Surgical Overview
SURGICAL TECHNOLOGY INTERNATIONAL Volume 35

Abdominal Fascia Closure Techniques During Laparoscopy

MARCO MOUANNESS, MD
CHIEF RESIDENT
DEPARTMENT OF OBSTETRICS AND GYNECOLOGY
AMERICAN UNIVERSITY OF BEIRUT MEDICAL CENTER
BEIRUT, LEBANON

SALLY KHOURY, MD
GYNECOLOGIST/OBSTETRICIAN
DEPARTMENT OF OBSTETRICS AND GYNECOLOGY
BEKHAZI MEDICAL GROUP AND TRAD HOSPITAL
BEIRUT, LEBANON

JOSEPH NASSIF, MD
ASSISTANT PROFESSOR
DEPARTMENT OF OBSTETRICS AND GYNECOLOGY/ LAPAROSCOPIC AND
MINIMALLY INVASIVE GYNECOLOGICAL SURGERY
AMERICAN UNIVERSITY OF BEIRUT MEDICAL CENTER
BEIRUT, LEBANON

ABSTRACT

Due to its decreased recovery time and increased patient satisfaction, laparoscopic surgery has witnessed an exponential rise in the last decade. In fact, the indications for laparoscopic surgery are currently numerous and involve multiple disciplines, including gastro-intestinal and gynecological surgery. With this boom, there is much focus on decreasing the rate of complications due to laparoscopy. This includes, but is not limited to, an increased interest in decreasing the risk of port-site herniation by ensuring proper closure of the abdominal wall at the site of port-insertion.

This text will review the anatomy of the abdominal wall, describe the different open and laparoscopic techniques developed to close the defects in the abdominal wall post-laparoscopic surgery, list the advantages and disadvantages of these described techniques, and offer a brief summary of recommendations to surgeons for abdominal fascia closure post-laparoscopy.

INTRODUCTION

The recent boom in the laparoscopic approach in surgery has opened the door to new technological challenges in this field, including fascial closure at port site. Port-site complications occur in 1% to 6% of cases of laparoscopic surgeries. Fascia closure is a main concern in laparoscopic surgery since failure of this closure may lead to an incisional hernia with all its possible complications—including bowel strangulation and infarction—hence hindering the objective of minimally invasive surgery.

Multiple factors pertaining to surgical technique of fascia closure, the instruments used, the type of surgery performed, and the patients themselves have been identified as risk factors for port-site hernias.

Although closure of large incision sites (10 to 12 mm trocar insertion sites) is recommended, incisional hernia can occur with a small port-site incision. In fact, incisional hernia has been described in the literature, even in cases of small incisions (as small as 3mm). Recent literature suggests that closure of these incisions leads to decreased risk of port-site incisional hernia and better postoperative recovery.

Blind suturing of the fascial defect might lead to inadequate suturing of the incision with consequent risk of incomplete closure and lesions of intraperitoneal organs. Therefore, a multitude of techniques have been described to optimize fascial closure, including the classical hand sutures-technique. The techniques can be classified into three groups: Open techniques requiring direct visualization by the operator, closed techniques with direct laparoscopic visualization, and closed techniques without direct laparoscopic visualization. The latter will not be discussed in this review since it is safer to close the fascia with some sort of visualization (either direct or laparoscopic) to ensure proper closure and avoid organ injury. The major disadvantage of most of these techniques is the requirement of additional special devices and the time required to perform them.

This review will list various techniques of fascia closure post-laparoscopic surgery and will include their advantages and potential complications. These techniques are not specific to gynecological laparoscopic surgeries and can, therefore, be used in any laparoscopic surgery.

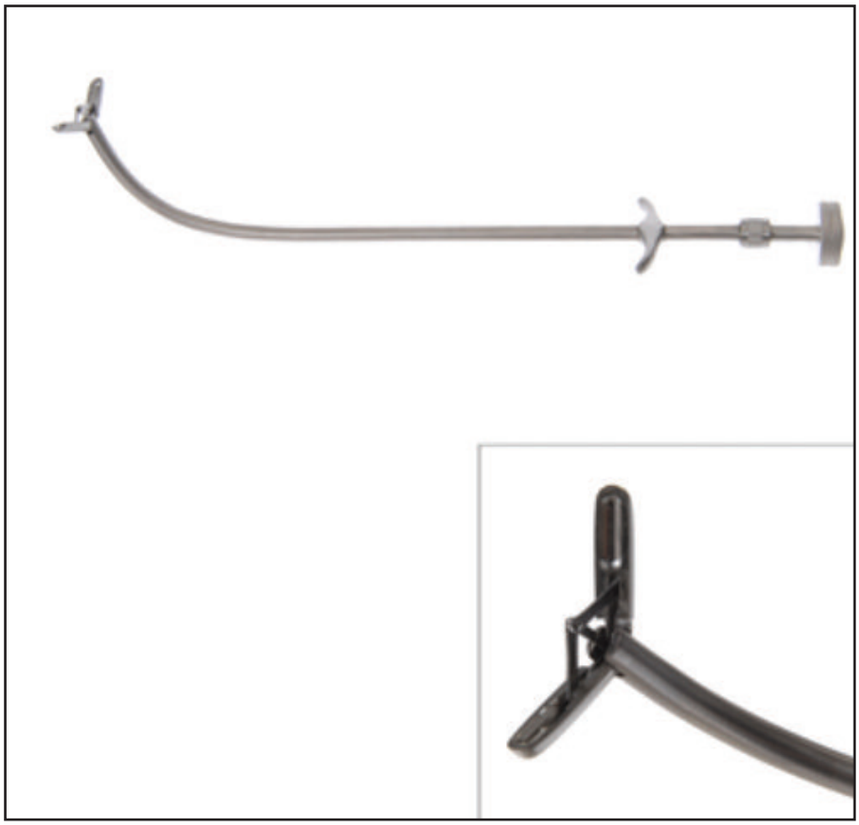

Figure 1. Lowsley Retractor®.

ANATOMY OF ABDOMINAL WALL

Although the anatomy of the abdominal wall has not changed, the methods used to operate on humans have developed greatly in order to decrease the damage inflicted during surgeries. One of the main concerns with the recent laparoscopic procedures is the burden of the blind entry for the first trocar placement, with the associated risk of bowel perforation and vascular injury. Port entry represents, therefore, a pivotal moment in laparoscopic surgery, and the choice of technique for entry and closure will affect the overall outcome of the surgery (including operative time, bleeding, infection rate, and recovery period). Knowledge of the anatomy of the abdominal wall is crucial in understanding the physiology behind the occurrence of hernias following laparoscopy and the need for fascia closure to decrease that risk.

Four essential muscles compose the bulk of the anterior wall: The rectus abdominis, the external and internal oblique, and the transversus abdominis. Insertion areas for the laparoscopic trocar vary depending on the type of surgery and its indication, which makes experience in the anatomy of the wall essential for any surgeon attempting laparoscopic entry to the abdomen.

The umbilicus is the predominant site of entry due to its landmark characteristics. It has a right major blood supply making left incisions less bloody. Its innervation is minimal due to the fibrotic fusion of all abdominal layers at its level, making it less painful for trocar insertion. The optical trocar at the umbilicus gives an optimal view to the pelvis and the upper abdomen.

There are no significant vascular structures that need to be respected upon insertion of the sub-umbilical trocar. Solely, strict attention must be given to holding to the median line to avoid any accidental damage to paramedian structures. The inferior epigastric arteries (arising from the external iliac artery) and the circumflex iliac superficial artery (arising from the femoral

artery) are the two main superficial abdominal wall arteries that should be avoided during laparoscopic entry, because even superficial injury to these vessels can lead to profuse bleeding and conversion to laparotomy.

There are three main ligaments of the anterior abdominal wall that help identify anatomic landmarks during laparoscopic entry into the abdomen:

1. Median ligament (plica umbilicalis mediana): Contains the obliterated urachus and requires no further attention. Sometimes, the bladder might be adherent to the abdominal wall at this site (especially after caesarean section).
2. Medial ligament (plica umbilicalis medialis): contains the obliterated umbilical arteries and is hazard-free after birth.
3. Lateral ligament (plica umbilicalis lateralis): containing the inferior epigastric artery which perforates the fascia of the transverse abdominis muscle.

Open techniques for fascia closure

Several techniques have been introduced over the last decades to aid in the suturing of fascial defects deep in the small trocar wound under direct vision. These are called "open techniques for fascial closure following laparoscopic surgery".

Primitive techniques were of the simplest designs. In fact, Khan et al. described in 1993 a simple technique of fascia closure that consists of placement of two stay sutures at each side of the trocar through the fascial sheath once it is exposed after skin incision. This will help bring up the fascial edges after the laparoscopic procedure is done and the cannula is withdrawn.[1,2]

The same year, the Lowsley Retractor® (Circon ACMI, Stamford, Connecticut; Fig. 1) was created. This device contained an expanding blade at the end of its vertical rod, allowing it to open 180 degrees. Once vertical traction is applied, the port is removed from the abdomen along the shaft of the Lowsley Retractor®, leaving only the retractor in the wound. The fascial edge would be stretched upwards to the surface, allowing easier access for hand suturing with 0 VICRYL® (Ethicon, Inc., Somerville, New Jersey) sutures.[3]

The insertion of this device into the market made Jager et al. realize that the same technique can be used to utilise simpler instruments for fascial closure. Therefore, they realized that the upward traction of an inflated Foley catheter balloon inserted through the incision port could serve the same purpose during fascial closure.[4]

Conlon and Curtin introduced the J-Needle (CooperSurgical Inc., Trumbull, Connecticut) into the market during the mid-1990s. They demonstrated that the introduction of a closed J-Needle attached to a suture can help achieve fascial closure in an easier way. The long J-Needle is adapted with a pointed hook shielded by an integral guard sheath. The hook is easily inserted parallel to the fascial edge at a 90-degree angle then rotated and angled upwards through the other edge of the fascia.[5-7]

A similar device was created by Chung et al. around the same time. This device, described as a "fish-hook" needle, was created by bending a hypodermic needle 180 degrees, allowing it to be used as a conduit to insert threads through the fascia.[8]

In the early 2000s, a simple technique using a "U-shaped" purse string was described, allowing for extension if needed.[9]

A newer technique was introduced in 2003 with the development of the "dual-hemostat" strategy (Fig. 2). Spalding et al. described, in their technique, the use of two hemostats in order to secure a firmer fascial closure. The first hemostat is inserted into the port and retracts the edge of the fascial sheath, while the second hemostat retracts the skin above it allowing for better exposure of the fascia. The needle is then driven through the edge of the fascia and out from the port-site entry. Multiple techniques and adjustments were applied to this technique including an "inside-out" strategy

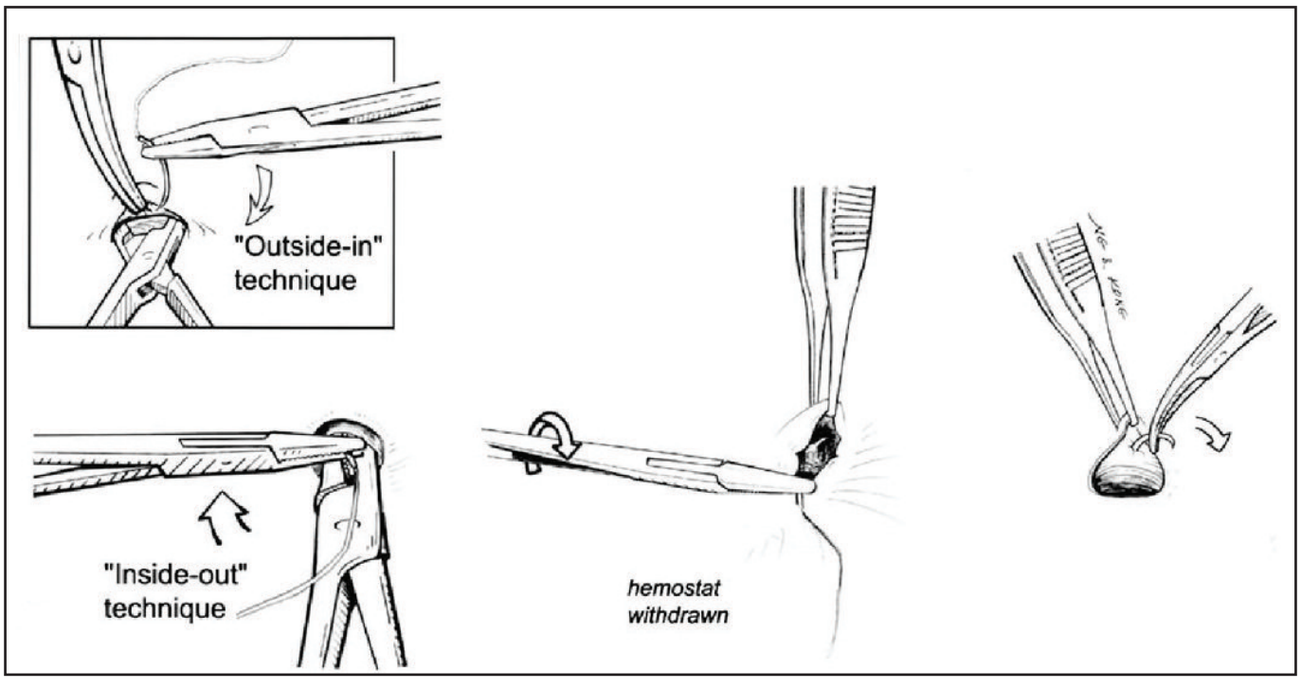

Figure 2. Dual Hemostat technique by Spalding.

- ◆The Deschamps needle (Sklar Surgical Instruments, West Chester, Pennsylvania) is a ligature carrier with right curvature.[22,23]
- ◆Semm's emergency needle with a distal eyelet.[17]
- ◆Dental awl with an eye (Fig. 6).

Special devices

Although specially designed devices increase the overall cost of an operation, they have been widely developed and are effective in the prevention of trocar-site herniation. The first category of these methods includes:

- ◆Tahoe surgical instruments ligature device (Carson Tahoe Sierra Surgery, Carson City, Nevada; Fig. 7) is a disposable device created in Puerto Rico that uses a 0-absorbable suture. The suture is placed into the hollow delivery Tahoe needle which is then inserted through the two holes on an introduction disk. The device is then introduced into the abdomen, after removal of the laparoscopic cannula, and the needle tips are guided to pierce the fascia on either side of the port site. The lock is released, and the handle is depressed until the metal retrieval loop is extended. The suture is fed into the delivery needle. The handle is released, allowing the retrieval loop to retract, thereby securing the suture in the closed metal loop. The entire device is withdrawn from the abdomen, thus delivering the tow ends of the suture onto the abdominal wall. The suture is tied at approximating the peritoneum and fascia.[7]
- ◆eXit disposable puncture closure device (Advanced Surgical, Mammoth Lakes, California) is a 10mm instrument with a right-angle needle that can be exposed by rotating a dial at the top of the instrument. The device is introduced through the 12mm laparoscopic port. Once laparoscopically visualized in the abdomen, the dial on the top of the device is rotated, thus exposing the needle inside the abdomen. The whole device is then pulled back up through the port, thereby drawing the needle up through the peritoneum and fascia away from the skin. Once the needle is visualized, a 0 absorbable suture is loaded into the hole and the entire device is pushed back inside the abdomen; therefore, making the suture pass through the fascia and the peritoneum. The device is rotated 180 degrees and then pulled through the layers again. The needle with the suture will appear in the subcutaneous layer. The suture is pulled up and the whole device is pushed back in, the dial tip is rotated to secure the needle, and then the entire device is removed from the abdomen. The suture can be tied at the abdominal surface at that point.[7]
- ◆Veress needle loop technique: This simple method uses the Veress needle as a guide for the entrance and exit pathway of the suture. The suture is then tied outside the abdomen after removal of the Veress needle.
- ◆The Monk device is expensive and not widely available. It uses two retracted curved ligature guides with a customized needle attached to the loop suture to secure fascial closure.[7,24]
- ◆The VersaOne™ fascial closure system (Medtronic Ltd., Dublin, Ireland;

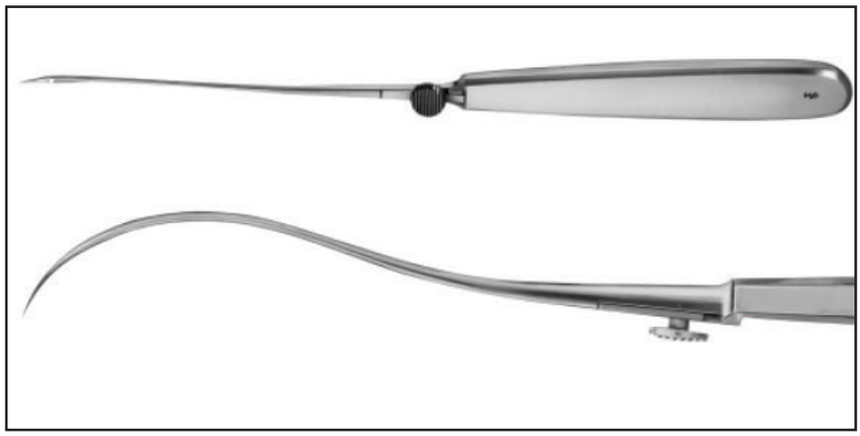

Figure 5. Reverdin Suture Needle.

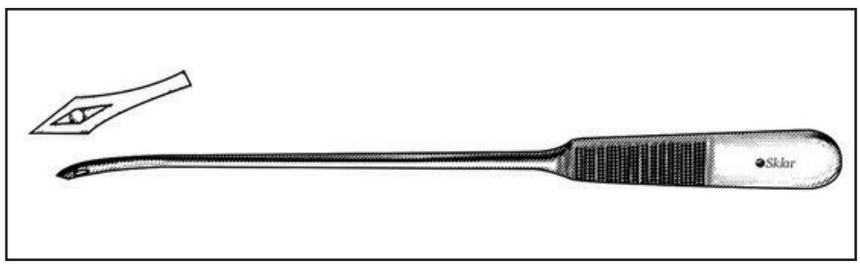

Figure 6. Obwegeser Awl (Integra LifeSciences Corporation, Plainsboro, New Jersey).

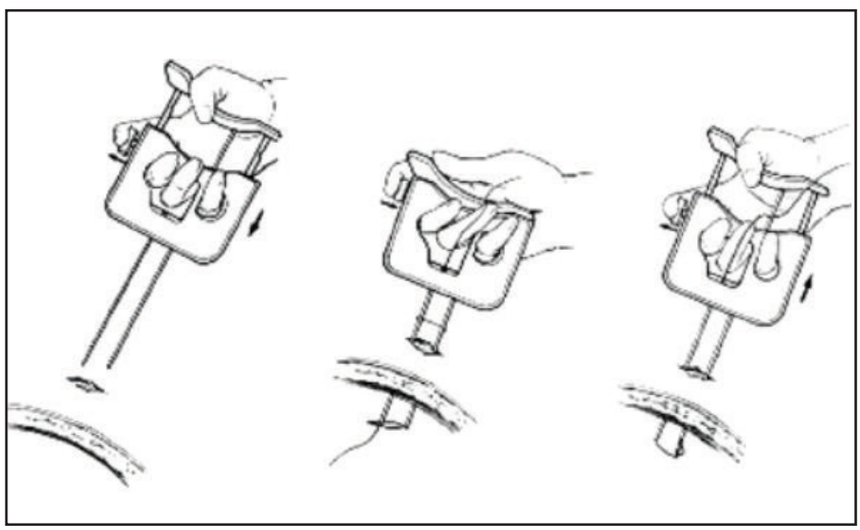

Figure 7. Tahoe ligature device.

instead of "outside-in", allowing better grasp of the fascia and less risk of bowel or organ perforation.[10-13] Another amendment to this technique was the use of a Kelly Clamp (AliMed, Inc., Dedham, Massachusetts) (instead of a hemostat) and the use of a vein retractor for the skin.

Another technique for port-site closure is the "port-plug technique". In this technique, the use of a bioabsorbable hernia plug allows closure of an iatrogenic hernia site. The device is easily and safely implanted in the umbilical trocar (10mm), allowing for complete closure without any risk of adverse effect or bowel injury.[14]

Laparoscopically assisted closed techniques for fascia closure

With the establishment of laparoscopy as a watershed event in the surgical management of multiple pathologies, a constellation of ingenious methods were created for trocar-site closure under laparoscopic guidance around the turn of the century. The manipulation of this group requires direct visualization of the suture/needle from inside the abdomen, providing maximum safety in avoiding visceral injuries.

These techniques require the use of readily available needle/angiocatheters or one of the following special items:

1. Needles
2. Devices
3. Carriers

Special needles

Straight needle: A simple technique of fascial closure was created in 1996 by Tasltas et al. requiring the use of a PROLENE® 2-0 straight needle (Ethicon Inc., Somerville, New Jersey).[15] The technique was first introduced in 1996 and only underwent minor changes. Ultimately, it consisted of introducing the straight needle on one side of the fascial defect, grasping it intra-abdominally by a needle grasper, and rotating upwards towards the other side of the fascial defect. The needle is then pushed back up through the layers, pulled outside the abdomen, and sutured outside. Another version of this technique used a Veress needle to push the needle through on the way out from the abdomen.[16] In 1999, another modification made to the technique required the use of two straight needles. Each entered on either side of the defect into the peritoneal cavity. The needles are then picked up and pulled out through a secondary port. Both needles are then cut off. The knots are pulled back into the peritoneal cavity towards the port hole to be closed.[17]

- Grice Laparoscopic Suture Needle (Lemaitre Vascular, Inc., Burlington, Massachusetts; Fig. 3): The needle, equipped with a suture, is inserted at an angle at one edge of the trocar site. The suture is visualized intraperitoneally and grasped to remove it from the needle of the Grice device. The device is removed and inserted again at the other edge of the fascial defect. The grasped suture is then handed to the needle intra-peritoneally. Once inside the needle, the suture is pulled outside with the whole device. After complete removal of the trocar, the suture is tied under direct laparoscopic visualization.[18]
- The Maciol needle[19] (Core Dynamics Inc., Jacksonville, Florida; Fig. 4) is a set of three needles: A golden handle retriever and two black handled introducers (one straight and one curved). The introducer needle (curved needle with an eye) is used to pass the suture through the abdominal wall into the peritoneal cavity from the subcutaneous tissue. Then, the retriever-barbed needle is passed into the abdomen on the opposite side of the defect to retrieve the suture. Note that the procedure is performed before withdrawal of the trocar.
- The Reverdin Suture Needle (Novo Surgical Inc., Oak Brook, Illinois; Fig. 5) resembles a needle holder and needle, together acting as a suture passer. The eye of the Reverdin can be adjusted by a sliding mechanism on the handle, thus making it easier to deliver suture material. This product features a slight curve and an overall length of six inches.[20,21]

Figure 3. Grice Laparoscopic Suture Needle.

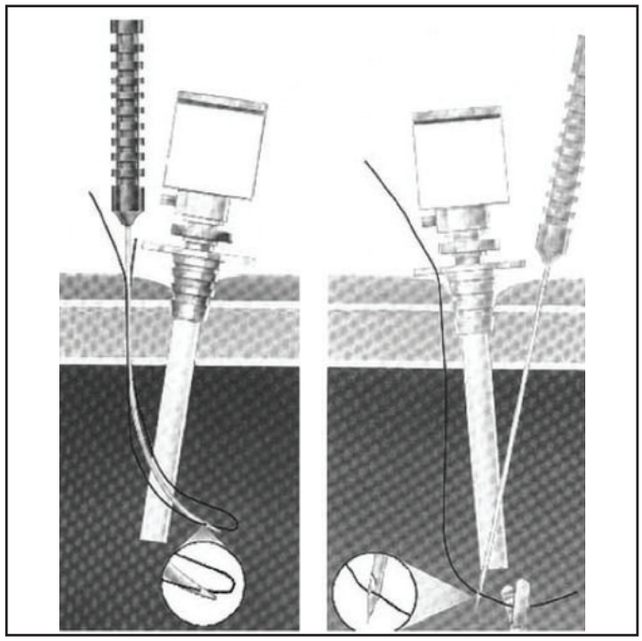

Figure 4. Maciol needle.

Figure 8. VersaOne™ fascial closure system.

Fig 8) is equipped with an obturator and a reusable needle passer. Unlike other closure devices that require their insertion after removal of the trocar, this device provides access to standard laparoscopic instruments and allows consistent fascial closure immediately at the end of the surgery. It therefore eliminates the need for removal of the trocar before fascial closure and does not require reinsuflation.

- The Weck® EFx Shield® Fascial Closure System (Teleflex Inc., Wayne, Pennsylvania; Fig. 9) is a shielded port closure device, providing enhanced sharps protection while ensuring consistent fascial closure. Once the device is inserted, the shielded wings will deploy.
- The CrossBow™ Fascial Closure System (SuturEase, San Jose, California; Fig. 10) is comprised of a guide and proprietary suture passer. No grasper is required, and the device's intuitive guide operation, enhanced snare loops, and controlled tissue "bite" help enable easy suture placement and retrieval. Additionally, it facilitates multiple stitch patterns, offering

Figure 9a, b. The Weck® EFx Shield® Fascial Closure System.

broad versatility to accommodate a variety of patient anatomies and surgical disciplines, including gynecology, bariatric, general surgery, and urology procedures.

- The EZStitch™ Port Site Closure System (SuturEase, San Jose, California; Fig 11) is ideally suited for bariatric surgery and it comprises an extended-length guide and proprietary suture-passing needle. A notch in the EZStitch™ guide allows consistent capture of the fascia edge, decreasing the risk of subcutaneous fat entrapment and dimpling of the incision. The EZStitch™ needle is always protected within the distal guide chamber, thus eliminating the risk of intra-abdominal injuries. The extended-length guide allows for passage down a trocar which is kept in place during closure.

Suture carrier

The second category of laparoscopically assisted methods makes use of a wide variety of instruments as a carrier for threading the suture through the fascia. This category includes all the open techniques that are aided by laparoscopy (i.e., the suture thread can be introduced while being grasped by a needle-tipped grasper).

They include[25,26]:

The Carter Thomason® Suture Passer (Cooper Surgical, Trumbull, Connecticut) is made of two parts, the pilot guide and the suture passer. First, the suture passer is used to push suture material through the pilot guide, then fascia, then muscle and peritoneum all the way into the abdomen. The suture is then dropped inside the abdomen and the pilot guide is removed. The suture passer is then pushed through the opposite side of the pilot guide, where it will be caught outside the abdomen. The pilot guide is then removed, and the suture is tied outside the abdomen. The advantage of this technique is the length of the instruments, initially designed for bariatric surgery and obese patients.[19]

- The GORE-TEX® suture passer[20] (Gore Medical, Neward, Delaware) is a reusable trocar closure device used while the trocar is still in place. The AutoStitch® (United States Surgical Corporation, Norwalk, Connecticut) is a modified Veress needle with a crotchet hook at the tip.[8]
- The Endo-Judge™ device (Synergistic Medical Technologies, Inc., Orlando, Florida) consists of a hollow J-Needle that serves as a carrier for suture material and a plastic oval shield. The aim of the plastic oval shield (olive) at the J-portion of the needle is to maintain pneumoperitoneum and prevent injury to underlying structures. Therefore, the Endo-Judge™ is passed into the

Figure 10. CrossBow™ Fascial Closure System.

Figure 11- EZStitch Port Site Closure System© (by SutureEase).

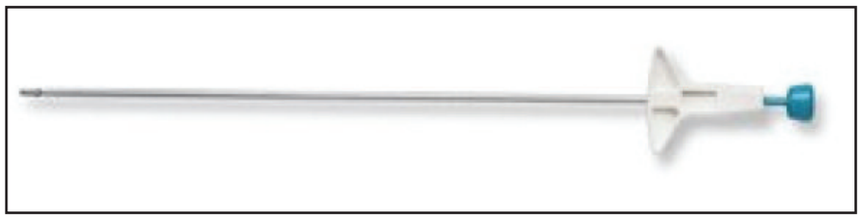

Figure 12. Endo Close™.

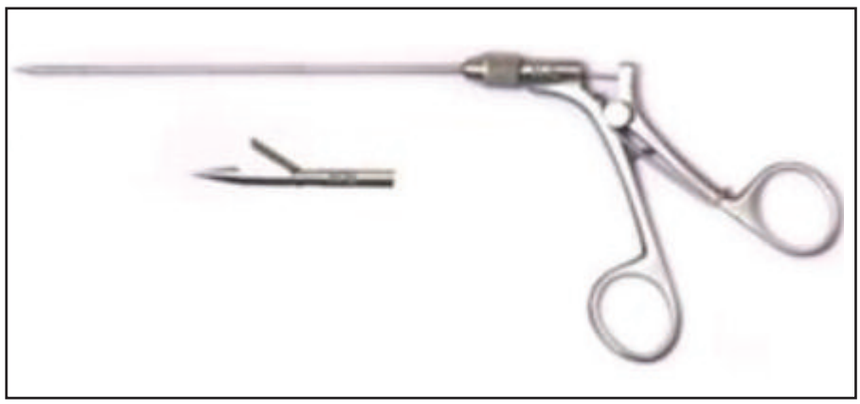

Figure 13. SZABO-BERCI needle.

Figure 14. Weck® EFx Classic Product for fascial closure.

abdomen until the olive is visible below the peritoneum. The needle is then exposed and passed through the fascia until the suture can be grasped exteriorly. The needle is dropped inside again, the device rotated 180 degrees, and the same procedure repeated. The two ends of the suture, that are now extra-abdominally, can be tied.[19]

- The Endo Close™ suture device (Covidien, Dublin, Ireland; Fig. 12) is a disposable spring-loaded suture carrier. The device is inserted through the port and the suture is dropped inside the abdominal cavity. The device is then removed and inserted at the opposite edge of the trocar site. With the help of a grasper inserted through a secondary port, the suture is reloaded onto the device and retracted outside.[7,19]
- The SZABO-BERCI needle (Karl Storz, Tuttlingen, Germany) is a reusable metallic needle that is relatively easy to utilize and uses the same principle as the above-cited techniques (Fig. 13).
- The Weck® EFx Classic Fascial Closure System (Teleflex Inc., Wayne, Pennsylvania; Fig. 14) is an improved suture passer with standard- and bariatric-length suture guides in a single package. It contains alligator-style graspers for fast and secure capture.
- The Weck® EFx Suture Passer Pilling Berci Suture (Teleflex Inc., Wayne, Pennsylvania) allows efficient one-hand operation while accommodating a wide range of trocar and suture sizes.

Spinal needle/angiocatheter

As early as the 1990s, different authors described the use of intravenous catheters and spinal needles as a guide for the introduction and retrieval of sutures during the closure of the fascia.[7,27-30]

The main issue with this technique was that it was cumbersome given the fact that all original authors described their methods with the cannula still in place to keep the abdomen inflated.[29,31] However, at the turn of the century, new methods of keeping the abdomen inflated all while removing the cannula made it easier for surgeons to close the port with this technique. These methods included the use of a gloved finger inserted into the port to keep it sealed,[32] or, even more ingeniously, the use of a transparent dressing.[30,33]

The development of these newer techniques would allow for unhurried and more precise placement of the catheter at a desired thickness, all while grasping full-thickened fascial and peritoneal closure under laparoscopic visualization.

GUIDELINES AND RECOMMENDATIONS

The port-site hernias are found with incidences of 0.23% at the 10mm port site and 1.9% at the 12mm port site, with markedly progressive increased incidence with a body mass index (BMI) greater than 30.[23,34,35] Since the risk of incisional hernia and visceral incarceration increases with port size, it is generally advised to close all ports of 10mm or larger size.[20,36,37]

Closure of fascial defects smaller than 10mm is a continuous debate.[10] Some authors advocate that all laparoscopic ports must be closed at the fascia level regardless of their size, especially in children; whereas, others postulate that studies have not shown the need for routine closure of 5mm ports.[38,39] However, when these ports, albeit small, have been used for active manipulation during a long operation, closure of the fascia should be considered to avoid herniation.

Hernia at port site is usually due to multiple factors including, most importantly, failure to reapproximate fascial edges, infection, and premature suture disruption.[19] Other risk factors listed in the literature include the trocar diameter, the trocar design, and pre-existing fascial defects.[40] These port-site hernias are classified into two categories depending on time of onset[32]:

1. The early-onset type: occurring immediately after the operation, with frequent small-bowel obstructions
2. The late-onset type: occurring several months after the operation, mostly with local abdominal bulging and no small-bowel obstructions

Some authors advocated prophylactic measures to decrease the risk of facial non-closure, including the insertion of a 10mm lateral trocar in an oblique fashion or as a Z-tract, thus reducing hernia formation by putting the external and internal fascias at different levels.[36,37] Other prophylactic measures include the closure of the fascial defect while maintaining the pneumoperitoneum; therefore, keeping the abdominal wall away from the bowel (avoiding injury) and ensuring adequate closure by a "gas-tight" seal test.[13]

Since the era of laparoscopy, many techniques have been created to ensure proper closure of the fascia at the port site, therefore attempting to decrease the rate of these complications. The main challenge with direct closure of the fascia is technical: it is difficult to close deep layers of the fascia through a small skin incision. However, in routine practice, most trocar holes can be easily closed under direct vision with a regular 0 absorbable suture on a curved needle, especially in non-obese patients, in patients who underwent prolonged operation with manipulation of the trocar site (stretched port-site incision), and for the midline ports (where a single fascial layers exists instead of two layers due to the midline fusion of layers). In these situations, a regular

hand-sutured closure technique can easily ensure closure of the fascia.

The problem arises when the patient is obese or the closure of the defect cannot be easily ensured due to difficult manipulation. These cases require one of the techniques that have been previously mentioned to guarantee proper fascial closure. Laparoscopically assisted techniques, or open techniques under direct visualization, have been shown to securely correct fascial defects and decrease the risk of postoperative herniation. This is specifically relevant in patients who are obese and in patients with risk factors for wound dehiscence, such as ascites, uremia, hypoproteinemia, chronic cough, and those under high-dose steroidal drugs.[30] However, most operating rooms are not equipped with these special devices/sutures, rendering the surgeon's job more difficult. It is advised to anticipate these situations to secure the proper equipment needed for the correct closure of the fascia. If that is not possible, the surgeon can simply grasp the fascia with a hemostat and attempt closure with a regular curved needle during operation. Starting with an "outside-in" suture is recommended and reverting to "inside-out" is reserved for failure of the first technique.[11]

Special techniques for fascial closure are not without complications (i.e., reusable instruments require constant maintenance and may be worn over time), and special devices are usually more robust in size, therefore causing more trauma to the fascia. In some cases, simpler devices, like the use of an intravenous catheter, can facilitate proper fascia closure without the added cost and the worry regarding availability.

CONCLUSION

Although multiple techniques and various devices of variable costs have been introduced in the market in past decades, none has gained unanimous acceptance. Therefore, continuous improvement in the techniques and devices for fascial closure are still needed and will ultimately lead to a gradual decrease in the rate of port-site herniation. Specific preoperative and intraoperative conditions may sway the surgeons toward the use of one technique instead of another, and this remains a case by case evaluation. It is important to note that even the most effective tool in the hand of an inexperienced surgeon might lead to a deleterious effect and will, therefore, be futile. Thus, the most relevant factor is to use devices or tools that the surgeon is familiar with. STI

AUTHORS' DISCLOSURES

The authors have no conflicts of interest to disclose.

REFERENCES

1. Khan A, Siddiqui MN, Ahmed M. A simple technique of umbilical port closure in laparoscopic cholecystectomy. Ann R Coll Surg Engl 1993;75(6):440.
2. Fox AD. A simple technique of umbilical port closure in laparoscopic cholecystectomy. Ann R Coll Surg Engl 1994;76(3):212–3.
3. Hampel N, Selzman AA. A new technique for closing abdominal fascial openings after laparoscopic surgery. Surg Laparosc Endosc 1994;4(6):436–7.
4. Jager RM. Safe repair of umbilical fascial wounds after laparoscopy. J Laparoendosc Surg 1994;4(3):199–200.
5. Conlon KC, Curtin J. A simple technique for the closure of laparoscopic trocar wounds. J Am Coll Surg 1995;181(6):565–6.
6. Garzotto MG, Newman RC, Cohen MS, et al. Closure of laparoscopic trocar sites using a spring-loaded needle. Urology 1995;45(2):310–2.
7. Elashry OM, Nakada SY, Wolf JS, et al. Comparative clinical study of port-closure techniques following laparoscopic surgery. J Am Coll Surg 1996;183(4):335–44.
8. Chung RS. Closure of trocar wounds in laparoscopic operations. The threading technique. Surg Endosc 1995;9(5):534–6.
9. Christey GR, Poole G. A simple technique of laparoscopic port closure allowing wound extension. Surg Endosc 2002;16(4):696–7.
10. Spalding SC, Ponsky TA, Oristian E. A new Dual-hemostat technique to facilitate the closure of small laparoscopic trocar incisions. Surg Endosc 2003;17(1):164–5.
11. Ng WT. Optimal cosmetic results without increased operative risk. Surg Endosc 2006;20(8):1332–3.
12. Ng WT. Perfecting the dual-hemostat port-closure technique. Surg Endosc 2003;17(11):1867–8.
13. Durkin DJ, Horner J. Further modification of the dual-hemostat port closure technique. Surg Endosc 2005;19(7):1002.
14. Moreno-Sanz C, Picazo-Yeste JS, Manzanera-Díaz M, et al. Prevention of trocar site hernias: Description of the safe port plug technique and preliminary results. Surg Innov 2008;15(2):100–4.
15. Tsaltas J, Lolatgis N, Lawrence AS, et al. A novel approach for the repair of an incisional hernia following laparoscopic hysterectomy. Gynaecol Endosc 1996;5(1):39–41.
16. Rumstadt B, Sturm J, Jentschura D, et al. Trocar incision and closure: daily problems in laparoscopic procedures—a new technical aspect. Surg Laparosc Endosc 1997;7(4):345–8.
17. Chatzipapas Ik, Hart Rj, Magos A. Simple technique for rectus sheath closure after laparoscopic surgery using straight needles, with review of the literature. J Laparoendosc Adv Surg Tech 1999;9(2):205–9.
18. Stringer NH, Levy ES, Kezmoh MP, et al. New closure technique for lateral operative laparoscopic trocar sites. Surg Endosc 1995;9(7):838–40.
19. Shaher Z. Port closure techniques. Surg Endosc 2007;21(8):1264–74.
20. Berguer R. A technique for full thickness closure of laparoscopic trocar sites. J Am Coll Surg 1995;180(2):227–8.
21. Fariña Pérez LA, Zungri Telo E. Closure of laparoscopic access ports using a Reverdin needle: a new use for an old instrument. Actas Urol Esp 2003;27(2):168–9.
22. Caruana MF, Singh SM. A simple, safe and effective method for laparoscopic port closure. Ann R Coll Surg Engl 2002;84(4):280.
23. Di Lorenzo N, Coscarella G, Lirosi F, et al. Port-site closure: a new problem, an old device. JSLS J Soc Laparoendosc Surg 2002;6(2):181–3.
24. Monk BJ, Gordon NS, Johnsrud JM, et al. Closure of fascial incisions made at the time of laparoscopy: development of a device. J Laparoendosc Surg 1994;4(4):257–9.
25. Carter JE. A new technique of fascial closure for laparoscopic incisions. J Laparoendosc Surg 1994;4(2):143–8.
26. Eid GM, Collins J. Application of a trocar wound closure system designed for laparoscopic procedures in morbidly obese patients. Obes Surg 2005;15(6):871–3.
27. Elkus RM. A simple technique for hemostasis of bleeding laparoscopic trocar sites. J Am Coll Surg. 1994;179(1):76–7.
28. Petrakis I, Sciacca V, Chalkiadakis G, et al. A simple technique for trocar site closure after laparoscopic surgery. Surg Endosc 1999;13(12):1249–51.
29. Nadler RB, McDougall E, Bullock AD, et al. Fascial closure of laparoscopic port sites: a new technique. Urology 1995;45(6):1046–8.
30. Ng WT. A simple, safe and effective method for laparoscopic port closure. Ann R Coll Surg Engl 2004;86(1):71-2; author reply 73.
31. Cinel A, Uluutku H, Kuguktulu U, et al. A new technique of repair for small abdominal wall defects Minim Invasive Ther Allied Technol 1998:311–3.
32. Majeski J, Anthony E. An improved, inexpensive, quick, and easily learned technique for closure of all large abdominal trocar wounds after laparoscopic procedures. J Am Coll Surg 2002;194(3):391–3.
33. Ng JW. An improved, inexpensive, quick,

and easily learned technique for closure of all large abdominal trocar wounds after laparoscopic procedures. J Am Coll Surg 2003; 196(1):165–6.
34. Kadar N, Reich H, Liu CY, et al. Incisional hernias after major laparoscopic gynecologic procedures. Am J Obstet Gynecol 1993; 168(5):1493–5.
35. Montz FJ, Holschneider CH, Munro MG. Incisional hernia following laparoscopy: a survey of the American Association of Gynecologic Laparoscopists. Obstet Gynecol 1994; 84(5):881–4.
36. Pamela D, Roberto C, Francesco LM, et al. Trocar site hernia after laparoscopic colectomy: a case report and literature review. ISRN Surg 2011;2011:725601.
37. Eltabbakh GH. Small bowel obstruction secondary to herniation through a 5-mm laparoscopic trocar site following laparoscopic lymphadenectomy. Eur J Gynaecol Oncol 1999;20(4):275–6.
38. Nezhat C, Nezhat F, Seidman DS, et al. Incisional hernias after operative laparoscopy. J Laparoendosc Adv Surg Tech 1997;7(2): 111–5.
39. CHAPMAN WHH. Trocar site closure: a new and easy technique. J Laparoendosc Adv Surg Tech 1999;9(6):499–502.
40. Holzinger F, Klaiber C. Trokarhernien Eine seltene, potenziell gefährliche Komplikation nach laparoskopischen Eingriffen. Der Chir 2002;73(9):899–904.