaginary line from the middle of the clavicle (Fig. 1). The Veress must be free during circular limited movements around its axis. With a good amount of pneumoperitoneum, depending on the patient, an optical viewer trocar is placed on the left flank. This can be done with straight 0° or 30° optic, with a direct view 5 mm trocar inserted with a 5 mm optical camera (with or without CO_2 inflation), 2 cm below the

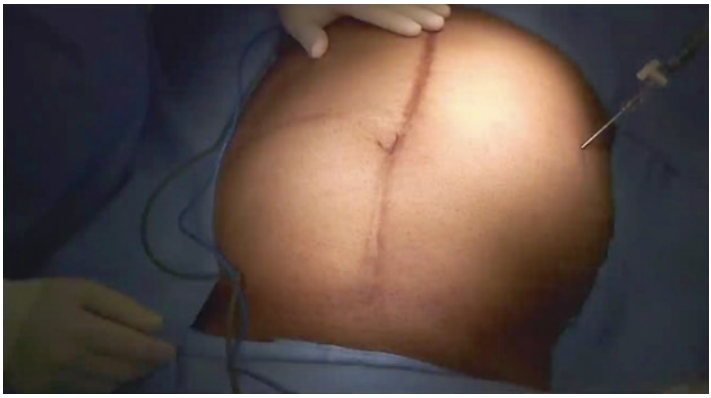

Fig. 1 Pneumoperitoneum: Veress needle

left costal margin at an imaginary line from the anterior axilla, watching each layer to be trespassed. Skin, fat, Scarpa, fat, external oblique, internal oblique, transversus, and peritoneum are normally seen before entering the cavity. When in the peritoneal cavity one must review the wall around the trocar, which must be transparent, using a 30° scope, going around 190° upper and lower vision against the proximal wall. {NOTE: Laparoscopic entry: A review of techniques, technologies, and complications, SOGC clinical practice guideline No. 193, May 2007}. Defects and adhesions are recognized at this point.

The other cannulas, one for the robotic optic and two for work arms, are located under direct view, preferably 20 cm away from the main adhesion point or center, calculating enough space for instruments to begin work (Fig. 2a, b). They could be in one lower quadrant, left or right with the camera in the middle or with the camera on the corner of the abdomen on the left lower quadrant between two robotic arms, one on the left flank and the other on hypogastrium, 2 cm above the pubic bone. At this position we can almost do any adhesiolysis with defect suturing. Docking for this rational is from the left shoulder or from the head. The initial steps of this dissection have the image pretty close to the camera. The adhesions are penetrated by the CO_2 and the limits from the bowel seromuscular layer and abdominal wall appear isolated for safe dissection. Electric cautery must be avoided. We used a bipolar fenestrated instrument on the left hand and a monopolar scissor on the right. The scope is 30° up view at this time.

During this total adhesiolysis an inadvertent or even strategic bowel opening must be immediately closed by suture (Fig. 3a–c). These lesions can become completely hidden afterwards if left to be treated at the end. All the instruments' movements should point the anterior abdominal wall; it looks like a painter painting the ceiling lying on a flat scaffold. All the traction is over a slight angle, almost parallel to the inverted surface, to expose adhesions for the scissor lamina to work, blunt and sharp dissections. It is a step-by-step procedure when the adhesion is too firm (Fig. 4). The camera is very close at these moments (Fig. 5). The patient-side surgeon must help push the abdominal wall to produce a flat condition for dissection,

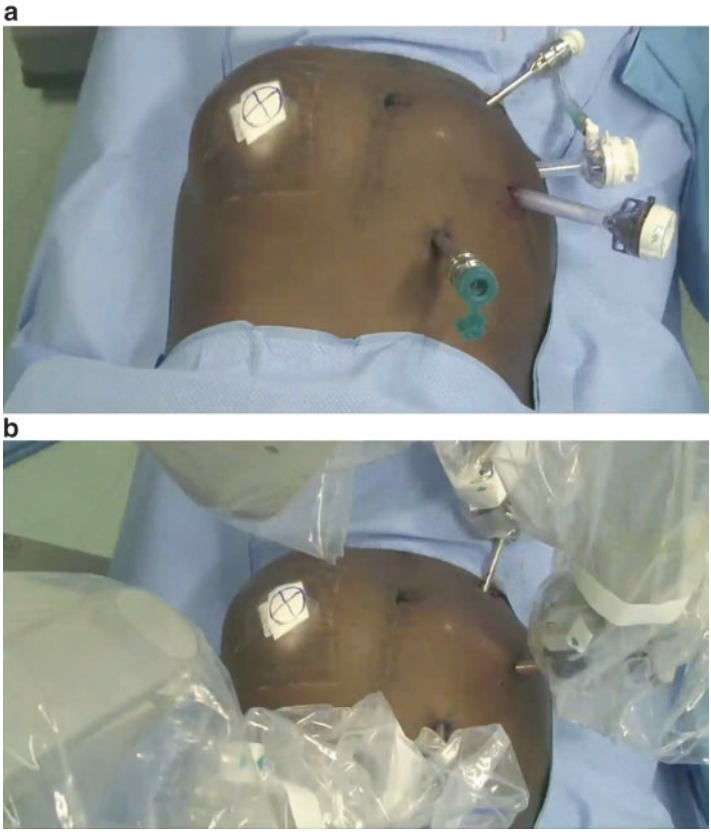

Fig. 2 (**a**) Trocars positioning: before docking. (**b**) Trocars positioning: after docking

sometimes bringing the hernia contents to the camera view or against the instruments' tip reach (Fig. 6).

Summary

Adhesions are common findings in abdominal surgery and even in surgery-virgin patients. They are not an emergent condition; they can occur as normal recovery, however, they can present as complications such as bowel obstruction, pain, or other emergencies [6]. When needed, minimally invasive surgery can help with the use of the pneumoperitoneum and better postoperative outcomes [20]. Robotic surgery with 3D view and articulated movements could facilitate this type of procedure even more [18], although care must always be taken to diminish the rate of conversion [21].

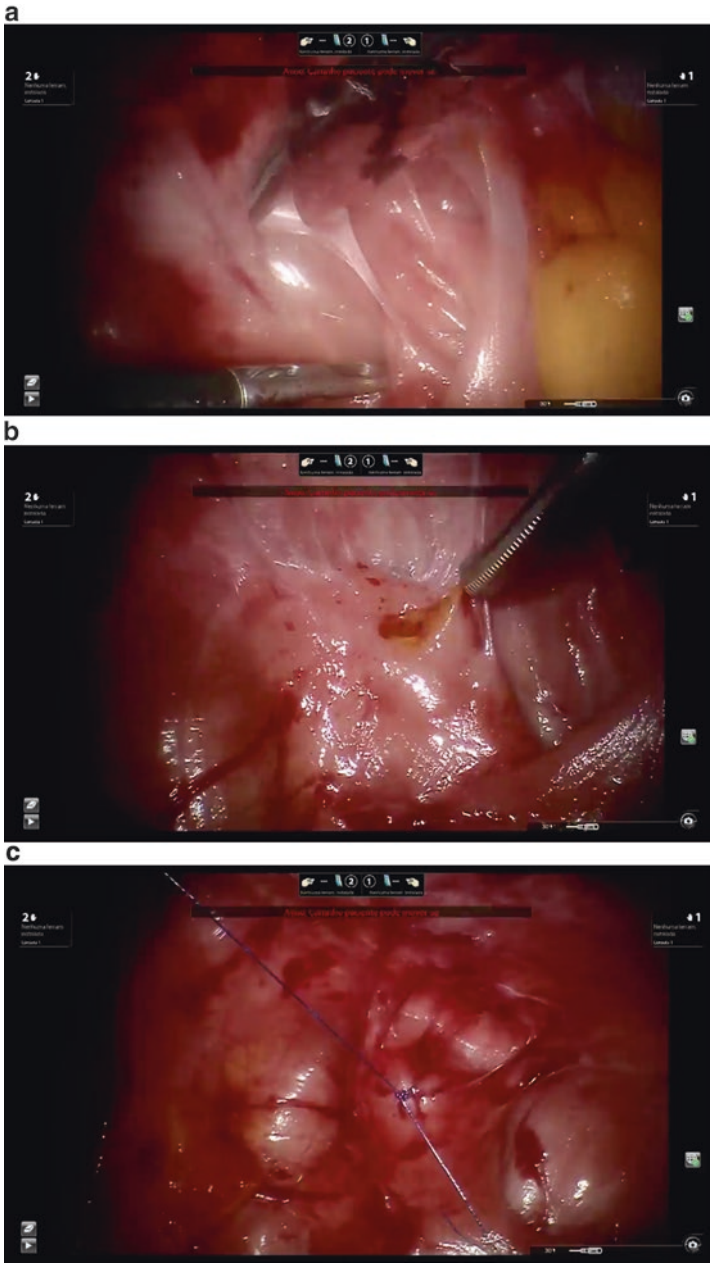

Fig. 3 (**a**) Adhesiolysis: traction and contra-traction. (**b**) Adhesiolysis: bowel injury. (**c**) Adhesiolysis: bowel repaired after injury

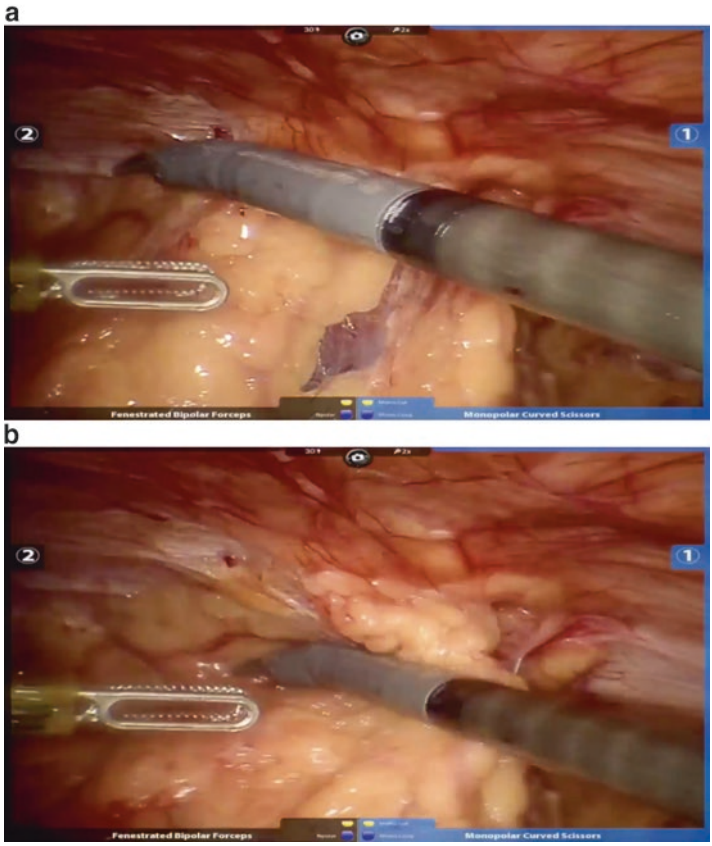

Fig. 4 (**a**) Adhesiolysis: instruments usage. (**b**) Adhesiolysis: instruments usage

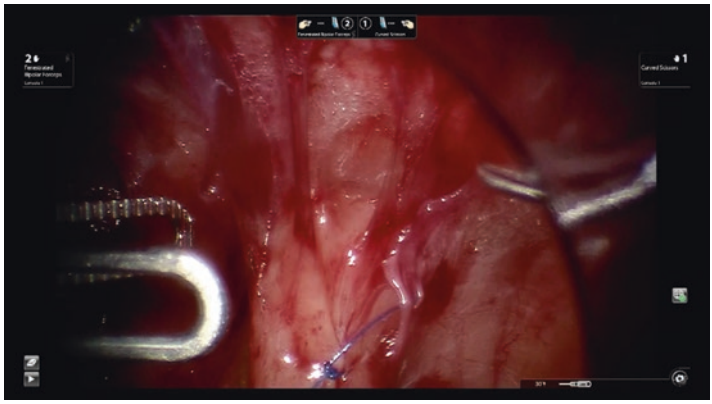

Fig. 5 Adhesions close to the camera

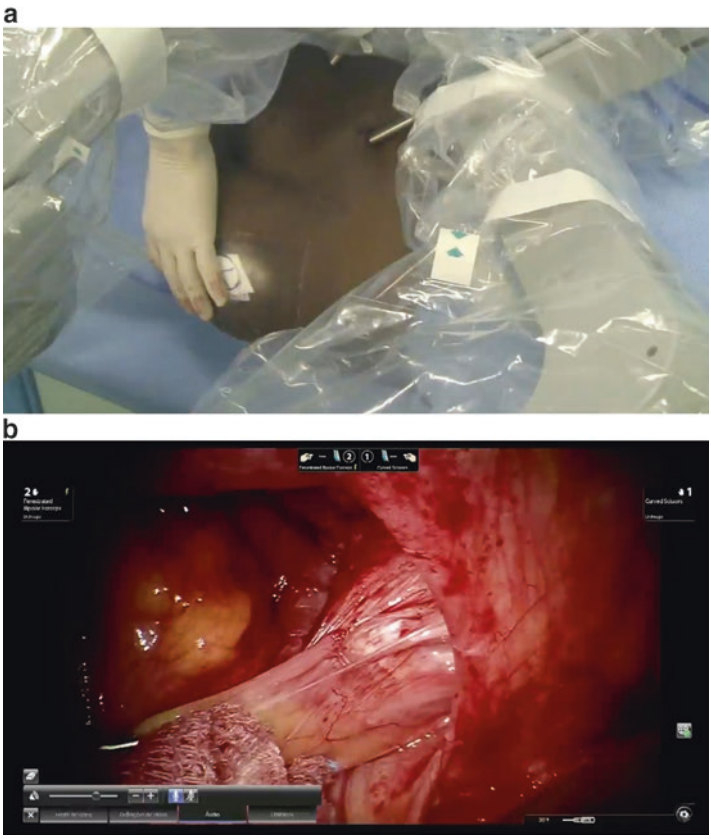

Fig. 6 (**a**) Assistant's help: inside view. (**b**) Assistant's help: outside view

Concluding Remarks

- Robotic adhesiolysis is an evolution in minimally invasive procedures for such complex situations.
- It needs persistence and patience to achieve a comfort zone.
- The most important surgical time for the procedure is its preoperative plan and it depends on the characteristic of each patient and each disease. Each patient is his or her own hypothesis creator; we must separate patients instead of classifying them to one standard.
- We must release all adhesions before defect repair. We must reach an open wide cavity with any bowel lesion treated before hernia repair.

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Miscellaneous: Meshes and Sutures

Marcelo Furtado

Key Points Summary

- Mesh repair is now standard in most countries and widely accepted as superior to primary suture repair.
- Tissue incorporation of a synthetic mesh is the goal and it depends upon many factors.
- The most important properties of meshes are the type of filament, tensile strength, and porosity.
- The choice of suture is determined by a balance of the various characteristics of suture materials most appropriate for the specific wound closure situation.

Meshes

The concept of using a mesh to repair hernias was introduced over 50 years ago. Until the 1960s, abdominal wall hernias were closed with primary suture repair. In 1958, Usher published his technique using a polypropylene mesh. This led to the Lichtenstein repair some 30 years later which popularized mesh for hernia repair. Mesh repair is now standard in most countries and widely accepted as superior to primary suture repair. Currently, about one million meshes are used per year worldwide [1]. As a result, there has been a rapid growth in the variety of meshes available and choosing the appropriate one can be difficult.

Nylon was the first plastic material used as a suture and was later woven into a mesh prosthesis for hernia repair [2]. Nylon was not suitable in hernia repair because

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R.Z. Abdalla, T.N. Costa (eds.), *Robotic Surgery for Abdominal Wall Hernia Repair*, DOI 10.1007/978-3-319-55527-0_11

it lost strength over time due to hydrolytic digestion and it required explantation if infected. Koontz et al. [3], in 1959, proposed the search for a nonmetallic, synthetic, nonabsorbable material that was resistant to infection. Since the studies of Koontz and the introduction of polypropylene (PP) in 1962, five different material groups have become available for hernia repair and abdominal wall reconstruction: PP, polytetrafluorethylene (PTFE), expanded-polytetrafluorethylene (ePTFE), polyester (POL), and the most recently, polyvinylidene fluoride (PVDF) [4].

Polypropylene is a hydrophobic polymer of carbon atoms with alternating methyl moieties. This material is flexible, strong, easily cut, readily integrated by surrounding tissues, and resists infection. The monofilament nature provides large pores facilitating fibrovascular ingrowth, infection resistance, and improved compliance. PP remains the most popular material in mesh hernia repair [4, 5].

PTFE is a chemically inert synthetic fluoropolymer that has a high negative charge, therefore water and oils do not adhere to it. This material does not incorporate into human tissue and becomes encapsulated. Poor tissue incorporation increases hernia recurrence and an infected PTFE mesh must be explanted. PTFE is microporous, which allows bacteria passage but prevents macrophage passage; therefore the body cannot clear the infection [6, 7]. PTFE was expanded to be improved, and it became a uniform, fibrous, and microporous structure with improved strength called ePTFE. Although it is not incorporated into tissue and has a high incidence of seroma formation, ePTFE remains inert and produces little inflammatory effects, which allows it to be placed directly on viscera.

POL is a carbon polymer of terepthalic acid and can be fashioned into strong fibers suitable to be woven into a prosthetic mesh. It is a hydrophilic material and is degraded by hydrolysis. The latest material developed is a PVDF monofilament, a synthetic yarn made from polyvinylidene fluoride. Its diameter is between 0.085 and 0.165 mm. It is an extremely ageing-resistant, thermoplastic fluoroplastic with suitably adapted elasticity.

The original logic behind using a mesh was very simple: the mesh was a material that could be used to reinforce the abdominal wall with the formation of scar tissue. It was expected that the best meshes would be those made of very strong material and able to induce the most fibrosis. A synthetic mesh should be biocompatible, strong, resistant to infection, nonimmunogenic, minimally bioreactive, and easy to manipulate and cut, particularly for laparoscopic and/or robotics surgery.

Tissue incorporation of a synthetic mesh is the goal and depends upon the material, density, three-dimensional construction, filament type, pore size, compliance, and electric charge [4].

The physical or mechanical properties of mesh materials are (terms and definitions):

The American Society for Testing and Materials specification D4850 defines terminology related to textile fabrics.

Weight: Measurement of the "heaviness" or "heft" of the material, weight/unit area

Shrinkage: Dimensional decrease in length or width of a material

Strain: Deformation of a material in response to an applied force, force/unit area

Tensile strength: Maximum stress that a material subject to a stretching load can withstand without tearing or breaking

Burst strength: The maximum uniformly distributed pressure applied at right angle to its surface that a material will withstand under standardized conditions pressure/unit area.

Elasticity: Property of a material whereby it changes its shape and size under the action of opposing forces, but recovers its original configuration when the forces are removed.

Stiffness: Ratio of steadily increasing or decreasing force acting on a deformable elastic material to the resulting displacement or deformation.

Compliance: Unit displacement or deformation of a material as the result of application of a unit force.

Isotropy: When a material does not exhibit differences in properties based on the direction of the applied load, the material is said to be isotropic.

These same terms are also used in description, testing and performance of mesh materials [8].

The most important properties of meshes were found to be the type of filament, tensile strength, and porosity. These determine the weight of the mesh and its biocompatibility. The tensile strength required is much less than originally presumed and lightweight meshes are thought to be superior due to their increased flexibility and reduction in discomfort. Large pores are also associated with a reduced risk of infection and shrinkage.

Calculations of intra-abdominal pressures proved that this would be possible without compromising mesh function. In fact, the tensile strength of a mesh required to withstand the maximum abdominal pressure is only a tenth of that of most meshes (Fig. 1). This realization led to the concept of lightweight meshes.

Lightweight meshes were first introduced in 1998 (Vypro) and their superiority over the heavyweight meshes is now widely accepted. These meshes have large pores (normally 3–5 mm) and a small surface area. They stimulate a reduced

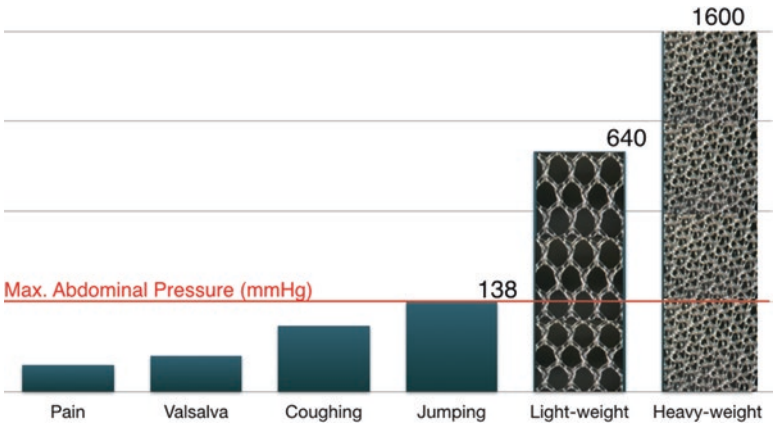

Fig. 1 Comparison of mesh (light- and heavyweight) strength with abdominal wall pressures

inflammatory reaction and, therefore, have greater elasticity and flexibility [9]. They also shrink less and have been shown to decrease pain after Lichtenstein inguinal hernia repair. Unfortunately, despite these improvements, they continue to have complications such as recurrence, infection, and adhesion formation.

The maximum intra-abdominal pressures generated in healthy adults occur while coughing and jumping (Fig. 1). These are estimated to be about 170 mmHg [10]. Meshes used to repair large hernias therefore need to withstand at least 180 mmHg before bursting (tensile strength up to 32 N/cm). This is easily achieved as even the lightest meshes will withstand twice this pressure without bursting (e.g., burst pressure of Vypro = 360 mmHg [11]. This illustrates that the tensile strengths of 100 N/cm of the original meshes were vastly overestimated.

Porosity is the main determinant of tissue reaction. Pores must be more than 75 μm in order to allow infiltration by macrophages, fibroblasts, blood vessels, and collagen. Meshes with larger pores allow increased soft tissue ingrowth and are more flexible because of the avoidance of granuloma bridging. Granulomas normally form around individual mesh fibers as part of the foreign body reaction. Bridging describes the process whereby individual granulomas become confluent with each other and encapsulate the entire mesh. This leads to a stiff scar plate and reduced flexibility. It occurs in meshes with small pores of less than 800 μm.

The weight of the mesh depends on both the weight of the polymer and the amount of material used (pore size) [12].

Heavyweight meshes use thick polymers, have small pore sizes, and high tensile strength. These meshes typically weigh 100 g/m^2 (1.5 g for a 10 × 15 cm mesh). The strength is derived from a large mass of material, which activates a profound tissue reaction and dense scarring.

Lightweight meshes are composed of thinner filaments and have larger pores (>1 mm). Their weight is typically 33 g/m^2 (0.5 g for a 10 × 15 cm mesh). They initiate a less pronounced foreign body reaction and are more elastic. Despite a reduced tensile strength, they can still withstand pressures above the maximum abdominal pressure of 170 mmHg (minimum tensile strength 16 N/cm).

A new generation of even lighter meshes includes the titanium/propylene composite meshes. These have been shown to be associated with a more rapid recovery in a recent, randomized controlled trial (RCT) [13]. The lightest of these (Extralight TiMesh) may have insufficient tensile strength in some situations (maximum tensile strength 12 N/cm).

Numerous randomized prospective trials have evaluated lightweight versus heavyweight mesh in ventral hernia repair with equal outcomes in ventral hernia repair recurrence [14–16]. The choice between a lightweight and heavyweight mesh is multifactorial and superiority has yet to be proven.

Shrinkage occurs due to contraction of the scar tissue formed around the mesh. Scar tissue shrinks to about 60% of the former surface area of the wound [11]. The smaller pores of heavyweight meshes lead to more shrinkage due to the formation of a scar plate.

The popularization of laparoscopic intraperitoneal mesh placement has led to increasing concern regarding mesh-related adhesions. Adhesions result from the fibrin exudates that follow any kind of trauma. These exudates form temporary

adhesions until the fibrinolytic system absorbs the fibrin. Absorption is delayed in the presence of ischemia, inflammation, or foreign bodies (e.g., meshes). In these situations, they mature into tissue adhesions.

All meshes produce adhesions when placed adjacent to bowel, but their extent is determined by pore size, filament structure, and surface area. Heavyweight meshes induce an intense fibrotic reaction that ensures strong adherence to the abdominal wall but also causes dense adhesions. In contrast, microporous ePTFE does not allow tissue ingrowth. It has a very low risk of adhesion formation, but is unable to adhere strongly to the abdominal wall.

These two extremes illustrate the difficulty of producing a mesh that will adhere well to the abdominal wall but not to the bowel. Composite meshes aim to do this by providing an additional surface that can be safely placed in contact with bowel while peritoneal mesothelial cells grow over the mesh. These combine more than one material and are the basis of most new mesh designs. The main advantage of the composite meshes is that they can be used in the intraperitoneal space with minimal adhesion formation. They require a specific orientation: the visceral side has a microporous surface to prevent visceral adhesions, whereas the nonvisceral side is often macroporous to allow parietal tissue ingrowth. Despite the vast selection of brands available, nearly all these meshes continue to use one or another of three basic materials; PP, POL, and ePTFE, which are used in combination with each other or with additional materials such as titanium, omega 3, monocryl, polyvinylidene fluoride (PVDF), and hyaluronate. However, all of them come with some disadvantages, contrary to the manufacturers' literature [4, 17].

There are two categories of composite meshes: absorbable and permanent. Barrier coatings in absorbable composite meshes require hydration prior to usage, and they are not amenable to modification, so they cannot be cut. However, they allow for neoepithelialization of the mesh before visceral adhesion, which mitigates viscera–mesh-related complications, and can aid in tissue ingrowth. Parietex® composite mesh was the first to offer a resorbable collagen barrier on one side to limit visceral attachments and a three-dimensional polyester knit structure on the other to promote tissue ingrowth and ease of use. The collagen film is composed of glycerol, polyethylene glycol, and porcine collagen. This balance of material properties produces superior cellular proliferation when compared to PP mesh in vitro and works with the body's natural systems to provide rapid fibrous ingrowth, minimal shrinkage, and strong tissue integration [18, 19].

Permanently combined meshes take advantage of the properties of both macro- and microporous meshes. A microporous mesh permits placement adjacent to viscera, whereas macroporous mesh promotes parietal tissue ingrowth. These meshes can be modified and are easily cut to fit specific applications. They have also been demonstrated in animal models to lessen visceral adhesions and complications [20]. These properties permit intraperitoneal placement (e.g., Dual Mesh®, Dulex®, and Composix®).

There are also absorbable synthetic meshes that are used in contaminated cases where primary abdominal closure is not feasible. These absorbable materials provide a lattice for new collagen formation and then become absorbed, thus they are not suitable for permanent hernia repair. The recurrence rate is >50%, but whatever

Mesh	Material	Absorption	Pros & Cons
Multi			
Vypro®, Vypro II®	PP - Polyglactin 910	Partially (42 days)	First lightweight mesh with large pores, Vypro is not suitable for ventral hernia repair
Dual Mesh®	ePTFE	No	Pore sizes are different on each side
Parietex®	POL - Collagen	Partially (20 days)	Short term benefit for anti-adhesional property
Mono			
Composix®	PP - ePTFE	No	Overlap of ePTFE stops adhesions at the edges
Proceed®	PP - Cellulose (ORC)	Partially (<30 days)	Oxidised cellulose is absorbable, polydioxanone film is not absorbable
Dynamesh®	PP - PVDF	Partially	PVDF causes minimal foreign body reaction
Sepramesh®	PP - Sodium	Partially (<30 days)	Seprafilm turns to gel in 48 h, and remains on mesh for 1 week to allow re-epithelisation
Ultrapro®	PP - Polyglecaprone	Partially (<140 days)	Monocryl has less inflammatory response than Vicryl
Ti-mesh™	PP - Titanium	No	Reduced inflammatory response compared to other meshes
C-Qur®	PP - Omega 3	Partially (120 days)	Short term benefit for anti-adhesional property

Fig. 2 A list of composite meshes (for intraperitoneal use) and their characteristics

recurrences develop could be repaired at a later date with a nonabsorbable mesh. Dexon® (polyglycolic acid) and Vicryl® (polyglactin 910) are examples of such meshes (Fig. 2).

Laparoscopic and Robotic Suture Materials

Suturing and knot tying in laparoscopic and da Vinci robotic surgery constitute advanced minimally invasive surgery skills. Developing proficiency in the standard methods with needle drivers is often an arduous process because of loss of tactile feedback. In laparoscopic surgery limited tactile feedback is present but in robotic surgery tactile feedback is replaced by haptic feedback. Recent advances in laparoscopic and robotic instrumentations have presented surgeons and gynecologists with easier methods of suturing and tying. The evolution of laparoscopic and da Vinci robotic surgery has expanded to more advanced and complex general surgery, and urological and gynecological procedures. For patients to get benefit from minimal access surgery surgeons must first develop and become expert in those laparoscopic surgery skills necessary for these advanced operations. Suturing and knot tying are among these advanced minimally invasive surgery skills required for many complex procedures. Developing proficiency in the standard methods of minimal access surgical suturing and knot tying with needle drivers may often be an arduous process [21].

The choice of suture is determined by a balance of the various characteristics of suture materials most appropriate for the specific wound closure situation.

Absorbable Versus Nonabsorbable

The major subdivision of sutures is important to understand. Sutures that lose the majority of their tensile strength within 60 days are considered absorbable sutures. The absorbable sutures are degraded by tissue enzymes or hydrolysis.

- The absorbable sutures in laparoscopic surgery are generally used as deep sutures; they do not need to be removed postoperatively, such as in myomectomy or intestinal anastomosis.
- The nonabsorbable sutures in laparoscopic surgery are used for reconstructive surgery and where manual removal of sutures postoperatively is not required, because it is not possible in minimal access surgery.

Tensile Strength

Depending on size (thickness) laparoscopic surgeons prefer to use the smallest size that will provide adequate strength. It is important to have less foreign body load on the tissue. The strength increases as the first digit decreases.

- 3-0 is a thick strong suture used for fine surgery in laparoscopic surgery.
- 6-0 is a thin comparatively weak suture used for ultrafine surgery such as tubal recanalization surgery.

Plasticity and Elasticity

In laparoscopic surgery the ability to retain length and strength after stretch and the ability to regain its original length after stretch, respectively, are very important. Laparoscopic instruments are always insulting the tissue because of tactile feedback. The laparoscopic surgeon should try to respect sutures as much as possible. This is important:

- To accommodate postoperative edema without cutting into the tissue
- To maintain epidermal approximation once the edema has resolved.

Ease of Handling and Knot Security

It is important for laparoscopic surgeons to keep in mind the coefficient friction of sutures. Ease of handling and knot security are determined by a number of related characteristics.

- A suture with a low coefficient of friction generally slides through tissue well but the knot will unravel more easily.
- A suture with a high memory will spring back to its original position and it is difficult to use this type of suture in laparoscopic surgery. Although nonabsorbable sutures such as Prolene sutures tend to be strong, they may be difficult to handle and have decreased knot security.
- A suture with high pliability can be easily bent, and will therefore handle well in laparoscopic surgery with good knot security.

Multifilament Versus Monofilament

In laparoscopic surgery the multifilament braided sutures handle more easily and tie well, but can potentially harbor organisms between fibers leading to increased infection risk. Although in laparoscopic surgery the chance of infection is less compared to open surgery because the interior milieu is maintained, if possible the multifilament should be avoided in contaminated wounds. They also tend to have higher capillarity therefore they can absorb and transfer fluid more easily increasing the potential for bacteria to enter from the skin surface.

- Monofilament sutures have a lower infection risk and a lower coefficient of friction, but with a lower ease of handling and knot security.

Tissue Reactivity

This refers to the degree of inflammatory response to the suture.

- Higher for natural products such as silk and gut
- Lower for synthetic fibers such as nylon

Concluding Remarks

- The choice between a lightweight and heavyweight mesh is multifactorial and superiority has yet to be proven.
- The main advantage of the composite meshes is that they can be used in the intraperitoneal space with minimal adhesion formation.
- There are two categories of composite meshes: absorbable and permanent. Each of them has its peculiarities.
- It is important for laparoscopic surgeons to keep in mind all the characteristics of the suture material such as: absorbance, tensile strength, tissue reactivity, plasticity, elasticity, number of filaments, ease of handling, and knot security.

Glossary

Expanded-polytetrafluorethylene (E-PTFE). PTFE was expanded to be improved, and it became a uniform, fibrous, and microporous structure with improved strength.

Polyester (POL) A carbon polymer of terepthalic acid that can be fashioned into strong fibers suitable to be woven into a prosthetic mesh.

Polypropylene (PP) Hydrophobic polymer of carbon atoms with alternating methyl moieties.

Polytetrafluorethylene (PTFE) Chemically inert synthetic fluoropolymer that has a high negative charge, therefore water and oils do not adhere to it.

Polyvinylidene fluoride (PVDF) A synthetic yarn made from polyvinylidene fluoride. Its diameter is between 0.085 and 0.165 mm.

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Molecular Biology

Renato Miranda de Melo

"Shape is the plastic image of function." Angelo Ruffini (1864-1929)

Keypoints Summary

- Collagen deficit: common findings between AAA and abdominal wall hernias
- Some evidence of metabolic etiopathogeny
- Mesh use strong recommendation or even imposition
- Complex hernia repair laparoscopic problems
- Robotic surgery solution portfolio

Introduction

For exactly three and a half decades, the association between smoking, abdominal aortic aneurysms (AAA), and inguinal hernias has attracted the attention of the international medical community. Under "Metastatic Emphysema" concept a new paradigm was broken revealing a systemic mechanism behind respiratory changes and the abdominal wall: blood flow proteases (elastases) arising from the current smoker's lungs [1]. In the early 1920s and based only on clinical observations, Keith and Harrison, independently, already foreshadowed this possibility, when they questioned dysmorphism as a single causative agent of inguinal hernias.

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R.Z. Abdalla, T.N. Costa (eds.), *Robotic Surgery for Abdominal Wall Hernia Repair*, DOI 10.1007/978-3-319-55527-0_12

Since then, several authors confirmed these and other connective tissue modifications in patients with hernia, inguinal or not [2]. It would then be seen as a systemic disease with localized manifestation (lower resistance sites), not mere isolated anatomical defects. The etiopathogenic substrate dipped in biochemical level, over the imbalance ratio of collagen type 1 (tougher) and type 3 (less resistant), at these patients' aponeuroses, making them weak and vulnerable to herniation of abdominal/peritoneal contents [3]. The fibroblast, directly responsible for the maintenance and renewal of connective tissue, also became the protagonist of these disorders [4].

Pros and Cons

Regarding the common etiophatogeny of both AAA as the abdominal wall defects, especially of incisional hernias (IH), there is strong evidence that both disease are related to changes of connective tissue, at the level of extracellular matrix, and its fibers (collagen and elastic) [5]. Patients undergoing reconstruction for AAA are three times as likely to develop IH, compared to patients with arterial occlusive disease, for example [6]. The basic metabolic shift in these conditions favors fibrillar rarefaction, because at the same time synthesis is inhibited, degradation is stimulated through overexpression of matrix metalloproteinases (MMPs), on one side, and a suppressing of their inhibitors (TIMP), on the other. Families with hernia patients are more likely to develop the disease, because the synthesis of those and any other protein express individual genetic patrimony.

This fact becomes quite evident in the Ehlers–Danlos and Marfan syndromes, for example. However, these collagenoses do not always have an evident clinical picture and the phenotype does not reflect the existence of the disease. Some patients are not diagnosed as having the syndrome, which will be perceived only on one or more episodes of hernia recurrence.

Some questions inevitably arise:

- Who and how many are they in general population?
- How can they be recognized on purely clinical grounds?
- What additional tests should be required to confirm the disease?
- Perhaps biopsy with histopathologic screening? From what part: of the skin, tendons, or aponeuroses?
- In these cases, do cutaneous superficial fibroblasts express the same collagen content and at the same proportions as the deep (aponeurotic) fibroblasts?
- If this is so, how do we explain the existence of hypertrophic or keloid scarring in the skin of patients who have concomitant underlying incisional hernia? One hypothesis refers to "metabolic paradox" of fibroblasts, wherein the same cell types have distinct gene expression on the same individual (Fig. 1).
- Should some form of adjuvant therapy or gene replacement be considered therefore?

Even if it becomes feasible, a possible side effect might result in undesirable adhesion formation, in the same local or distant to the site of hernia. If that occurs,

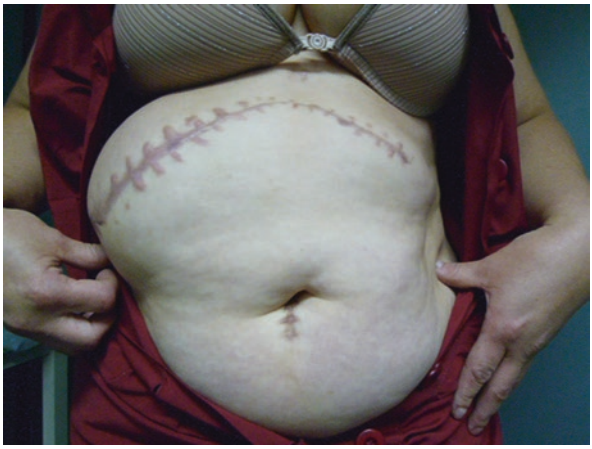

Fig. 1 Hypertrophic scarring/keloid in patients with underlying incisional hernia

it could lead to organ incarceration by serous thickening (pleura, pericardium, peritoneum), visceral obstruction, or hollow structures (intestines, vas deferens, fallopian tube, duodenal papilla, cardiac valves) caused by the induction of a "hyper scarring" systemic state.

Undeniably, many of these issues still need consistent response in the literature, but the biggest challenge, and certainly the only alternative is to try to recognize vulnerable groups or those at increased risk for hernia recurrence who are not typically syndromic. Until they could be identified, routinely, with noninvasive and inexpensive tests, the surgeon should guide any decision on the clinical suspicion at epidemiological basis. In other words, he or she has to recognize and validate elements for tracking patients with subclinical or asymptomatic collagenosis.

The inflammatory reaction is exacerbated and chronically installed on these sites, as an additional hazard of metabolic deficiency, further distorting the tissue architecture even more, by the phagocytic activity (proteolytic) and the fibrosis that develops.

Mesh: The Necessary Evil

The use of prophylactic mesh is proposed to reinforce laparotomy wound closure, in susceptible IH patients, even in vascular and bariatric surgery or other abdominal procedures [7]. This strategy has its value but its effect is purely topical or local [8]. The results show the greater protection afforded to the scar, substantially reducing the incidence of IH, with no increase of local events, although some papers in the literature are controversial as to the number of cases of seroma and chronic pain associated with mesh use [9–12].

In spite of these advantages, there is always the possibility that these patients can develop fistulas and/or chronic surgical site infection and that the presence of a mesh, already incorporated in the wall tissues may create an obstacle to future laparotomies, as happens for trauma or cancer.

Unfortunately, we don't know the intimate mechanism by which the hernia is triggered, in a given location, from one or more metabolic alterations, on a systemic level, nor which of these events start and/or perpetuate other ones [6]. It must be considered, though, that hernia etiology is a multifactorial affection, where different causes are involved, metabolic factors (genetic), environmental/behavioral (smoking, obesity), anatomical (dysmorphism), and also of technical/iatrogenic origin (inadequate closure of abdominal wounds, surgical site infection). The contribution of these factors to a greater or lesser extent could explain the occurrence of these defects, which sometimes assume catastrophic proportions.

A New Look at the Abdominal Wall

It seems inevitable to consider the abdominal wall as a multisystem organ. Its contractile prerogative, thanks to the striated musculoaponeurotic contour, interspersed with periods of relaxation, promote changes in intra-abdominal pressure (IAP). This alternating pressure modifies both the form and content of viscera and peritoneal cavity structures, optimizing the performance of each organ that is located there, as well as the whole abdomen. Digestive, urogenital, cardiovascular, and respiratory systems gain efficiency, wherein the abdominal wall has a supporting role, but also the stability, splanchnic protection, and trunk movements, specific attributes of its locomotor interface. The latter, associated with cutaneous vitality, establishes and maintains body contouring, whose aesthetic consequences cannot be underestimated. Therefore, as in any organ, it is essential that the integrity of its neurovascular contingent is preserved, to perform all these functions completely.

Restoring or Rehabilitating

The surgeon will be required, depending on destruction degree and structural wall remaining, to not only do the simplest repair, but a complete restoration of the entire abdominal continent, in view of the complexity achieved by hernia disease. In this sense, all valuable reachable measures with the objective of re-establishing contents and continent must be done as a way to recover anatomical and physiological balance of the abdominal wall. Recovering its structure, partially or completely, is the only way to regain functional capacity to the wall.

Regardless of the success in getting the coveted parietal "dynamic support," the availability of prostheses of all kinds and sizes, is essential to meet the needs of each case. However, it is imperative that the surgeon always adhere to the "restorative principle," because any prostheses used for the repair of the abdominal wall seek only to restore the lack of continuity, offering a holding and fibrosis-inducing barrier, not new muscle fibers. There is no cell regeneration in these tissues, just scar. Even without this scaffold, the homeostatic forces of the body will try to do this (fibrosis) to fill the defect. The hernia sac, with its dense and mesothelial connective structure, is proof of this great effort, even though insufficient. Neither the mesh nor

the hernia sac provides active support to the wall. Only the musculoaponeurotic component well vascularized and innervated is capable of doing that.

Therefore, the most effective way to correct these lesions is to restore the continuity of this contractile belt surgically, often by combining techniques and prostheses [13]. On the degree of complexity achieved by hernia disease, in some circumstances, it must also subtract the herniated content (visceral and omentum resections). Working from the surface to the depth, the idea is to reconstitute all affected layers, considering relaxing incisions (discharge) and muscle advancing techniques. Even if it is possible to cover the parietal defect completely, reinforcement of the wall with the use of prostheses could be chosen, in a superficial position (onlay) or preferably deep (sublay or underlay) to decrease the chance of hernia recurrence [14].

Moreover, it is also important that the surgeon promote an acceptable cosmetic result, removing unsightly scars and associating dermolipectomy in patients with "fat apron abdomen". This procedure is, moreover, strategic and aims to create a suitable route of access to the musculoaponeurotic layer, so the anatomy can be contemplated in its full magnitude where the defect is even without primary aesthetic purpose. Similarly, resection of such large excesses of skin and subcutaneous fat will reduce the effect of the traction exerted on the suture lines and the mesh, when placed in a preaponeurotic position (onlay). In this regard, the collaboration of a plastic surgeon is extremely useful because the tactics and aesthetic prerogatives may be associated in the same surgical procedure and are shared by all.

From Laparoscopic Platform to Robotic Jump

When all the goals of treatment seem to be well defined and achievable by conventional or open surgery, the videolaparoscopic approach became available just to cover or line up those parietal defects. Applying extensive prostheses in the intraperitoneal position, without promoting any kind of muscular approximation was shown to be possible and feasible to repair both IH and primary ventral hernias. But what *should be* done must be always balanced with what *can be* done to achieve a goal.

Patients with midline incisional hernia treated with reconstruction of the linea alba have a isokinetic contraction strength of trunk muscles greater than patients who have undergone only mesh defect covering. Moreover, the presence of any intraperitoneal foreign body, the adhesions that promote on the wall (incorporation) and also in the abdominal contents can create difficulties for *de novo* interventions that could be time consuming to access the cavity and/or also present a higher risk of accidental lesions or inadvertent visceral injury.

The technical difficulty imposed by wider rings (>10 cm), where there is no room to overlay adjacent tissues beyond the defect borders in sufficient extension to support and fix the mesh, surely helped discourage most surgeons in laparoscopic repair of large abdominal wall hernias.

However, to be able to perform the full range of necessary procedures to make a complete abdominal wall repair (anatomical and physiological), using mini-invasive surgery, has become the major challenge for laparoscopic surgeons. They saw themselves limited, not for personal reasons such as a lack of ability or nonacceptance of the method, even with the equipment and materials (videocameras, monitors, blowers, special energy sources and forceps, coated fabrics, staplers etc.), but because of the imperfect ergonomics and restricted hand movement provided by laparoscopic surgical instruments. This forced the surgeons to expend much effort in intracavitary maneuvers and even more in the parietal layers because they were forced to work with rigid and straight tools in the same axis they use to approach the cavity. The only aim they had was to modify the operative table degree and switch a variety of instruments between trocars, several times in each procedure, taking as much advantage as possible of the natural abdominal shape. Laparoscopy favored a complete and global understanding, as a diagnostic tool, of the parietal defects, especially in hernia with multiple rings, but it was frustrating from the therapeutic point of view, because of method limits.

The statement "treat illness being minimally aggressive to the patient" has always been a doctor's corollary, moreover. The advance represented by minimally invasive videosurgery to solve cavity problems preserving abdominal wall healthy, abbreviating convalescence, was notorious for the surgeon and patient. Adapting it also to approach and repair defects of abdominal continent was missing.

Robotic surgery filled this gap, making feasible the complete treatment of the most severe and extensive parietal injuries through a minimally invasive approach, inherited from laparoscopic surgery. It represents a whole set of possibilities, mediated by the surgeon, enabling similar maneuvers in performance even more precise than human hands inside the abdominal cavity (because of greater range and degree of freedom in robotic arm articulation) in a safer, ergonomic, and comfortable way. Those procedures are made in both continent (wall) or contents (viscera) of the abdomen. In addition, it rescued the experience of the three-dimensional view.

Laparoscopic surgery is considered a great step forward when compared to the conventional approach (open), but the distance represented by robotics, regarding laparoscopy, is exponentially larger. This progress has been so extensive that the robotic arms allow the surgeon to do even better, almost everything one could do with bare hands, but without extra-damage, thanks to the minimally invasive approach. When these two modalities are close in fact, they summarize their advantages and subtract their disadvantages from each other at the same time.

Neither robotic nor laparoscopic surgery corrects skin lesions and subcutaneous tissue, unfortunately (unsightly scars, ulcers, entero-atmospheric fistulas, fat apron abdomen), a common finding in most patients with complex hernias. This is for obvious reasons and even in the conventional open approach they are not routinely treated at the same surgical time. Its correction will continue to be performed in the classic open way, either by general surgeons or, preferably, by a plastic surgeon.

Concluding Remarks

- Several authors confirmed connective tissue modifications in patients with hernia.
- Although it can cause various complications, mesh is an advisable tool in some or many hernia repairs.
- The abdominal wall is a multisystem organ.
- The surgeon has to restore the abdominal wall, often by combining techniques and prostheses.
- Robotic surgery can make feasible the complete treatment of the most severe and extensive parietal injuries through a minimally invasive approach.

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Anesthesia for Robotic Surgery

Claudia Marquez Simões

Keypoints Summary

- Physiological changes
  - How the different positions for robotic surgery can affect the main physiological functions such as cardiovascular, renal, and respiratory
- Positioning
  - Point out the most commonly used positions and the alterations
- Specific aspects of different procedures
  - Prostatectomy
  - Intra-abdominal procedures
  - Thoracic surgery
  - Transoral surgery
- Complications
  - Intra- and postoperative complications to which the anesthesiologist may pay attention in order to diagnose as quickly as possible to avoid severe complications

Introduction

Robot-assisted surgery has become a very popular technique in different surgeries. Robotic surgery has all the advantages of laparoscopic surgeries and some technical specific advantages for the surgeons that may also improve results.

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R.Z. Abdalla, T.N. Costa (eds.), *Robotic Surgery for Abdominal Wall Hernia Repair*, DOI 10.1007/978-3-319-55527-0_13

It's very important to know all physiological changes that can occur during a robotic surgery. There are many effects associated with the pneumoperitoneum that can be worsened in robotic surgery with some positioning aspects. So let's start with the physiological changes associated with the pneumoperitoneum.

Respiratory Changes

Abdominal insufflation leads to the increase of intra-abdominal pressure: the diaphragm is pushed upwards and the total volume of the lungs is reduced. Functional residual capacity is reduced and may have atelectasia and ventilation/perfusion (V/Q) mismatch, being at risk for hypoxemia and hypercarbia. There's also an increase in airway resistance and reduced pulmonary compliance [1].

Renal Changes

The increased intra-abdominal pressure reduces by compression of renal vessels and parenchyma, the glomerular filtration, causing oliguria. The increased abdominal pressure stimulates the renin–angiotensin–aldosterone system followed by decreased renal perfusion, which results in renal cortical vasoconstriction. There is an increase in ADH, renin, and aldosterone after pneumoperitoneum insufflation [2]. The renal effects are transient and reversible, including creatinine levels [3, 4].

Cardiovascular Changes

The pneumoperitoneum causes hypercarbia followed by acidosis. These alterations together with increased intra-abdominal pressure may lead to cardiovascular changes. Innitially there is an increase in the intrathoracic pressure as well as intra-abdominal compression about the splanchnic venous bed and vena cava, which increases venous return. An euvolemic status is important to reduce any cardiac depression via reduced preload. But after some time the compressive effects on the arterial vasculature and capillaries increase afterload, systemic vascular resistance (SVR), and arterial pressure, although stroke volume and cardiac output decrease. The greater the intra-abdominal pressure, the greater the hemodynamic effects. With an intra-abdominal pressure of 15 mm Hg there is an increase of 35% in the mean arterial pressure, 65% increase in systemic vascular resistance, 90% increase in pulmonary vascular resistance, and a decrease in cardiac index by 20% [5].

The hypercarbia activates sympathetic stimulation, leading vasoconstriction in some areas such as the pulmonary circulation and also in the hepatic arterial territory. Moderate to severe hypercarbia causes vasodilation and has a myocardial depressant effect [6]. During laparoscopic cholecystectomy the cardiac index can have a reduction of 30% [7].

Splanchnic Changes

The splanchnic circulation is impaired with the intra-abdominal pressure (IAP) raise. There is a decreased portal and superficial hepatic blood flow and hepatic and intestinal tissue pH with IAP of 14 mm Hg [8]. With an IAP of 15 mm Hg there is a reduction in blood flow of 40–54% in stomach, 32% in jejunum, 44% in colon, 39% in liver, and 60% in peritoneum [9].

Positioning

Patient positioning is extremely important for robotic surgery and varies with the procedure. A multidisciplinary team training is mandatory to achieve success, involving surgeons, nurses, and anesthetists. The Trendelenburg position (head down) is one of the most frequent positions in lower abdominal surgeries, but there are other positions with different physiological changes that must be known. Most parts of the changes are time-dependent, therefore the length of the surgical procedure is crucial. There are some patient-related and some procedure-related risks for positioning injuries (Tables 1 and 2) [10, 11].

Trendelenburg Position (Head Down)

Many lower abdominal robotic surgeries need a steep Trendelenburg position, but the whole surgical team must be concerned with the physiological consequences. The classic Trendelenburg position was initially described with the torso supine and the legs upon the shoulders of an assistant with 45° head-down tilt. However, the term is now often used to describe any head-down position,

Table 1 Patient-related risk factors for positioning injuries

BMI <20 or >30
Diabetes mellitus
Limited physical mobility
Age over 70 years
Malnutrition
Peripheral arterial occlusive disease
Smoking and COPD
Anatomical abnormality
Pre-existing neuropathies

Table 2 Procedure-related risks for positioning injuries

Lengthy procedures (>3 h)
Interventions performed in the lithotomy position
Interventions performed in the steep Trendelenburg position

including the steep Trendelenburg used for laparoscopic and robotic surgery [12]. In the steep position the patient must be stabilized at the surgical table not to slide down. A gel mattress or a vacuum mattress can be used to help sliding avoidance at the surgical table in the steep position [10]. The Trendelenburg position is associated with reduced total lung capacity, compliance, and increased airway pressures. Lung volume approaches closing capacity with resultant atelectasis and shunt. The endotracheal tube can be displaced with the table movement so the ventilation must be periodically checked for selective intubation. Many complications may be associated with this position because nondangerous complications such as light facial edema or more dangerous complications such as facial and airway edema may lead to respiratory distress in some cases [13]. Regarding hemodynamics the Trendelenburg position associated with the pneumoperitoneum is associated with elevation of pulmonary arterial pressure and central venous pressure and cardiac index decrease by as much as 50% [14, 15]. There are also some reports of visual loss after the steep Trendelenburg position associated with posterior ischemic optic neuropathy [16]. Intraocular pressure (IOP) is increased in the steep Trendelenburg position and the increase is time related. In general, robotic surgery in the steep Trendelenburg position appears to pose little or no risk from IOP increases in patients without pre-existing ocular disease [17], but there may be additional risks for patients with glaucoma. Unfortunately there are no current guidelines for monitoring and preparing patients with glaucoma undergoing surgical procedures, but there are some successful cases described [18].

It remains to be elucidated whether the Trendelenburg position increases intracranial pressure (ICP). It's well known that the head-down tilt increases central venous pressure and impairs venous drainage of the head. Other factors that can be involved with possible increase in ICP is the elevated impedance of drainage of the lumbar venous system secondary to the elevated intra-abdominal pressure, that may decrease reabsorption of cerebrospinal fluid. Chin et al. evaluated sonographic optic nerve sheath diameter (ONSD) to identify ICP. Their study did not definitively prove that there is a rise in ICP with the steep Trendelenburg position, but proposes that the ONSD provides a better understanding of the effect of the transient steep Trendelenburg position [19].

Reverse Trendelenburg Position (Head up)

The reverse Trendelenburg position is used in the upper abdominal laparoscopic and robotic surgeries. Regarding respiratory function this position can increase residual functional capacity and avoid collapse of the inferior area of the lungs. The patient will have an increased venous return and must be prepared to tolerate this fluid challenge [1]. Sliding on the surgical table can also occur in the reverse position and the same caution must be taken.

Arms and Legs Positioning

Depending on the procedure, the arms can be alongside the body with limited access for the anesthesiologist, thus the venous access and also monitors such as arterial line and pulse oxymeter must be well positioned and correctly functioning before the beginning of the surgery. Some precautions are also important to avoid brachial plexus injury. The head must be in neutral position to stretch the brachial plexus and the occiput must be protected; if possible the head must be slightly moved in order not to have prolonged pressure at the same point because such pressure can cause postoperative alopecia [20]. Arm boards can be used and it is preferred to tuck the arms to the patient's sides with the palms facing the thighs, avoiding abduction, external rotation, or extension of the arms. The patient must be stabilzed at the surgical table and to avoid stretching the brachial plexus and acromium a cross-chest strap technique can be used as described by Shveiky et al. [20]. The cross-chest strap technique uses two straps of foam material placed over the acromio-clavicular joint level and the contralateral breast. Each strap is secured to the table with wide tape, without any pressure on the shoulders.

In some surgeries the legs must be spread and positioned at holders that must be padded and at the same height. The adequate positioning is not easy, especially in obese patients, so sufficient personnel are necessary to prevent lumbosacral injury and hyperflexion of the hips. Another important precaution when the arms are along the body and the legs at holders is to watch out for the position of the fingers to prevent crush injury when moving the leg holders [10].

Specific Aspects for Different Procedures

Prostatectomy

Robotic prostatectomy is nowadays the most commonly performed robotic surgery. The blood loss with the technique may vary but stays around 150–250 mL and the surgical time depends on the surgeon's experience, but can be very fast in experienced hands, performed in 2–2.5 h. Regarding anesthesia the main concerns in robot-assisted prostatectomy are related to the positioning: the steep Trendelenburg position with the legs spread and the feet higher than the head. The arms stay alongside the body and the hands must be carefully positioned and protected [21]. Once the surgery starts, access to the patient is very limited, so all monitors and venous access must be completely safe and functional before the beginning of the procedure. Usually a large bore peripheral catheter is enough for fluid replacement, including cases with unintentional vascular accidents that may happen. Blood loss is normally minimal, however, the required fluid reposition is not small. Usually 1,500–2,000 mL are required to avoid postoperative oliguria, but the fluid reposition has to have adequate timing in order not to make the surgical approach of the

anastomosis difficult due to intraoperative urine formation [22]. Postoperative analgesia can be provided with systemic opioids or even with regional anesthesia [23].

Intra-Abdominal Procedures

Regarding abdominal robotic procedures some specific issues may be important to consider. Nitrous oxide should be avoided to minimize bowel distension and possibly reduce postoperative pain related to it [24]. Another important consideration is neuromuscular blockade that is mandatory for patient safety and also to improve surgical conditions. Regarding neuromuscular blockade level, there is no evidence to support deep compared with moderate neuromuscular block [25] . Monitoring is related to the surgical procedure and patient condition, not the surgical approach. Fluid responsiveness is a challenge and may be difficult in some surgeries, such as robotic esophagectomy. Traditional clinical indicators are unreliable to guide fluid reposition [26]. Fluid reposition influences postoperative outcomes after abdominal surgery, and is a point for major attention for the anesthetist. Restrictive fluid therapy improves outcome after major gastrointestinal surgery, avoiding bowel edema formation [27].

Thoracic Surgery

Video-assisted thoracoscopic surgery has impaired vision and restricted maneuverability of surgical instruments, thus they often require the use of lung isolation techniques. The anesthesiologist must be skilled in these techniques including the use of double lumen tubes and bronchial blockers. Double lumen tubes are the most often used technique [28]. The whole surgical team must know that positioning may alter tube positioning, therefore the lung isolation must be checked after positioning and before starting the surgery. In robotic surgery once the robot is docked, it does not allow changes in patient position on the operating room table, another important reason to check lung isolation after positioning. If the patient is expected not to be extubated immediately after the surgery, the use of bronchial blockers may be strongly considered to prevent tube exchange, which may predispose the patient to complications with airway management [29].

Lobectomy is one of the most frequent pulmonary robotic surgeries. Patients undergoing robot-assisted thoracic lobectomy must have an arterial line due to the restricted access and the potential intraoperative complications [28]. The anesthesiologist must always be ready to the possibilty of conversion to open thoracotomy. The rate of conversion may be higher if lung isolation is lost, so the correct isolation technique and bronchoscopic evaluation are required skills for the anesthesiology team [30]. Postoperative analgesia may be a challenge, mostly related to the chest tubes. The most intense postoperative pain is in the first 48 h. Different techniques including regional anesthesia or systemic medications may provide high-quality analgesia [31].

Transoral Surgery

The main advantages of transoral robotic surgery (TORS) in patients with head and neck cancer are access to anatomical sites not accessible conventionally, absence of a neck incision, absence or decreased duration of tracheotomy, absence or decreased duration of nasogastric or gastric feeding tube, and decreased length of hospital stay [32]. If indicated, some surgeons perform neck dissection in the same surgery and others do it after 1 or 2 weeks. In the second option anesthesiologists must be twice worried about airway management: edema and fibrosis may be present after the previous surgery, many times added to previous adjuvant radio- and chemotherapy.

Airway management in TORS is also a challenge, mainly in extubation. Safe extubation techniques may be employed in cases where tracheotomy is not performed. Some of the techniques that can be employed include the use of a laryngeal mask airway, to guarantee airway patency, called the Bailey maneuver [33]. Another option is the use of tube exchange catheters. They are semi-rigid, long, thin, radiopaque catheters with holes in their distal-blind tips. If extubation fails, it can be used as a guide to reintubate the patient. An advantage of this device is the ability to oxygenate the patient through the distal aperture with jet ventilation [34]. However, barotrauma and fatal complications of oxygen insufflation and jet ventilation have been reported [35].

Complications

The whole intraoperative team must be trained for intraoperative crisis. Protocols may be necessary because of the complexity of robotic dock and instrumentation, the physical distance between the physicians and the patient, complex undocking of the robot quickly, and the size and bulk of the robot, which may block access to the patient during the intraoperative period [36]. It's important to have specific rules for each member of the team and the emergency may be conducted by a team leader with effective comunication. The team must also be prepared for seamless and quick conversion to open surgery. Some situations that may seem very simple must be trained; for instance, during a cardiac arrest, the team must be able to bring the CPR cart into the operating room and be able to make it possible to defibrillate the patient if necessary. Despite all the advancements of technology and monitors, the surgical team's vigilance is the basis of safe practice [37].

The anesthesiologist must always pay attention to some uncommon, but possible pitfalls during robotic surgery. In robotic surgery we must not forget that the tactile sensation is lost, therefore despite rigorous revision of hemostasis, internal bleeding must always be considered as a possible complication in the end of abdominal procedures, under pneumoperitoneum. The perception of different surgeons is that there is no loss in the tactile sensation, but there's little to no evidence to support these data [38]. After the pneumoperitoneum is no longer present, bleeding may develop hemodynamic instability and must be suspected.

As mentioned before depending on the positioning, mainly the steep Trendelenburg position, we must also consider possible complications related to edema and airway-related complications [39].

Concluding Remarks

- The surgeon must know the physiological alterations secondary to the positioning and also the pneumoperitoneum. Teamwork is mandatory in these surgeries and a good result depends on team interaction.
- Positioning protocols may help to avoid complications and minimize the time to start the surgery.
- The whole intraoperative team must be familiar with different robotic procedures that may have specificities.
- Complications should be detected as soon as possible and the environment must be prepared to manage the crisis situation, even undocking the robot and converting to an open surgery.

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R.Z. Abdalla, T.N. Costa (eds.), *Robotic Surgery for Abdominal Wall Hernia Repair*, DOI 10.1007/978-3-319-55527-0