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Outcomes of laparoscopic ventral hernia repair with routine defect closure using “shoelacing” technique

Sean B. Orenstein · Jillian L. Dumeer · Julie Monteagudo · Mun Jye Poi · Yuri W. Novitsky

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Abstract

Introduction Laparoscopic approach has become standard for many ventral hernia repairs. The benefits of minimal access include reduced wound complications, faster functional recovery, and improved cosmesis, among others. However, “bridging” of hernia defects during traditional laparoscopic ventral hernia repair (LVHR) often leads to seromas or bulging and, importantly, does not restore a functional abdominal wall. We have modified our approach to LVHR to routinely utilize transabdominal defect closure (“shoelacing” technique) prior to mesh placement. Herein, we aim to analyze outcomes of LVHR with shoelacing.

Methods Consecutive patients undergoing LVHR with shoelacing were reviewed retrospectively. Main outcome measures included patient demographics, previous surgical history, intraoperative time, mesh type and size, postoperative complications, length of hospitalization, and hernia recurrence.

Results Forty-seven consecutive patients underwent LVHR with defect closure. Average body mass index (BMI) was 32 kg/m^2 (range 22–50 kg/m^2). Eighteen (38%) patients had an average of 1.5 previous repairs (range 1–3). Mean defect size was 82 cm^2 (range 16–300 cm^2), requiring a median of 4 (range 2–7) transabdominal stitches for shoelacing. Two patients required endoscopic component separation to facilitate defect closure. Mean mesh size used was 279 cm^2 (range 120–600 cm^2). Mean operative time was 134 min (range 40–280 min). There were no intraoperative complications. Average length of hospitalization was 2.9 days (range 1–10 days). There were two major postoperative complications [one pulmonary embolism (PE), one stroke]; however, there was no wound-related morbidity or significant seromas. At mean follow-up of 16.2 months, there have been no recurrences.

Conclusions LVHR with defect closure confers a strong advantage in hernia repair, shifting the paradigm towards more physiologic abdominal wall reconstruction. In this series, we found our approach to be safe and comparable to historic controls. While providing reliable hernia repair, the addition of defect closure in our patients essentially eliminated postoperative seroma. We advocate routine use of the shoelace technique during laparoscopic ventral hernia repair.

Keywords Laparoscopic ventral hernia repair · LVHR · Defect closure · Shoelace

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S. B. Orenstein · M. J. Poi · Y. W. Novitsky (✉)
Department of Surgery, Connecticut Comprehensive Center for Hernia Repair, University of Connecticut Health Center, 263 Farmington Avenue—MC 3955, Farmington, CT 06030, USA
e-mail: ynovit@gmail.com

J. L. Dumeer · J. Monteagudo · Y. W. Novitsky
University of Connecticut School of Medicine, Farmington, CT, USA

Restoration of the abdominal wall after ventral hernia remains a constant challenge. For repair of primary and incisional ventral hernias, surgeons employ a multitude of techniques and materials to enhance procedure safety and limit patient morbidity. Unfortunately, providing durable repairs with low recurrence rates continues to be daunting, with failure rates ranging from 18 to 63% for primary suture closure [1–4]. Though recurrence rates have been significantly reduced with the use of prosthetic mesh to a range of 2–32% [1–5], the larger incisions and extensive dissections associated with open repairs have led to significant wound-related morbidity [4, 6–8].

In an effort to reduce postoperative morbidity and wound complications, minimally invasive techniques have been developed to achieve abdominal wall reconstruction. Compared with open repair (OR), laparoscopic ventral hernia repair (LVHR) results in reduced wound complications, quicker recovery of bowel function, shorter hospital stay, reduced total costs, and improved cosmesis, while maintaining low recurrence rates [5, 9–13]. Because of these beneficial attributes, LVHR has become standard for many ventral hernia repairs [14, 15].

A major goal of any ventral hernia repair should be reconstruction of a functional, dynamic abdominal wall. Traditional LVHR relies on intraperitoneal "patching" of defects as an underlay. However, this bridging technique fails to close the actual defect and may result in adynamic areas of abdominal wall. Clinically, this may lead to bulging at the site of hernia repair, especially in the long term. Moreover, significant seroma accumulation may occur in the dead space created above the mesh patch [16]. By closing the hernia defect, medialization of the rectus muscles occurs, thus allowing for better functional and cosmetic reconstruction [8]. We aim to reveal outcomes of LVHR in patients undergoing routine defect closure using our laparoscopic shoelace technique.

Methods

Forty-seven consecutive patients undergoing LVHR with the shoelace technique between March 2007 and November 2009 were retrospectively reviewed. For each patient, demographic, intraoperative, and postoperative data were collected and analyzed. Patient demographics included age, gender, body mass index (BMI), number of prior abdominal surgeries, number of prior hernia repairs, comorbidities, and hernia characteristics. Intra- and postoperative data were also collected and included size of fascial defect, size and type of synthetic mesh used, operative time, complications, length of hospitalization, duration of follow-up, and hernia recurrences.

Surgical technique

The patient is positioned supine with at least one arm tucked. Nasogastric tubes are used in patients with incarcerated defect or when lysis of intestinal adhesions exceeds 1 h. For patients with defects extending beyond the level of umbilicus, we use a three-way Foley catheter to facilitate identification of the urinary bladder. Pneumoperitoneum is achieved using an Optiview^{TM} trocar (Ethicon Endo, New Brunswick, NJ, USA) in the subcostal area. Additional 5-mm trocars are placed under direct vision laterally along the anterior to midaxillary line. Often, two additional 5-mm ports are placed contralaterally to facilitate intra-abdominal mesh introduction and fixation. Adhesiolysis is performed sharply, with limited use of electrosurgery or ultrasonic coagulators. Reduction of hernia contents is performed using blunt graspers and sharp dissection from the inside and manual compression from the outside. The hernia sac is usually left in situ, and the edges of the hernia sac are not altered. The size of the abdominal wall defect is measured using transabdominal spinal needles.

A vertical line is then drawn through the middle of the defect, and the sites for subsequent figure-of-eight stitches are marked every 3 cm. Using a laparoscopic suture passer, the defect is then closed with multiple figure-of-eight stitches using #1 Prolene (Ethicon Inc., Somerville, NJ, USA) (Fig. 1). Each stitch is placed through a stab incision in the skin (traversing the hernia sac) and incorporates 1–2 cm of fascia on each side. Once all the stitches are placed, the pneumoperitoneum is released and the knots are tied in the subcutaneous tissue. To facilitate closure, we tie the knots sequentially, starting at the superior and inferior aspects of the defect and moving towards the center. For defects larger than 10 cm, we perform endoscopic fascial release as described by Rosen et al. [1]. The mesh is then tailored to achieve at least a 5-cm overlap above and below the defect. Because the width of the mesh is not calculated according to the original width of the defect, we routinely use 10 to 14-cm-wide pieces of mesh. This allows for 5–7 cm of overlap from the newly re-created midline.

Four size-0 permanent sutures are placed at the midpoint of each side of the mesh before it is introduced into the abdominal cavity through a 12-mm trocar placed close to the midline (the site that will subsequently be covered by mesh). Once the mesh is placed inside the abdominal cavity, the mesh is unrolled, oriented, and secured to the abdominal wall with the preplaced sutures. Metal or absorbable tacks are then used circumferentially at approximately 1-cm intervals to prevent intestinal herniation. Additional full-thickness, absorbable monofilament sutures are placed every 5–6 cm around the circumference of the mesh, tied with knots buried subcutaneously. Finally, full-thickness, nonabsorbable U-stitches are placed every 4–5 cm on each side of the midline closure, approximately 2 cm lateral to midline. These stitches are key to our technique, as they relieve any tension at the midline closure and redistribute this tension along a large portion of the mesh (Fig. 1). In addition, placement of these stitches helps to incorporate the mesh and "reinforce" the midline closure, thus allowing for placement of the mesh with the adjusted width (and not according to the original defect width).

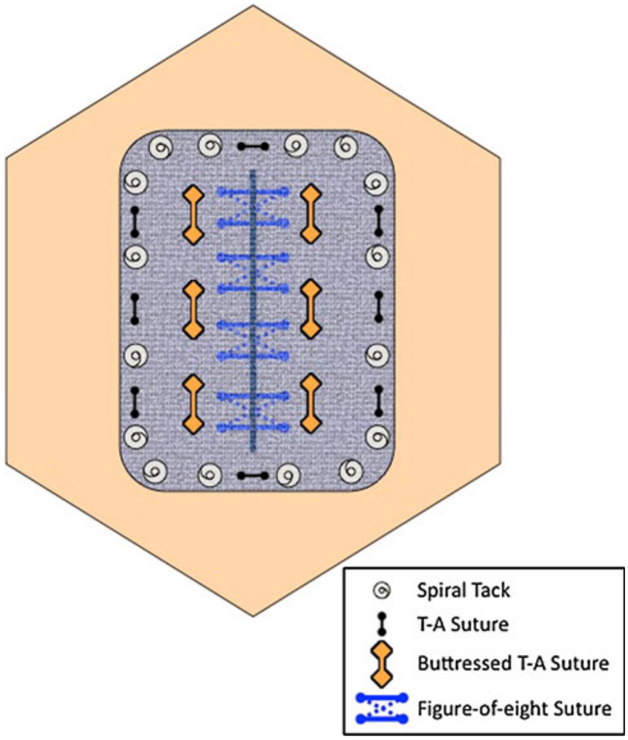

Fig. 1 Schematic representation of abdomen following "shoelace" defect closure and mesh placement. T-A Suture, transabdominal suture

Drains are not used. Perioperative deep vein thrombosis prophylaxis includes placement of compression stockings or sequential compression devices on both lower extremities. We add low-molecular-weight heparin treatment for patients with history of deep vein thrombosis. All patients are aggressively mobilized to ambulate on the first postoperative day. Diet is typically advanced slowly. Postoperative pain regimen includes around-the-clock scheduled intravenous (IV) muscle relaxants (diazepam 3–5 mg IV every 6 h) for 24–48 h to alleviate postoperative discomfort/muscle spasm. Routine follow-up evaluation of herniorrhaphy is performed by an attending surgeon at 3–4 weeks, 3 months, 6 months, 12 months, and yearly thereafter.

Results

Patient demographics

Forty-seven patients underwent LVHR with hernia defect closure using the shoelace technique. Patient demographics included the following (Table 1): female-male ratio of 26 (55%) to 21 (45%), and mean age of 56 years (range 30–85 years). Mean BMI was 31.8 kg/m^2 (range 22–50 kg/m^2); 34% of patients were morbidly obese (BMI ≥35 kg/m^2). Eighteen (38%) patients presented with recurrent hernia, with a range of one to three previously failed repairs. All but seven (15%) patients had midline defects: three patients had flank hernias, two patients had Spigelian hernias, and the other two had off-midline defects stemming from previous Pfannenstiel incisions. Pertinent comorbidities included chronic obstructive pulmonary disease (COPD) (11%), diabetes mellitus (DM) (17%), and use of immunosuppression (2%); 4% admitted to some form of tobacco use. Preoperative assessment of hernia characteristics revealed 36 (77%) incarcerated hernias and 11 (23%) reducible hernias.

Table 1 Patient demographics

Total patients (*n*)	47
Gender	
Male	21
Female	26
Age (years)	
Mean	56
Range	30–85
BMI (kg/m^2)	
Mean	31.8
Range	22–50
Number of prior abdominal surgeries	
Mean	1.96
Range	0–8
Number of prior hernia repairs	
Mean	0.57
Range	0–3
Comorbidities, *n* (%)	
COPD	5 (11%)
DM	8 (17%)
Immunosuppression	1 (2%)
Tobacco use	2 (4%)
Hernia characteristics, *n* (%)	
Incarcerated	36 (77%)
Reducible	11 (23%)

BMI body mass index, *COPD* chronic obstructive pulmonary disease, *DM* diabetes mellitus

Operative findings

Intraoperative measurements of hernia defects ranged from 16 to 300 cm^2 with mean defect area of 82 cm^2. A median of 4 (range 2–7) transabdominal figure-of-eight sutures were necessary for shoelace defect closure. All implanted meshes utilized an antiadhesion barrier for intra-abdominal placement; 83% were polyester based, with the remaining 17% being polypropylene based. Mean mesh size was 279 cm^2 (range 120–600 cm^2). Operative times ranged

Table 2 Operative data

Size of fascial defect (cm^2)	
Mean	82
Range	16–300
Size of synthetic mesh used (cm^2)	
Mean	279
Range	120–600
Type of synthetic mesh used, *n* (%)	
Polyester	39 (83%)
Polypropylene	8 (17%)
Operative time (min)	
Mean	134
Range	40–280
Intraoperative complications	None

from 40 to 280 min, with a mean of 134 min. There were no intraoperative complications (Table 2).

Because of perceived excessive tension placed on the hernia defect during closure, endoscopic component separation was utilized for facial release to facilitate defect closure in two patients.

Postoperative findings

Two patients experienced major postoperative complications, including one pulmonary embolism and one cerebrovascular accident. However, both patients recovered without significant long-term sequelae or disability. There was no wound-related morbidity, including no seromas or bulging at hernia repair sites (Table 3).

Mean length of hospital stay was 2.9 days (range 1–10 days). Twelve patients (25.5%) were discharged home within 24 h of surgery. During mean follow-up of 16.2 months (range 3–36 months), there were no hernia recurrences. Postoperative computed tomography (CT) was obtained on 11 patients (23%); all CTs revealed complete medialization of rectus muscles.

Table 3 Postoperative data

Postoperative complications, *n* (%)	
Total	2 (4%)
CVA	1 (2%)
PE	1 (2%)
Seroma	0 (0%)
Wound infection	0 (0%)
Length of hospitalization (days)	
Mean	2.9
Range	1–10
Duration of follow-up (months)	
Mean	10
Range	3–25
Hernia recurrences	None

CVA cerebrovascular accident, *PE* pulmonary embolism

Discussion

During the evolution of ventral hernia repair, surgeons have seen their recurrence rate decrease substantially, most notably with the utilization of mesh prosthetics to support the hernia defect. Over the last several years, laparoscopic repair has become the standard for many ventral hernia defects [14, 15] due to its efficacy and safety [11, 12, 17, 18]. Though LVHR has become very popular among surgeons, "bridging" of defects during repair has evolved to become one of its commonly mentioned limitations. Closure of the hernia defect remains a debated topic. In this study we demonstrated that routine closure of fascial defects using our laparoscopic shoelace technique resulted in very durable repairs and elimination of significant postoperative seromas and visceral bulging in patients undergoing LVHR.

When addressing ventral hernia repair, abdominal wall mechanics/physics is an important topic that necessitates some discussion. Pascal's principle states that pressure applied to a confined fluid is transmitted equally throughout the fluid, as well as the container walls [19]. Additionally, a hernia defect is akin to a vascular aneurysm, with respect to a focal weakness or thinning of its wall. According to an extension of the law of LaPlace [20], as the abdominal wall radius increases and thickness decreases, wall tension across the hernia defect is greatly increased. Because a hernia defect provides an outlet for abdominal pressure, the force applied across the defect is substantially increased. As discussed by Agarwal et al., mesh covering the defect in a traditional "bridged" fashion bears this multiplied intra-abdominal pressure point, possibly leading to mesh instability, excessive suture tension, and bulging [16]. Thus, it can be hypothesized that, by closure of the defect, abdominal wall integrity is restored, leading to equalized pressure and tension across the abdominal wall and intra-abdominally placed mesh.

The term "shoelace repair" was initially coined by Abrahamson and Eldar for open ventral hernia repair [21]. It involved incising the anterior rectus sheath followed by a continuous suture for reapproximation of the midline to provide a "tension-free repair." Further techniques of defect closure have been developed for use in LVHR. Palanivelu et al. have utilized continuous intracorporeal sutures for defect closure with intraperitoneal onlay mesh (IPOM) [22]. Agarwal et al. describe their "double-breasted" fascial closure with interrupted sutures followed by IPOM [16]. Similarly, our laparoscopic shoelace technique employs the use of interrupted sutures to reapproximate the hernia defect edges, though without overlap of the defect edges. However, our technique adds two very critical rows of transabdominal stitches on each side of the "primary" closure to redistribute tension at the site of the figure-of-eight stitches over the large surface of the mesh. We strongly believe that these "buttress" stitches relieve tension in the newly recreated linea alba and assist with physiologic tension throughout the entire abdominal wall.

It has been suggested that a key goal of any ventral hernia repair should be reconstruction of an abdominal wall that resembles native musculature and fasciae [8]. As a result, an additional major focus of our defect closure is restoration of a functional, dynamic abdominal wall. By closing the defect, the rectus abdominis is reapproximated and the major insertion point of abdominal musculature, the linea alba, is restored. Our laparoscopic shoelace repair combines techniques of both primary defect closure along with mesh prosthesis placement for reinforcement. Although we were not able to evaluate "functionality" of the abdominal wall, routine defect closure resulted in subjective elimination of adynamic areas of abdominal wall and postoperative bulging at the site of hernia defects.

Postoperative seroma is a common complication of traditional LVHR [6]. Regardless of whether an open or laparoscopic approach is used, dissection of the hernia sac results in a potential space that is filled with serous fluid postoperatively. Traditional laparoscopic techniques utilize a mesh (placed as a bridge across the defect) to serve as a floor of a large potential space, leading to seroma formation [16]. Although such seromas are common and typically do not require intervention, they may be a source of significant postoperative discomfort and wound-related morbidity [8, 11]. Closure of the defect results in a near-total decrease of the dead space, and it also prevents contact between the mesh implant and any residual hernia sac. As a result, routine laparoscopic shoelacing essentially eliminated significant seromas in our series of patients, providing yet another benefit to our patients.

Appropriate sizing of the mesh is considered to be one of the key features of effective LVHR. Our technique presents us with two options: size the mesh according to the original width of the defect, or adjust the mesh to provide 5–7 cm overlap from the midline closure. We chose the second option and routinely use mesh no wider than 12–14 cm. The use of transabdominal stitches according to our description has allowed us to make this choice safely. The efficacy of our repair provides further basis for this reduction in mesh width needed. Since our closure technique does not reduce the vertical dimension of the defect, we aim at 5–7 cm of mesh overlap of the original vertical defect size. The use of narrower meshes facilitated mesh positioning and allowed us to avoid essentially "bisecting" the abdominal cavity with large/wide meshes. Furthermore, smaller meshes should result in a reduction in the overall foreign-body response and fibrotic reactions to the mesh. With diminished lateral scar tissue to the mesh, patients should experience improved mobility and decreased long-term postoperative discomfort. Such reduction in the width of the mesh implant is one of the major benefits of our laparoscopic shoelacing technique.

Routine defect closure with reapproximation of the rectus muscles restores a near-native anatomy of the abdominal wall. As a result, we postulate that normal abdominal wall mechanics are restored, and reduction of tension across the previous defect site and the intracorporeally placed mesh is achieved. With reduced wall tension, hernia recurrence rate should be diminished. We detected no recurrences at mean 1-year follow-up. Along with our current study, other studies demonstrate that utilization of laparoscopic defect closure with mesh placement resulted in an extremely low recurrence rate, ranging from 0 to 3% [15, 16, 22, 23]. Although our follow-up period is relatively short, lack of recurrences to date has been very encouraging. Close ongoing clinical observation and long-term outcomes will be needed to further validate our technique.

Conclusions

Laparoscopic ventral hernia repair with defect closure provides durable repair with low recurrence rate. In this series, we found our shoelace technique safe and comparable to historic controls as well as other defect-closure techniques. By avoiding mesh bridging, defect closure results in restoration of a functional and dynamic abdominal wall that may be more physiologic in nature. While providing reliable hernia repair, addition of defect closure in our patients eliminated postoperative seromas and subjective bulging, and it reduced the size of implanted mesh. We advocate routine use of the shoelace technique during laparoscopic ventral hernia repair.

Disclosures S. Orenstein, J. Dumeer, J. Monteagudo, M. J. Poi, and Y. Novitsky have no conflicts of interest or financial ties to disclose for this study.

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