2 Preoperative Considerations Prior to Minimally Invasive Ventral Incisional Hernia Repair

Deepa V. Cherla and Mike K. Liang

Introduction

Ventral incisional hernias are abdominal wall fascial defects secondary to incisions as opposed to primary ventral hernias that are congenital or spontaneous in etiology (e.g., umbilical hernia) [1]. Although much of the evidence behind the management of patients and treatment of these two diseases is similar, there are important differences. Most striking are the differences in surgical outcomes. For example, high-quality studies demonstrate the long-term hernia recurrence rate of ventral incisional hernias to be 30–70% while for primary ventral hernias to be 5–30% over the course of 5–10 years [2–5]. These differences in absolute risk affect decision-making by shifting the balance of risk and benefit. This chapter will focus on ventral incisional hernias and only briefly discuss the nuances of the care of patients with primary ventral hernias.

Patients with ventral incisional hernias often present with medical history and physical exam findings that affect surgical decision-making [6, 7]. Options for the patient and clinician include nonoperative management or surgical repair [6–12]. The choice of treatment can change over time as presentation and comorbidities evolve. Once the decision for surgical repair is made, the process of selecting open, laparoscopic, or robotic repair is affected by multiple factors including surgeon skill/experience, patient history, and hernia type [7].

Minimally invasive ventral hernia repair has been shown to decrease rates of surgical site infection and hospital length of stay compared to open repair; yet, less than one-third of all ventral hernia repairs are performed using a minimally invasive surgical technique [13–19]. Not all cases may be amenable to a minimally invasive approach and not all surgeons may feel comfortable performing a minimally invasive repair, particularly in complex settings. Some of the barriers to adoption of laparoscopic ventral hernia repair may be able to be overcome by utilizing a robotic platform. The robotic approach is increasingly being used for ventral hernia repair in the United States of America (USA) [20]. In 2014, 25% of USA hospitals had at least one robotic surgical platform and worldwide 570,000 robotic assisted surgical procedures were performed [21]. Much of this demand may be driven by industry, patients, and surgeons who may perceive robotic surgery to be associated with less pain, shorter hospital stays, and faster recovery [22, 23].

D. V. Cherla (✉)
Department of Surgery, University of Texas Health Science Center at Houston, Houston, TX, USA

Basking Ridge, NJ, USA

M. K. Liang
Department of Surgery, University of Texas Health Science Center at Houston, Houston, TX, USA
e-mail: mike.liang@uth.tmc.edu

K. A. LeBlanc (ed.), *Laparoscopic and Robotic Incisional Hernia Repair*,
https://doi.org/10.1007/978-3-319-90737-6_2

Patient Clinical History

A patient's clinical history is important in decision-making between the nonoperative and surgical treatment options for a ventral incisional hernia. Factors that affect the outcomes include not only surgical technique but also patient factors. Potentially modifiable patient risk factors associated with surgical complications include obesity, medical comorbidities, and smoking.

Obesity and Obesity-Related Comorbidities

Obesity and obesity-related comorbidities such as diabetes mellitus are an epidemic in the USA and other developed nations. Currently, it is estimated that two-thirds of adults in the USA are overweight (body mass index [BMI] ≥ 25 kg/m^2) or obese (BMI ≥ 30 kg/m^2) [24, 25]. The mean BMI of patients with ventral hernias typically hovers around 33 kg/m^2 [26–30]. In an analysis of the American College of Surgeons National Surgery Quality Improvement Project, 67% of patients undergoing laparoscopic ventral hernia repair were obese [26, 27]. Following ventral hernia repair, obese patients are at an increased risk of prolonged hospital length of stay, reoperation, hospital readmission, surgical site infection, and hernia recurrence [6, 7, 26–30]. While it is widely accepted that elective surgery in patients with BMI greater than or equal to 50 kg/m^2 is at prohibitive risk for hernia recurrence and complications, a growing body of evidence suggests that even among patients with a BMI of 40–50 kg/m^2, outcomes are poor, with high wound complications and hernia recurrence [6, 7, 31–33]. Some surgeons believe that elective ventral hernia repair should only routinely be undertaken among patients with BMI less than 40 kg/m^2 [6, 7]. Clearly, this is not always feasible but signifies the importance of obesity as a risk factor.

In addition, obesity is associated with related medical problems such as diabetes mellitus, which affect wound healing and increase the risk of wound complications. Outcomes of patients with well-controlled as opposed to poorly controlled diabetes are vastly different following abdominal surgery. These patients are at twofold increased odds (odds ratio [OR] 1.95–2.32, 95% confidence interval [CI] 1.11–4.82) of suffering from a major complication or infectious complications [6, 7, 34, 35]. Elective ventral hernia repair is not recommended in patients with a glycosylated hemoglobin (HbA1C) higher than 8.0%, and individualized preoperative interventions, including diet modification and glucose control plans are recommended for individuals with HbA1C between 6.5 and 8.0% [6, 7].

Among comorbid patients where it is safe to delay elective ventral hernia repair, preoperative medical interventions such as counseling, physical conditioning, and weight loss programs (prehabilitation) including surgical interventions such as weight loss surgery can be initially offered [36–38]. While no studies have evaluated this issue specifically in patients with ventral hernias, among patients with other surgical diseases, these programs have been shown to be effective in achieving weight loss [36–38]. It is unclear if the effectiveness of these programs to achieve weight loss and improve physical conditioning can be translated to patients with ventral hernias. Exercise and diet have potential unique challenges in patients with hernias related to underlying poor patient physical function and the risk of exercise exacerbating hernia-related symptoms and signs. Another option includes weight loss surgery, which is the only sustainable method for prolonged weight loss, but may not be appropriate for all patients [6, 7]. The safety and feasibility of weight loss surgery before or in conjunction with ventral hernia repair is unknown. Currently, ventral hernia repair among patients with BMI greater than 30 kg/m^2 should (ideally) not be recommended without individualized preoperative intervention (this may include counseling, diet, physical fitness programs, or weight loss procedure). There is an ongoing trial assessing the impact of a preoperative exercise and weight loss program on outcomes after VHR [39].

Once it has been decided that a comorbid patient will be scheduled for elective ventral hernia repair, the choice of surgical approach must be determined. Because of the increased risk of

wound complications in comorbid patients, there has been great interest in the role of minimally invasive ventral hernia repair in this population. In studies of the National Surgical Quality Improvement Program [26, 27, 29] the effect of laparoscopy on reducing complications in ventral hernia repair was greater in obese patients than for nonobese patients. Furthermore, the hospital length of stay was significantly decreased in patients with a BMI greater than 30 kg/m^2. These benefits of minimally invasive surgery are also seen among patients with diabetes when evaluating national databases [40].

Minimally invasive repair of ventral hernias is feasible and often provides the best surgical option for diabetic or obese patients requiring surgery [13–16]. Scant published research exists concerning robotic incisional hernia repair in obese or diabetic individuals; however, surgeons report that the robotic platform may make the surgery technically and physically easier for the surgeon to perform [21–23].

Tobacco Use

Smoking affects ventral hernia outcomes through the development of lung disease, coughing, and its impact on wound healing. Current smokers have an increased risk for surgical site infections and hernia recurrence following ventral hernia repair, as supported by large database studies (Table 2.1) [41–46]. Subsequently, many hernia experts currently do not recommend elective ventral hernia repair for patients who are current smokers or who are utilizing tobacco products, such as chewing tobacco, cigars, and pipe-smokers [6, 7, 41–46]. Nicotine testing is reasonable to perform, but may be reserved for patients who report quitting smoking yet for whom physicians maintain high clinical suspicion of tobacco use [6, 7]. Patients should abstain from smoking for at least 1 month prior to elective repair, as randomized controlled trials have demonstrated that smoking cessation for 4 weeks or more prior to surgery improves outcomes (Table 2.1) [47–50].

Table 2.1 Smoking and surgery

Study	Year	Population	*N*	Primary outcome	OR (95% CI)
Large cohort studies and effect of smoking on outcomes of ventral hernia repair					
Danzig et al. [41]	2016	NSQIP	3730	Repeat VHR at 1 year	1.70 (1.08–2.70)
		VHR			
Kaoutzanis et al. [42]	2015	NSQIP	28,269	Wound infection	1.46 (1.13–1.88)
		VHR			
Fischer et al. [43]	2014	NSQIP	1974	Complications	1.41 (1.04–1.91)
		VHR with Panniculectomy			
Lovecchio et al. [44]	2013	NSQIP	17,211	Readmission	1.30 (1.05–1.62)
		VHR			
Swenson et al. [45]	2008	VHR with mesh	506	Mesh infection	2.18 (1.09–4.36)
Finan et al. [46]	2005	VHR	1505	SSI	2.46 (1.33–4.57)
Randomized controlled trials on effect of preoperative smoking cessation					
Thomsen et al. [47]	2010	Breast cancer	130	All complications	1.00 (0.75–1.33)
Lindstrom et al. [48]	2008	Inguinal hernia	117	All complications	0.51 (0.27–0.97)
		Umbilical hernia			
		Cholecystectomy			
		Joint prosthesis			
Sorensen et al. [49]	2007	Inguinal hernia	189	Wound infection	1.43 (0.51–5.03)
		Incisional hernia			
Moller et al. [50]	2002	Orthopedic	108	All complications	0.34 (0.19–0.64)

NSQIP national surgical quality improvement program, *VHR* ventral hernia repair, *SSI* surgical site infection, *OR* odds ratio

The magnitude of benefits seen with minimally invasive surgery in patients with comorbidities such as obesity and diabetes are not seen with smokers [51]. This is likely because many of the poor outcomes associated with smoking are not just related to wound healing but include respiratory complications such as pneumonia or higher rates of postoperative intubation [51]. Thus, even with the use of minimally invasive techniques, elective ventral hernia repair is not recommended in current smokers.

Surgical History

Adhesions can significantly affect the complexity of a ventral hernia repair and make a minimally invasive approach formidable. Patients with multiple prior open abdominal surgeries, prior lysis of adhesions for small bowel obstruction, prior mesh placement, or prior intra-abdominal inflammatory process (i.e., intestinal perforation or major abdominal trauma), may require an extensive lysis of adhesions during ventral hernia repair. This may or may not be feasible through a minimally invasive approach [13–16].

While a minimally invasive lysis of adhesions can be safely performed by experienced surgeons, the risk of enterotomy or missed enterotomy represents a high-stakes complication [13–16]. Recognizing when to convert to open prior to causing an enterotomy is crucial; this threshold depends on individual surgeon skill and judgment to optimize the proportion of cases that can be safely performed with a minimally invasive technique while avoiding missed enterotomies. Inexperienced surgeons have reported extremely high rates of missed and recognized bowel injuries [52–54]. Patients who suffer an enterotomy during laparoscopic ventral hernia repair are four times as likely to suffer complications, including mesh infection and enterocutaneous fistula [55–58]. Even if the enterotomy can be repaired with minimally invasive techniques, synthetic mesh placed in the intraperitoneal space is at increased risk of mesh infection and complications. Thus, these patients may need to be converted to open (increased risk for wound complication), have a repair with utilizing a highly infection resilient mesh (biologic or bioprosthetic), or perform an even more complex repair with preperitoneal or retromuscular mesh placement (see section below on contamination [55–58].

Among the most serious complication for ventral hernia repair is a missed enterotomy [55–58]. Intestinal injuries can occur either as an unrecognized full thickness bowel injury or a partial thickness injury such as a thermal injury that then evolves into a full thickness injury. Patients may present with fever, leukocytosis, tachycardia, or even sepsis due to substantial intra-abdominal contamination. In this setting the repair should be considered "failed" and any intraperitoneal synthetic mesh needs to be removed. These patients are at increased risk of major complications including enterocutaneous fistula and death [55–58].

High-quality data on the safety, efficacy, and effectiveness of robotic surgery with lysis of adhesions do not exist. Some surgeons contend that robotics facilitates technically superior adhesiolysis to laparoscopic approaches through wristed instruments, three-dimensional video imaging systems that provide improved views of complex anatomical relationships, and improved instrument manipulation and ergonomics [59–61]. The robotic platform may allow surgeons to perform a minimally invasive, complex lysis of adhesions that otherwise be more difficult using a pure laparoscopic approach. However, other surgeons argue that the robot remains limited for complex lysis of adhesions. For example, if extensive adhesions exist throughout the abdomen, some surgeons recommend that adhesiolysis be performed laparoscopically prior to docking the robot since the robotic platform is better suited for working in a targeted area not involving more than two abdominal quadrants [22, 59–61]. Some of these limitations are lessened with the newest generation of robotic platforms that allows for true multi-quadrant surgery [22, 59–61]. A multi-institutional retrospective review of 368 patients showed that surgeons performing a ventral or incisional robotic hernia repair converted to open in only 0.8% of cases,

most frequently due to dense adhesions [62]. Rates of conversion for laparoscopic to open incisional hernia repair, in contrast, range from 0 to 12% [13–16].

While minimally invasive ventral hernia repair has substantially improved short-term outcomes compared to open surgery, surgeons should use their best judgment based upon their skill and experience as to when to utilize minimally invasive approaches and when convert to open to minimize the risk of enterotomy and missed enterotomy. A robotic platform may have a role for some surgeons to perform a minimally invasive lysis of adhesions in a safer fashion in select patients.

Hernia Characteristics

Important hernia-related considerations that affect the decision between robotic, laparoscopic, and open ventral hernia repair include the hernia size and the ability to achieve primary fascial closure, hernia location, and the presence of contamination. In addition, the nuances of treating primary ventral hernias as opposed to ventral incisional hernia will be reviewed.

Defect Size

The European Hernia Society has defined ventral incisional hernias as small (<4 cm in width), medium (4–10 cm in width), and large (>10 cm width) [1]. An additional category regardless of defect size is loss of domain where substantial intra-abdominal contents chronically reside outside of the abdominal domain. In general, minimally invasive surgery is suggested for small- and medium-sized hernias; laparoscopy can be challenging for large hernias and hernias with loss of domain [63]. One of the main reasons that minimally invasive surgery is challenging for large hernia defects is because of the growing interest on the benefits of primary fascial closure.

The role of primary fascial closure during minimally invasive hernia repair continues to be debated, as no high-quality, conclusive evidence currently exists that support this technique [64–67]. Proponents argue that fascial defect closure may be associated with fewer postoperative seromas and decreased long-term hernia recurrence as well as a lower risk of mesh eventration [66, 67]. A 2014 systematic review of 11 studies examining primary fascial closure with laparoscopic ventral hernia repair concluded that while only poor-quality data currently exists, primary fascial closure compared to non-closure resulted in lower recurrence rates (0–5.7 vs. 4.8–16.7%) and seroma formation (5.6–11.4 vs. 4.3–27.8%) rates over a follow-up period of 1–108 months [67]. In addition, patients reported improve patient centered outcomes including satisfaction with abdominal wall cosmesis and satisfaction. Currently, multiple randomized controlled trials are ongoing [68].

Defects between 6 and 10 cm in width may be challenging for surgeons to close with a minimally invasive technique [66, 67]. Compared to standard laparoscopic approach, the robotic platform may facilitate the intracorporeal suturing needed for fascial closure by allowing for ergonomic movements, seven degrees of motion, three-dimensional imaging, and dexterous wristed instrumentation [22, 59–61]. This theory is supported by the increased frequency of fascial closure in robotic intraperitoneal mesh placements and robotic retromuscular ventral hernia repairs [69, 70].

For large defects, myofascial release (component separation) may be needed to achieve fascial closure. While endoscopic component separation has been described and is feasible with laparoscopic surgery, the amount of release may be limited and associated with increased wound complications [71]. Among experts, endoscopic component separation is used sparingly due to the limited release and high seroma rates [6, 71]. The robotic platform has brought about an interest in performing minimally invasive retromuscular repairs and posterior component separation. Robotic posterior component separation has been shown to be feasible and efficacious when performed by experts. Short-term outcomes demonstrate similar outcomes compared to open with shorter hospital length of stay [72, 73]. However,

existing studies are at high risk for bias and these conclusions can only be considered hypothesis generating. In addition, skeptics cite persistent concerns regarding value (cost/quality), missed enterotomy (which appears to be more common with robotic cases as compared to open procedures), and an overuse of component separation to achieve primary fascial closure. Both efficacy and effectiveness randomized controlled trials are needed.

Location

Lateral, suprapubic, subxiphoid, and subcostal ventral hernias typically are more challenging due to adjacent structures (e.g., bone, bladder, diaphragm, nerves) and the need for more complex dissection. Robotic ventral hernia repair may provide improved visualization for dissection and mesh fixation. Some authors have commented on being able to take precise bites of tissue to better anchor the mesh on or near lateral abdominal borders more easily with the robot. Mesh fixation with tacks, which is typically utilized during standard laparoscopic ventral hernia repair, can be challenging in these locations and risk injuring vital structures [7]. Alternatively, skeptics argue that surgeons may experience decreased haptic and tactile feedback with the robot that makes hernia repair in these locations more challenging [20–23]. Because these ventral hernias are uncommon, it is unlikely that any adequately powered, randomized controlled trials will be completed to compare robotic repair as opposed to open or laparoscopic repair of ventral hernias in these locations. Insight for these relatively uncommon hernias will likely need to be sought through examination of large databases or registries.

Contaminated Ventral Hernia Repairs

Contaminated cases include those falling within Wound Class II (clean contaminated; the respiratory, gastrointestinal, genital, or urinary tract is entered under controlled conditions), Wound Class III (contaminated; the case involves gross spillage from the gastrointestinal tract or nonpurulent inflammation), or Wound Class IV (dirty or infected; infection is present in the initial operative field) [6, 7]. Higher wound classes are associated with increased surgical site infection rates, which in turn are associated with increased rates of hernia recurrence and reoperation [7, 74]. Much of the literature on contaminated cases has focused on mesh type and placement rather than surgical platform.

In contaminated ventral hernia repair, the desire to minimize recurrence through prosthetic mesh reinforcement must be balanced against potential infectious complications, reoperations, and possible need for mesh explanation. Choices include suture only repair, placement of mesh that is more resistant to bacterial contamination, staged repair, or leaving a planned ventral hernia and performing an elective repair in the future [6, 7]. Mesh reinforcement decreases hernia recurrence rates but the evidence supporting mesh use is derived from uncomplicated, elective ventral hernias with no contamination [5, 6]. In a study on of the National Surgical Quality Improvement Project, 33,832 cases of ventral hernia repair demonstrated that mesh reinforcement of contaminated ventral hernia repairs compared to suture repair substantially increases rates of surgical site infection and 30-day complications [75].

If mesh is utilized in a contaminated field, it may also be placed in one of several locations but there is also little data on the safety of each location [5]. It is widely believed that intraperitoneal mesh placement of synthetic mesh in the intraperitoneal (underlay) position is unsafe [76]. Alternatively, mesh placement in the retrorectus (sublay) or onlay position may be safer. The findings of a review of 1200 patients at seven academic centers involved with the Ventral Hernia Outcomes Collaborative undergoing Wound Class II-IV ventral hernia repair are summarized in Table 2.2 [7]. Most of these cases were open procedures as few laparoscopic procedures were performed in contaminated setting.

In standard laparoscopic ventral hernia repair where synthetic mesh is placed in the intraperito-

Table 2.2 Ventral hernia outcomes collaborative outcomes of mesh type and mesh location

		Wound class			Mesh location	
		II	III	IV	Sublay	Underlay
Suture (n = 136)	*N*	1	1	3		
	Width (cm)	2.3 ± 0.6	–	–		
	SSI (%)	1 (100%)	1 (100%)	0		
	Deep SSI (%)	0	0	0		
	Recurrence (%)	1 (100%)	0	0		
Synthetic[a] (n = 747)	*N*	107	5	1	131	578
	Width (cm)	3.9 ± 3.6	14.6 ± 9.0	8.0 ± 0	4.1 ± 4.8	5.1 ± 4.2
	SSI (%)	15 (14.0%)	2 (40.0%)	0	22 (16.8%)	89 (15.4%)
	Deep SSI (%)	7 (6.5%)	1 (20.0%)	0	6 (4.6%)	39 (6.7%)
	Recurrence (%)	15 (14.0%)	2 (40.0%)	0	10 (7.6%)	83 (14.4%)
Biologic (n = 336)	*N*	51	43	23	49	257
	Width (cm)	8.9 ± 5.4	10.0 ± 6.2	11.3 ± 5.8	12.3 ± 6.0	9.6 ± 5.6
	SSI (%)	7 (13.7%)	5 (11.6%)	4 (17.4%)	8 (16.3%)	33 (12.8%)
	Deep SSI (%)	5 (8.9%)	2 (4.7%)	2 (8.7%)	3 (6.1%)	12 (4.7%)
	Recurrence (%)	7 (13.7%)	10 (23.3%)	0	5 (10.2%)	46 (17.9%)

[a]Light- or mid-density (weight) mesh

neal (underlay) position, the risk of surgical site infection, in particular mesh infection, is high [76]. While small series have reported the efficacy laparoscopic repair clean-contaminated cases, these remain extremely small series in carefully selected patients with minimal contamination (e.g., tubal ligation or laparoscopic cholecystectomy for biliary colic with no spillage). The safety and effectiveness of routinely placing intraperitoneal synthetic mesh in patients with wound class II or higher is not supported by large nationwide database studies [76].

This leaves the minimally invasive surgeon a few options other than conversion to open: (1) laparoscopically suture the defect closed alone, (2) place a biologic mesh laparoscopically, or (3) place mesh in a location other than intraperitoneal/underlay (e.g., preperitoneal or retromuscular, sublay). While suture repair may be an acceptable therapy for primary ventral hernias in contaminated setting due to the lower absolute risk of hernia recurrence, it has an unacceptably high recurrence rate, even for small defects, for ventral incisional hernia repairs [2–5]. Alternatively, laparoscopic intraperitoneal mesh repair with a biologic mesh has been reported and is feasible. However, there are technical challenges associated with this practice and no high-quality data that exists to support the use of nonsynthetic mesh including biologic, biosynthetic, or bioabsorbable [77–79]. Technical challenges with nonsynthetic meshes include the risk of eventration with a bridged repair (i.e., need for primary fascial closure), challenges in fixation, and mesh selection given the wide variety and array of choices. Finally, placing a mesh in a sublay position (preperitoneal or retromuscular) may protect the mesh from intra-abdominal contamination. While this has been reported, it has substantial technical challenges, has unclear generalizability, and has not undergone the rigors of a randomized controlled trial [80–82].

Little literature has examined robotic hernia repair of contaminated cases. However, many of the technical challenges to performing a minimally invasive ventral hernia repair in the face of contamination may be simplified using the robotic platform. Primary fascial closure and mesh fixation of biologic mesh can be easier using the robotic platform [69, 70, 83]. In addition, sublay mesh repair seems to be more feasible with robotic platform as compared to laparoscopic approach [72, 73, 84]. However, these studies report on the results of high volume hernia experts with advanced minimally invasive skills. Safety, efficacy, and effectiveness of these approaches still require assessment through rigorously performed randomized controlled trials.

Primary Ventral Hernias

Primary ventral hernias are hernias that arise spontaneously on the abdominal wall and are not associated with any incision (e.g., umbilical hernia, epigastric hernia, Spigelian hernia, lumbar hernia) [1]. These hernias have substantially different outcomes, such as surgical site infection and hernia recurrence, when compared to ventral incisional hernias [5, 14]. While many treatments have similar reductions in relative risk, the differences in absolute risk reduction affect the nuances of treatment [2–5]. For example, mesh repair as opposed to suture repair has a similar relative risk reduction in hernia recurrence with primary ventral hernias and ventral incisional hernias (relative risk reduction of two- to threefold). However, the absolute risk reduction is substantially different (8% vs. 20% at 2–3 years postoperative). Because of this, while suture repair may be acceptable in certain settings with primary ventral hernias, suture repair of ventral incisional hernias should be avoided whenever possible. In a real-world example, while performing a laparoscopic cholecystectomy, a primary ventral hernia in a low-risk patient may be effectively treated with suture repair (11% recurrence at 2 years); however, a sutured ventral incisional hernia would not yield acceptable results (43% recurrence at 3 years) [2–5].

This similar risk/benefit consideration should be utilized when assessing minimally invasive surgery in primary ventral hernia. While laparoscopic surgery has a similar relative risk reduction of surgical site infection (two- to fourfold) the absolute risk reduction is highly variable [14]. Thus, a low-risk patient undergoing primary ventral hernia repair has a similar risk of surgical site infection with laparoscopic (<0.5%) vs. open (1%). This is quite different from the high-risk patient undergoing ventral incisional hernia repair that has a risk with laparoscopic of 1–5% but 20% with the open technique. In addition, many technical factors may affect the decision-making between minimally invasive repairs versus open repairs in patients with primary ventral hernias. Patients with multiple defects (umbilical and epigastric hernia), lateral defect (Spigelian or lumbar hernia), or concomitant diastasis recti may be easier to repair with a minimally invasive approach. We recommend minimally invasive ventral hernia repair in high-risk patients with a primary ventral hernia (overweight/obese, diabetes mellitus, smoker within the past year, chronic obstructive pulmonary disease, immunosuppression), multiple defects, lateral defects, and patients with diastasis recti [6, 7, 85].

The technical aspects of minimally invasive primary ventral hernia repair are also different from ventral incisional hernia repair. With primary ventral hernias, many predominantly contain preperitoneal fat and the hernia sac (peritoneum) which are easily separable from the other layers of the abdominal wall [85, 86]. If this tissue is not removed, patients often complain of a persistent bulge/mass and imaging will demonstrate tissue eventration (entrapment of preperitoneal fat and hernia sac). Because of this, we recommend that the hernia sac and preperitoneal fat be meticulously excised with all laparoscopic primary ventral hernia repairs. The role of primary fascial closure in primary ventral hernias may be substantially different as compared to ventral incisional hernias [87]. This effect is most likely due to hernia defect size rather than hernia type: the vast majority of primary ventral hernias are small (<2 cm fascial defect) as opposed to ventral incisional hernias which are commonly larger. Fascial closure may have a more substantial impact with a larger defect as opposed to smaller defects. The mesh is more likely to bulge or protrude (mesh eventration) through a large defect as opposed to a small defect [88]. We routinely close all fascial defects larger than 3 cm in width and bridge most defects smaller than 3 cm in width [7]. Most primary ventral hernias that we encounter have a fascial defect of less than 3 cm in width.

Existing Evidence Comparing Surgical Platforms

Open Versus Laparoscopic Incisional Hernia Repair

There is extensive, high-quality scientific literature evaluating open versus laparoscopic inci-

sional hernia repair. Most meta-analyses and systematic reviews demonstrate that laparoscopic ventral hernia repair is associated with a decreased risk of surgical site infection but not wound complications (e.g., including seromas, hematomas) with no difference in risk of hernia recurrence [13–16]. A recent network meta-analysis of 19 randomized controlled trials demonstrated that laparoscopic repair had the lowest probability of being associated with a surgical site infection as compared to open mesh procedure, while no substantial difference existed in the risk of hernia recurrence comparing laparoscopic to open mesh repairs of ventral hernias [5]. Other meta-analyses have similar findings with decreased surgical site infection but no difference in hernia recurrence [13–16]. Some studies have demonstrated that although laparoscopic surgery is associated with a shorter hospital length of stay, the risk of bowel injury is higher compared to open ventral hernia repair (relative risk, 3.68; 95% CI, 1.56–8.67). Nationwide databases have validated the results of randomized controlled trials demonstrating that laparoscopy is associated with fewer early postoperative complications and shorter hospital length of stay [17, 89].

Open Versus Robotic Hernia Repair

Two published studies compare open and robotic ventral hernia repairs [72, 73]. Both studies are cohort studies at high risk for bias and the authors of both studies have significant financial conflicts of interest with industry. Robotic repair, in both studies, was associated with shorter hospital length of stay; however, the two articles differed in impact of surgical platform on the rate of surgical site occurrence and major complications.

These studies represent preliminary results of a limited number of highly specialized robotic hernia surgeons. Efficacy and effectiveness randomized controlled trials are needed to assess the true impact of robotic platform in the repair of complex ventral hernias. Currently, two randomized controlled trial are listed in clinicaltrials.gov to compare laparoscopic and robotic ventral hernia repair [90].

Laparoscopic Versus Robotic Incisional Hernia Repair

Four published studies compare laparoscopic and robotic ventral hernia repairs [69, 70, 83, 84]. All four studies are cohort studies at high risk for bias and the authors of all four of the studies have significant financial conflicts of interest with industry. Robotic repair was associated with clinical benefits in all four studies but differed in which outcomes were improved including ability to close the fascial defect, surgical site occurrence, and shorter length of stay. Three of the four studies demonstrated robotic ventral hernia repair was associated with increased hospital length of stay while the only study to assess cost demonstrates robotic repair was associated with higher costs.

These studies represent preliminary results of a limited number of highly specialized robotic hernia surgeons. Efficacy and effectiveness randomized controlled trials are needed to assess the true impact of robotic platform in the repair of complex ventral hernias. Currently, a single randomized controlled trial is listed in clinicaltrials.gov to compare open and robotic ventral hernia repair [91].

Conclusions

There is an intimate relationship between medical comorbidities such as obesity or diabetes and ventral incisional hernia. These diseases not only increase the risk of developing a ventral incisional hernia but also increase the risk of complications following repair of ventral incisional hernia. Minimally invasive surgical techniques have been demonstrated to decrease the risk of short-term surgical complications with similar long-term outcomes following ventral hernia repair with the greatest benefit in the comorbid patient. Despite this, adoption of laparoscopic ventral hernia repair remains limited. Barriers to adoption of minimally invasive techniques may be related to technical challenges of performing a complex procedure in a complex setting. The robotic platform may be able to overcome many of these challenges and "level" the

playing field for even the most experienced surgeon when performing a minimally invasive hernia repair. High-quality studies (e.g., multi-surgeon/center randomized trials) comparing robotic ventral hernia repair to laparoscopic or open ventral hernia repair are needed to validate this assumption. The role of robotics in ventral hernia repair remains to be elucidated, but currently robotics may have the greatest role for surgeons who desire to perform minimally invasive retromuscular mesh repairs.

In addition, not all patients and hernias are suitable for ventral hernia repair, even a minimally invasive repair. Many patients can benefit from preoperative weight loss, glucose control, and smoking cessation prior to surgical intervention. Patient selection and preoperative optimization is key to a successful hernia practice in combination with evidence based surgical technique including minimally invasive surgery.

References

1. Muysoms FE, Miserez M, Berrevoet F, et al. Classification of primary and incisional abdominal wall hernias. Hernia. 2009;13(4):407–14.
2. Luijendijk RW, Hop WC, van den Tol MP, et al. A comparison of suture repair with mesh repair for incisional hernia. N Engl J Med. 2000;343(6):392–8.
3. Burger JW, Luijendijk RW, WCJ H, et al. Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. Ann Surg. 2004;240(4):578–83; discussion 583–5
4. Mesh Versus Suture Repair for Umbilical Hernias (HUMP). Clinicaltrials.gov. NCT00789230. Accessed on July 29, 2017. Presented at the Americas Hernia Society Meeting, Washington, DC, 2016.
5. Holihan JL, Hannon C, Goodenough C, et al. Ventral hernia repair: a meta-analysis of randomized controlled trials. Surg Infect. 2017;18(6):647–58.
6. Liang MK, Holihan JL, Itani K, et al. Ventral hernia management: expert consensus guided by systematic review. Ann Surg. 2017;265(1):80–9.
7. Holihan JL, Alawadi ZM, Harris JW, et al. Ventral hernia: patient selection, treatment, and management. Curr Probl Surg. 2016;53(7):307–54.
8. Holihan JL, Flores-Gonzalez JR, Mo J, et al. A prospective assessment of clinical and patient-reported outcomes of initial non-operative management of ventral hernias. World J Surg. 2017;41(5):1267–73.
9. Kokotovic D, Sjølander H, Gögenur I, et al. Watchful waiting as a treatment strategy for patients with a ventral hernia appears to be safe. Hernia. 2016;20(2):281–7.
10. Verhelst J, Timmermans L, van de Velde M, et al. Watchful waiting in incisional hernia: is it safe? Surgery. 2015;157(2):297–303.
11. Bellows CF, Robinson C, Fitzgibbons RJ, et al. Watchful waiting for ventral hernias: a longitudinal study. Am Surg. 2014;80(3):245–52.
12. Holihan JL, Henchcliffe BE, Mo J, et al. Is non-operative management warranted in ventral hernia patients with comorbidities?: a case-matched, prospective, patient-centered study. Ann Surg. 2016;264(4):585–90.
13. Al Chalabi H, Larkin J, Mehigan B, McCormick P. A systematic review of laparoscopic versus open abdominal incisional hernia repair, with meta-analysis of randomized controlled trials. Int J Surg. 2015;20:65–74.
14. Arita NA, Nguyen MT, Nguyen DH, et al. Laparoscopic repair reduces incidence of surgical site infections for all ventral hernias. Surg Endosc. 2015;29(7):1769–80.
15. Zhang Y, Zhou H, Chai Y, al e. Laparoscopic versus open incisional and ventral hernia repair: a systematic review and meta-analysis. World J Surg. 2014;38(9):2233–40.
16. Sauerland S, Walgenbach M, Habermalz B, et al. Laparoscopic versus open surgical techniques for ventral or incisional hernia repair. Cochrane Database Syst Rev. 2011;3:CD007781.
17. Savitch SL, Shah PC. Closing the gap between the laparoscopic and open approaches to abdominal wall hernia repair: a trend and outcomes analysis of the ACS-NSQIP database. Surg Endosc. 2016;30(8):3267–78.
18. Aher CV, Kubasiak JC, Daly SC, et al. The utilization of laparoscopy in ventral hernia repair: an update of outcomes analysis using ACS-NSQIP data. Surg Endosc. 2015;29(5):1099–104.
19. Funk LM, Perry KA, Narula VK, et al. Current national practice patterns for inpatient management of ventral abdominal wall hernia in the United States. Surg Endosc. 2013;27(11):4104–12.
20. Stoikes N, Webb D, Voeller G. Robotic hernia repair. Surg Technol Int. 2016;XXIX:119–22.
21. Robotic Surgery. ECRI Institute. 2015. https://www.ecri.org. Accessed 29 July 2017.
22. Ahmad A, Ahmad ZF, Carleton JD, et al. Robotic surgery: current perceptions and the clinical evidence. Surg Endosc. 2017;31(1):255–63.
23. Boys JA, Alicuben ET, DeMeester MJ, et al. Public perceptions on robotic surgery, hospitals with robots, and surgeons that use them. Surg Endosc. 2016;30(4):1310–6.
24. National Institute of Diabetes and Digestive and Kidney Diseases. Overweight and obesity statistics. https://www.niddk.nih.gov/health-information/health-statistics/overweight-obesity. Accessed 29 July 2017.

25. Centers for Disease Control and Prevention. Obesity and overweight. https://www.cdc.gov/nchs/fastats/obesity-overweight.htm. Accessed 29 July 2017.
26. Regner JL, Mrdutt MM, Munoz-Maldonado Y. Tailoring surgical approach for elective ventral hernia repair based on obesity and National Surgical Quality Improvement Program outcomes. Am J Surg. 2015;210(6):1024–9; discussion 1029–30
27. Fekkes JF, Velanovich V. Amelioration of the effects of obesity on short-term postoperative complications of laparoscopic and open ventral hernia repair. Surg Laparosc Endosc Percutan Tech. 2015;25(2):151–7.
28. Fischer JP, Wink JD, Nelson JA, et al. Among 1,706 cases of abdominal wall reconstruction, what factors influence the occurrence of major operative complications? Surgery. 2014;155(2):311–9.
29. Lee J, Mabardy A, Kermani R, et al. Laparoscopic vs open ventral hernia repair in the era of obesity. JAMA Surg. 2013;148(8):723–6.
30. Novitsky YW, Orenstein SB. Effect of patient and hospital characteristics on outcomes of elective ventral hernia repair in the United States. Hernia. 2013;17(5):639–45.
31. Pernar LI, Pernar CH, Dieffenbach BV, Brooks DC, Smink DS, Tavakkoli A. What is the BMI threshold for open ventral hernia repair? Surg Endosc. 2017;31(3):1311–7.
32. Liang MK, Goodenough CJ, Martindale RG, et al. External validation of the ventral hernia risk score for prediction of surgical site infections. Surg Infect. 2015;16(1):36–40.
33. Berger RL, Li LT, Hicks SC, et al. Development and validation of a risk-stratification score for surgical site occurrence and surgical site infection after open ventral hernia repair. J Am Coll Surg. 2013;217(6):974–82.
34. Goodenough CJ, Liang MK, Nguyen MT, et al. Preoperative glycosylated hemoglobin and postoperative glucose together predict major complications after abdominal surgery. J Am Coll Surg. 2015;221(4):854–61.
35. Dronge AS, Perkal MF, Kancir S, et al. Long-term glycemic control and postoperative infectious complications. Arch Surg. 2006;141(4):375–80. discussion 380
36. van Rooijen SJ, Engelen MA, Scheede-Bergdahl C, et al. Systematic review of exercise training in colorectal cancer patients during treatment. Scand J Med Sci Sports. 2018;28(2):360–70.
37. Looijaard SM, Slee-Valentijn MS, Otten RH, et al. Physical and nutritional prehabilitation in older patients with colorectal carcinoma: a systematic review. J Geriatr Phys Ther. 2017. https://doi.org/10.1519/JPT.0000000000000125. [Epub ahead of print].
38. Moran J, Guinan E, McCormick P, et al. The ability of prehabilitation to influence postoperative outcome after intra-abdominal operation: a systematic review and meta-analysis. Surgery. 2016;160(5):1189–201.
39. Clinicaltrials.gov. Modifying Risk in Ventral Hernia Patients. Identifier NCT02365194. https://clinicaltrials.gov/ct2/show/NCT02365194. Accessed 29 July 2017.
40. Huntington C, Gamble J, Blair L, et al. Quantification of the effect of diabetes mellitus on ventral hernia repair: results from two national registries. Am Surg. 2016;82(8):661–71.
41. Danzig MR, Stey AM, Yin SS, et al. Patient profiles and outcomes following repair of irreducible and reducible ventral wall hernias. Hernia. 2016;20(2):239–47.
42. Kaoutzanis C, Leichtle SW, Mouawad NJ, et al. Risk factors for postoperative wound infections and prolonged hospitalization after ventral/incisional hernia repair. Hernia. 2015;19(1):113–23.
43. Fischer JP, Basta MN, Wink JD, et al. Optimizing patient selection in ventral hernia repair with concurrent panniculectomy: an analysis of 1974 patients from the ACS-NSQIP datasets. J Plast Reconstr Aesthet Surg. 2014;67(11):1532–40.
44. Lovecchio F, Farmer R, Souza J, et al. Risk factors for 30-day readmission in patients undergoing ventral hernia repair. Surgery. 2014;155(4):702–10.
45. Swenson BR, Camp TR, Mulloy DP, et al. Antimicrobial-impregnated surgical incise drapes in the prevention of mesh infection after ventral hernia repair. Surg Infect. 2008;9(1):23–32.
46. Finan KR, Vick CC, Kiefe CI, et al. Predictors of wound infection in ventral hernia repair. Am J Surg. 2005;190(5):676–81.
47. Thomsen T, Tønnesen H, Okholm M, Kroman N, Maibom A, Sauerberg ML, Møller AM. Brief smoking cessation intervention in relation to breast cancer surgery: a randomized controlled trial. Nicotine Tob Res. 2010;12(11):1118–24.
48. Lindström D, Sadr Azodi O, Wladis A, et al. Effects of a perioperative smoking cessation intervention on postoperative complications: a randomized trial. Ann Surg. 2008;248(5):739–45.
49. Sørensen LT, Hemmingsen U, Jørgensen T. Strategies of smoking cessation intervention before hernia surgery—effect on perioperative smoking behavior. Hernia. 2007;11(4):327–33.
50. Møller AM, Villebro N, Pedersen T, et al. Effect of preoperative smoking intervention on postoperative complications: a randomised clinical trial. Lancet. 2002;359(9301):114–7.
51. Kubasiak JC, Landin M, Schimpke S, et al. The effect of tobacco use on outcomes of laparoscopic and open ventral hernia repairs: a review of the NSQIP dataset. Surg Endosc. 2017;31(6):2661–6.
52. Ahonen-Siirtola M, Rautio T, Biancari F, et al. Laparoscopic versus hybrid approach for treatment of incisional ventral hernia. Dig Surg. 2017;34(6):502–6.
53. ten Broek RP, Schreinemacher MH, Jilesen AP, et al. Enterotomy risk in abdominal wall repair: a prospective study. Ann Surg. 2012;256(2):280–7.
54. Salameh JR, Sweeney JF, Graviss EA, et al. Laparoscopic ventral hernia repair during the learning curve. Hernia. 2002;6(4):182–7.
55. Sharma A, Khullar R, Soni V, et al. Iatrogenic enterotomy in laparoscopic ventral/incisional hernia

repair: a single center experience of 2,346 patients over 17 years. Hernia. 2013;17(5):581–7.
56. Tintinu AJ, Asonganyi W, Turner PL. Staged laparoscopic ventral and incisional hernia repair when faced with enterotomy or suspicion of an enterotomy. J Natl Med Assoc. 2012;104(3–4):202–10.
57. LeBlanc KA, Elieson MJ, Corder JM III. Enterotomy and mortality rates of laparoscopic incisional and ventral hernia repair: a review of the literature. JSLS. 2007;11(4):408–14.
58. LeBlanc KA. Laparoscopic incisional and ventral hernia repair: complications-how to avoid and handle. Hernia. 2004;8(4):323–31.
59. Allison N, Tieu K, Snyder B, et al. Technical feasibility of robot-assisted ventral hernia repair. World J Surg. 2012;36(2):447–52.
60. Ballantyne GH, Hourmont K, Wasielewski A. Telerobotic laparoscopic repair of incisional ventral hernias using intraperitoneal prosthetic mesh. JSLS. 2003;7(1):7–14.
61. Corcione F, Esposito C, Cuccurullo D, et al. Advantages and limits of robot-assisted laparoscopic surgery: preliminary experience. Surg Endosc. 2005;19(1):117–9.
62. Gonzalez A, Escobar E, Romero R, et al. Robotic-assisted ventral hernia repair: a multicenter evaluation of clinical outcomes. Surg Endosc. 2017;31(3):1342–9.
63. Earle D, Roth JS, Saber A, et al. SAGES Guidelines Committee. SAGES guidelines for laparoscopic ventral hernia repair. Surg Endosc. 2016;30(8):3163–83.
64. Papageorge CM, Funk LM, Poulose BK, et al. Primary fascial closure during laparoscopic ventral hernia repair does not reduce 30-day wound complications. Surg Endosc. 2017;31(11):4551–7.
65. Wennergren JE, Askenasy EP, Greenberg JA, et al. Laparoscopic ventral hernia repair with primary fascial closure versus bridged repair: a risk-adjusted comparative study. Surg Endosc. 2016;30(8):3231–8.
66. Tandon A, Pathak S, Lyons NJ, et al. Meta-analysis of closure of the fascial defect during laparoscopic incisional and ventral hernia repair. Br J Surg. 2016;103(12):1598–607.
67. Nguyen DH, Nguyen MT, Askenasy EP, et al. Primary fascial closure with laparoscopic ventral hernia repair: systematic review. World J Surg. 2014;38(12):3097–104.
68. Clinicaltrials.gov. Primary fascial closure with laparoscopic ventral hernia repair: a randomized controlled trial. NCT Number 02363790; The Influence of Closing the Gap on Postoperative Seroma and Recurrences in Laparoscopic Ventral Hernia Repair (CLOSURE). NCT Number 01719718; The Effect of Laparoscopically Closing the Hernia Defect in Laparoscopic Ventral Hernia Repair on Postoperative Pain (CLOSE-GAP). NCT Number 01962480.
69. Gonzalez AM, Romero RJ, Seetharamaiah R, et al. Laparoscopic ventral hernia repair with primary closure versus no primary closure of the defect: potential benefits of the robotic technology. Int J Med Robot. 2015;11(2):120–5.
70. Prabhu AS, Dickens EO, Copper CM, et al. Laparoscopic vs robotic intraperitoneal mesh repair for incisional hernia: an Americas Hernia Society Quality Collaborative Analysis. J Am Coll Surg. 2017;225(2):285–93.
71. Holihan JL, Askenasy EP, Greenberg JA, et al. Ventral Hernia Outcome Collaboration Writing Group. Component separation vs. bridged repair for large ventral hernias: a multi-institutional risk-adjusted comparison, systematic review, and meta-analysis. Surg Infect. 2016;17(1):17–26.
72. Bittner JG 4th, Alrefai S, Vy M, et al. Comparative analysis of open and robotic transversus abdominis release for ventral hernia repair. Surg Endosc. 2017;32(2):727–34.
73. Carbonell AM, Warren JA, Prabhu AS, et al. Reducing length of stay using a robotic-assisted approach for retromuscular ventral hernia repair: a comparative analysis from the Americas Hernia Society Quality Collaborative. Ann Surg. 2018;267(2):210–7.
74. Holihan JL, Alawadi Z, Martindale RG, et al. Adverse events after ventral hernia repair: the vicious cycle of complications. J Am Coll Surg. 2015;221(2):478–85.
75. Choi JJ, Palaniappa NC, Dallas KB, et al. Use of mesh during ventral hernia repair in clean-contaminated and contaminated cases: outcomes of 33,832 cases. Ann Surg. 2012;255(1):176–80.
76. Orr NT, Davenport DL, Roth JS. Outcomes of simultaneous laparoscopic cholecystectomy and ventral hernia repair compared to that of laparoscopic cholecystectomy alone. Surg Endosc. 2013;27(1):67–73.
77. Atema JJ, de Vries FE, Boermeester MA. Systematic review and meta-analysis of the repair of potentially contaminated and contaminated abdominal wall defects. Am J Surg. 2016;212(5):982–95.
78. Kissane NA, Itani KM. A decade of ventral incisional hernia repairs with biologic acellular dermal matrix: what have we learned? Plast Reconstr Surg. 2012;130(5 Suppl 2):194S–202S.
79. Primus FE, Harris HW. A critical review of biologic mesh use in ventral hernia repairs under contaminated conditions. Hernia. 2013;17(1):21–30.
80. Luque JA, Luque AB, Menchero JG, et al. Safety and effectiveness of self-adhesive mesh in laparoscopic ventral hernia repair using transabdominal preperitoneal route. Surg Endosc. 2017;31(3):1213–8.
81. Prasad P, Tantia O, Patle NM, et al. Laparoscopic transabdominal preperitoneal repair of ventral hernia: a step towards physiological repair. Indian J Surg. 2011;73(6):403–8.
82. Prasad P, Tantia O, Patle NM, et al. Laparoscopic ventral hernia repair: a comparative study of transabdominal preperitoneal versus intraperitoneal onlay mesh repair. J Laparoendosc Adv Surg Tech A. 2011;21(6):477–83.
83. Walker PA, May AC, Mo J, et al. Multicenter review of robotic versus laparoscopic ventral hernia repair: is there a role for robotics? Surg Endosc. 2018;32(4):1901–5.
84. Warren JA, Cobb WS, Ewing JA, et al. Standard laparoscopic versus robotic retromuscular ventral hernia repair. Surg Endosc. 2017;31(1):324–32.

85. Holihan JL, Liang MK. Umbilical hernias. In: Hope WW, Cobb WS, Adrales GL, editors. Textbook of hernias. 2017;1(1):305–15.
86. Liang MK, Berger RL, Li LT, Davila JA, Hicks SC, Kao LS. Outcomes of laparoscopic vs open repair of primary ventral hernias. JAMA Surg. 2013;148(11):1043–8.
87. Lambrecht JR, Vaktskjold A, Trondsen E, et al. Laparoscopic ventral hernia repair: outcomes in primary versus incisional hernias: no effect of defect closure. Hernia. 2015;19(3):479–86.
88. Carter SA, Hicks SC, Brahmbhatt R, et al. Recurrence and pseudorecurrence after laparoscopic ventral hernia repair: predictors and patient-focused outcomes. Am Surg. 2014;80(2):138–48.
89. Colavita PD, Tsirline VB, Walters AL, et al. Laparoscopic versus open hernia repair: outcomes and sociodemographic utilization results from the nationwide inpatient sample. Surg Endosc. 2013;27(1):109–17.
90. Clinicaltrials.gov. Laparoscopic "DA VINCI" Robot Assisted Abdominal Wall Hernia Repair (ARTE). NCT 0297414, 00908193. https://clinicaltrials.gov/ct2/show/NCT00908193?term=00908193&rank=1. Accessed 29 July 2017.
91. Clinicaltrials.gov. Open Versus Robotic Retromuscular Ventral Hernia Repair (ORREO). NCT 03007758. https://clinicaltrials.gov/ct2/show/NCT03007758. Accessed 29 July 2017.