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A single institutional comparison of endoscopic and open abdominal component separation

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Abstract
Background The authors analyzed surgical factors and outcomes data in the largest single institutional study comparing endoscopic (ECS) and open component separation (OCS) in ventral hernia repairs (VHR).
Methods A prospectively maintained database was reviewed, identifying 76 patients who underwent component separation for VHR with mesh from 2010 to 2013: 34 OCS and 42 ECS. Comparisons were made for demographics, surgical risk factors, and peri-operative outcomes. Wound complications and hernia occurrence post-operatively were reviewed. Risk analyses were performed to determine the association of pre-operative risk factors with surgical site occurrences.
Results Twenty-five ECS patients underwent subsequent laparoscopic hernia repair, and 17 underwent open repair. Operative time for ECS was longer than OCS (334 vs. 239 min; $P < 0.001$); however, there was no difference in length of stay (4 days in both groups, $P = 0.64$) and estimated blood loss (ECS: 97 vs. OCS: 93 cc, $P = 0.847$). In a sub-analysis of ECS patients, those who underwent laparoscopic hernia repair had a 96 min shorter operative time ($P < 0.001$) and lower EBL (63 vs. 147 cc, $P < 0.001$) than open repair. Wound complications were 24 % in the ECS ($n = 10$) and 32 % in OCS group ($n = 11$). There was one midline hernia recurrence in the ECS group (mean follow-up of 8 months, range 0.5–34.5 months) and no hernia recurrences in the OCS group (mean follow-up 10 months, range 0.5–30 months). Three of the patients in the ECS group developed new lateral abdominal wall hernias post-operatively.
Conclusions The ECS group had a significantly longer operative time than the OCS group. Post-operative wound complications were similar between ECS and OCS groups. Patients in the ECS group who underwent subsequent

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laparoscopic VHR had a shorter operative time and blood loss than open repair.

Keywords Endoscopic · Component separation · Ventral hernia repair · Laparoscopic

Ventral hernia repairs are among the most common surgeries performed around the world. Several sources cite an incisional hernia occurrence rate of 6 to 24 % in patients following abdominal surgery [1]. With the advent of newer biomedical technologies and minimally invasive operative techniques, surgeons and researchers are striving to find ways to minimize peri-operative morbidity in patients undergoing hernia repair while producing similar or better results. Significant complications following complex hernia repair include, but are not limited to, wound infections, seromas, enterocutaneous fistulas, and wound dehiscence. It is well known that with each additional operation for these occurrences, the risk of other complications and hernia recurrence increases. Generally, primary repair may be achieved in hernias with a transverse diameter up to 3 cm [2, 3]. The use of mesh and muscle relaxation techniques, as the Rives–Stoppa retrorectus and component separation techniques, has helped to reduce recurrence rates following larger defect closure [2–4]. Open component separation (OCS), introduced by Ramirez in 1990, was a major advancement in the approach to ventral hernia repair. This reconstructive technique uses fascial release to allow greater rectus midline advancement [5, 6]. Hence, this technique is commonly used when surgeons are faced with large defects. The concept of endoscopic component separation (ECS) with minimally invasive herniorrhaphy was first introduced in 1997 by Lowe et al. [7], in an attempt to reduce morbidity associated with OCS [8]. Although many surgeons still only use the open technique, others criticize the extensive undermining, large lipocutaneous flaps and compromised blood supply to the abdominal wall. Anecdotally, however, ECS is associated with a learning curve and can be more challenging, especially at the beginning of a surgeon's experience with the technique. Small retrospective reviews have reported that endoscopic release of the external oblique aponeurosis may result in fewer wound complications [7–12]. Attempts are made to preserve the perforating vessels to the anterior abdominal wall originating from the epigastric vessels in the endoscopic approach, while most OCSs require dividing these vessels to create large adipocutaneous flaps [5, 6]. Disturbance of perforator vessels can lead to significant morbidity, including poor wound healing, skin necrosis, and dehiscence [9, 10]. The literature and data on ECS are sparse. ECS, when used in hernia repair, can be followed by laparoscopic or open fascial reapproximation. On the other hand, when OCS is used, closure of the defect is performed in an open fashion. The authors analyzed surgical risk factors, early peri-operative, and follow-up outcomes data in the largest single institutional study, comparing open and ECS, while offering a guide for patient selection for ventral hernia repair.

Materials and methods

After the institutional review board approval, a retrospective review was performed of a prospectively maintained database, identifying patients Johns Hopkins Medical Institutions who underwent component separation for ventral hernia repair with biomaterial reinforcement from October 2010 to July 2013. The ECS cases were performed by a single surgeon. Inclusion criteria for ECS for the surgeon included transverse defect size of greater than 6 cm in abdominal wall hernias. Patients excluded were those younger than 18 years, those with potentially contaminated operative fields, those having had previous abdominal flap reconstructive surgery, as well as patients who underwent a concomitant gastrointestinal or abdominal wall surgery. The patients were identified from a review of plastic and reconstructive surgery and general surgery component separation databases, and verified with operative billing records.

Demographics and surgical factors such as age, BMI, and defect size were analyzed. Defect size dimensions were obtained from pre-operative imaging, operative notes, and/or both. Group comparisons were made for ASA class, percent of patients with a history of prior ventral hernia and abdominal surgery, smoking (with or without COPD), diabetes, and requiring chronic anticoagulation. Estimated blood loss (EBL), operative time, and length of stay were analyzed. Wound complications and hernia occurrence post-operatively were the main outcomes of interest. Wound complications included any surgical site occurrence post-operatively which delayed or hindered primary wound healing, such as abscess, seroma requiring drainage, dehiscence, necrosis, cellulitis, and hematoma. Intervention for wound complications, including surgery, bedside wound care, and radiologic percutaneous drainage or re-operation, were noted.

Continuous variables were examined by Shapiro–Wilk test for normality. Variables with normal distribution were further calculated to obtain mean and standard deviation, and those not normally distributed were calculated to provide median and interquartile range (IQR). Due to a restriction of sample size, group differences by continuous variables were compared using simulation ANOVA. Group differences for categorical variables were assessed by

Fisher's exact test. Univariate analyses were performed to explore the association between pre-operative risk factors with outcomes, including hernia recurrence and complications. Multivariate analyses were also performed to further assess the association between procedure types and outcomes after adjusting for each risk factor. A *P* value of less than 0.05 (two-tailed) was considered statistically significant. Statistical analysis was performed using Stata 12 (StatCorp LP).

Surgical technique

Discussion on technique will be limited to ECS, as the open technique for external oblique release was performed as traditionally described by Ramirez [5]. Biologic prosthetic or synthetic mesh reinforcement was used in all cases. A Rives–Stoppa retrorectus dissection was not performed in the patients included in this series; the synthetic/biologic prosthetic was placed in an intraperitoneal underlay fashion in both groups. Procedural details on ECS will focus on our institutional method and subsequent laparoscopic/open hernia repair, similar to what has been previously described [13, 14]. Generally, patients are considered for laparoscopic ventral hernia repair after ECS at our institution if the hernia is non-incarcerated, if the patients do not have a history of multiple previous abdominal surgeries (typically <3 with few exceptions) that would require extensive adhesiolysis, and are stable from a cardiopulmonary status [13]. If cardiopulmonary status is a concern, then typically an open hernia repair is performed after ECS. Otherwise, if a patient has had multiple previous abdominal surgeries (typically ≥ 3 with some exceptions) and ventral hernia repairs with significant distortion of abdominal musculature and fascial planes, OCS with open ventral hernia repair was the preferred method.

Endoscopic component separation

Prior to incision, a line is drawn extending from the xiphoid superiorly, down to the pubic bone inferiorly. Left and right costal margins are delineated. An incision is made in the upper quadrant, lateral to the semilunar line, and performed horizontally on the edge of the costal margin at the mid-clavicular line. Blunt dissection is carried down to the external oblique aponeurosis, locating the fibers running in a superior-lateral to inferior-medial direction. After the appropriate space is found, a 1-cm horizontal incision is made through the external oblique aponeurosis. Afterward, blunt dissection is used to open the space below the external oblique aponeurosis.

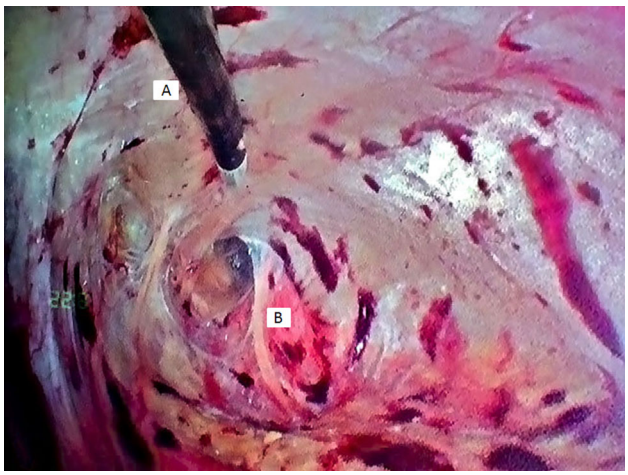

Fig. 1 Laparoscopic instruments *A* are used to facilitate dissection and the identification of perforator vessels *B* to the abdominal wall; perforator vessels are spared in the endoscopic technique

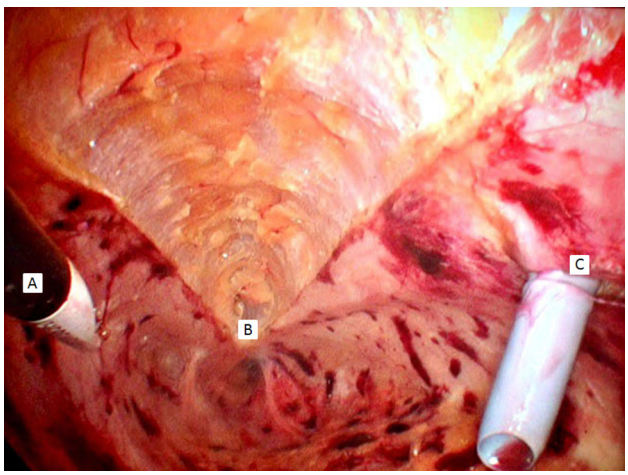

Fig. 2 Hook cautery *A* is used to release the aponeurosis of the external oblique *B* endoscopically; an additional port *C* is typically placed in an inferolateral position to facilitate dissection

Next, a circular dissecting balloon is placed into this space, with an accompanying scope within the trocar lumen. After the appropriate plane has been dissected, a 12-mm balloon-tipped trocar is then placed through the incision at the aponeurosis and secured. Insufflation is at 12 mmHg, revealing areolar tissue between the internal oblique muscle layer posteriorly and external oblique aponeurosis anteriorly. A second 5-mm trocar is placed slightly anterior to the anterior superior iliac spine under direct vision. Oftentimes, a third 5-mm trocar is placed to help facilitate dissection and is inserted a few centimeters laterally to the 12-mm trocar.

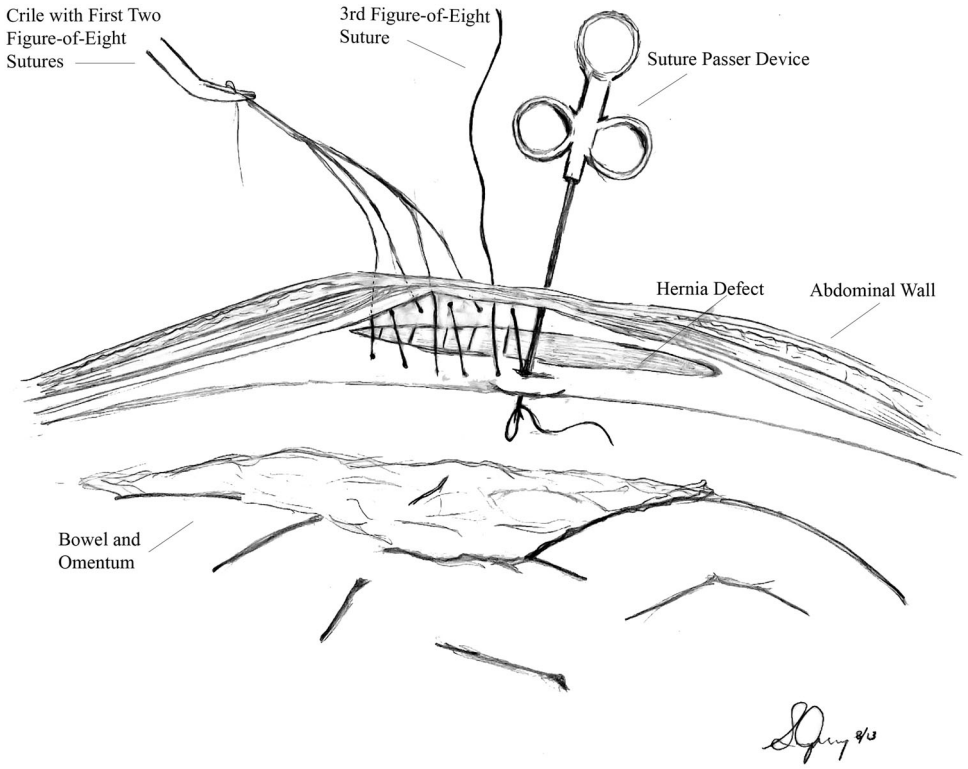

Fig. 3 Using 1-gauge monofilament absorbable suture placed in a figure-of-eight fashion, edges of the defect are reapproximated with a suture passer device through punctate incisions overlying the defect

The areolar tissue is swept down with blunt dissection. The external oblique is separated from the internal oblique as far laterally as possible, extending the dissection toward the mid-axillary line. Dissection is extended inferiorly toward the inguinal canal until the external oblique aponeurosis can be seen merging with the canal to form the inguinal ligament. Small perforator vessels are encased within the areolar tissue, and should be spared once encountered and whenever possible (Fig. 1). Dissection is continued superiorly past the costal margin, where the external and internal oblique muscles are found. The external oblique aponeurosis should be divided at least 4 cm past the superior and inferior edge of the ventral hernia defect and at least 2 cm lateral to the semilunar line (Fig. 2). Division is performed with hook cautery and can extend inferiorly toward the inguinal ligament and superiorly past the costal margin.

After the aponeurosis is divided, the overlying fatty tissue can also be divided with hook cauterization past Scarpa's fascia to allow further separation of the cut edges. There should be uniform separation of the cut edges throughout the incision, and a separation of at least 3–4 cm should be achieved. The external oblique aponeurosis on the contralateral left side is divided in the same manner. Afterward, the 12-mm left upper quadrant trocar incision site can then be used as a way to safely enter the abdominal cavity with a visible trocar for laparoscopic reduction of the hernia and reapproximation of the defect.

Laparoscopic ventral hernia repair

In the laparoscopic approach, the edges of the defect are reapproximated with a suture passer device through punctate incisions overlying the defect using 1-gauge monofilament absorbable suture placed in an interrupted figure-of-eight fashion (Fig. 3). The fascial edges should come together with minimal tension.

After approximation of the fascial defect, the mesh is secured in an underlay manner. A synthetic or biologic substitute may be utilized. The edge of the mesh should extend at least 3–4 cm past the original site of the fascial defect. This usually ensures that the mesh extends past the semilunar line, which may minimize the risk of a Spigelian-type defect during the component separation [15, 16]. Transfascial sutures are placed on the edge of the mesh at 4-cm intervals, and the mesh is tacked to the anterior abdominal wall in a double-crown technique with 1-cm gaps.

Open ventral hernia repair

With an open approach, the mesh can be placed in an underlay or sublay fashion; however, in this series, an underlay position was used in all patients. In the underlay position, the mesh is placed at least 10 cm from the edge of the approximated fascia. For larger defects, the lateral edge of the mesh was positioned 2–3 cm beyond the semilunar

Table 1 Comparison of select demographic, surgical, and operative data between open and endoscopic component separation groups

	Patient information						
	Age (years)	BMI (kg/m^2)	Defect size (cm^2)	Mesh size (cm^2)	Estimated blood loss (ml)	[a]Operative time (min)	Length of stay (days)
Endoscopic ($n = 42$)							
Mean	58 ± 11	34.8 ± 8	174.3 ± 190.3	331.4 ± 185.1	97 ± 74	334 ± 86	4 ± 1.6
Median	56	34.2	120	300	62.5	300	4
Interquartile range	52–66	28.5–40.1	56–191	150–500	50–100	300–420	3–5
Open ($n = 34$)							
Mean	50 ± 11	42.0 ± 13	268.0 ± 156.3	345.5 ± 111.5	93 ± 84	240 ± 97	4 ± 1.1
Median	50	40.9	262.5	358	75	223	4
Interquartile range	43–59	35.4–47.5	155–300	252–448	20–100	175–291	3–5

[a] Indicates statistical significance between groups ($P < 0.001$)

line to reinforce the weakened site of release of the external oblique aponeurosis. Transfascial sutures are placed at the lateral edge of the mesh with the 4-cm spacings, and positioned through punctate skin incisions with a Reverdin needle. The mesh sutures are positioned to displace tension and allow the fascial edges to lie symmetrically and flat, closely reapproximated at midline. The fascial defect is closed under physiologic tension with running 0-gauge absorbable monofilament suture. A subfascial drain is not typically placed unless biologic prosthesis is used as a means to remove the excess seroma.

Results

Fulfilling our inclusion and exclusion criteria, 76 patients underwent component separation for abdominal wall hernia repair at the Johns Hopkins Medical Institutions: 34 conventional and 42 endoscopically assisted. The ECS group had a lower BMI (35 vs. 42 kg/m^2; $P = 0.004$), older age (58 vs. 50; $P = 0.0016$), and smaller defect size (174 vs. 268 cm^2; $P = 0.028$) (Table 1), with no significant differences in other surgical factors. Synthetic mesh was used in the majority of cases in both groups: 74 % of ECS cases and 82.4 % of open cases. In two OCS cases (5.8 %), both a synthetic overlay and biologic underlay were used; the remainder of the open and endoscopic cases were repaired with biologic prosthetics. Indications for selecting biologic grafts in non-contaminated cases included conditions of diabetes, chronic steroid use, history of tobacco cigarette smoking, and COPD. Pre-operative counseling was provided to patients with a significant history of smoking to ensure that such activity was not resumed prior to surgery.

Table 2 Comparison of patient and surgical information between open and endoscopic component separation groups

	Operative data	
	Endoscopic *n* (%)	Open *n* (%)
Male (%)	15 (36)	9 (26)
ASA class[a]		
I	0	2 (6.5)
II	22 (52)	14 (45.2)
III	20 (48)	15 (48.4)
IV	0	0
V	0	0
Mesh type		
Biologic	11 (26)	4 (11.8)
Synthetic	31 (74)	28 (82.4)
Both	0	2 (5.8)

[a] Indicates American Society of Anesthesiologists Classification, range of I–V

The majority of patients in both groups were female, with only 15 (36 %) of the patients being male in the endoscopic group, and 9 (26 %) in the open group (Table 2). Forty-eight percent of patients in each of the ECS and in the OCS groups were classified as American Society of Anesthesiologist (ASA) class 3, and there were no class 4 or 5 patients in either group. Comorbidities were similar between groups, and nearly 20 % of the patients in each group had a diagnosis of diabetes and were on medications for glucose management at the time of surgery (Table 3). Also, approximately 17 % of the patients in the ECS group and 15 % of the patients in the OCS group had a history of smoking. Of the ECS patients, 98 % had previous abdominal surgery and 24 % had prior ventral hernia repair, and similarly, of the OCS patients, all had prior

Table 3 Comparison of surgical risk factors and comorbidities between groups

	Risk summary						
	Smoking history *n* (%)	Diabetes mellitus *n* (%)	COPD *n* (%)	Chronic anticoagulation *n* (%)	Chronic steroids *n* (%)	Prior VHR *n* (%)	Prior abdominal surgery *n* (%)
ECS	7 (17)	8 (19)	5 (12)	4 (10)	1 (2)	10 (24)	41 (98)
OCS	5 (15)	6 (18)	4 (12)	1 (3)	0	11 (32)	34 (100)

COPD chronic obstructive pulmonary disease, *VHR* indicates ventral hernia repair

Table 4 Comparison of post-operative wound complications and hernia occurrences between groups

	Post-operative wound complications and hernia outcomes								
	Seroma *n* (%)	Hematoma *n* (%)	Dehiscence *n* (%)	Abscess *n* (%)	Fat necrosis *n* (%)	Skin necrosis *n* (%)	Cellulitis *n* (%)	Recurrent midline hernia *n* (%)	Other Hernia[a] *n* (%)
Endoscopic ($n = 42$)	3 (7)	2 (5)	1 (2)	3 (7)	0	0	1 (2)	1 (2)	3 (7)
Open ($n = 34$)	3 (9)	1 (3)	1 (3)	4 (12)	1 (3)	1 (3)	0	0	0

[a] Other Hernia indicates lateral abdominal wall hernia

abdominal surgery and 32 % of patients had prior ventral hernia repair.

In the ECS group, 25 patients (60 %) underwent subsequent laparoscopic hernia repair, and 17 (40 %) underwent open repair. Primary fascial closure was achieved in all ECS patients, and all but one OCS patient (97 %). Operative time for ECS was significantly longer than OCS (334 vs. 239 min; $P < 0.001$) even when adjusting for BMI ($P = 0.021$) and defect size ($P = 0.023$); however, there was no difference in length of stay (4 days in both groups, $P = 0.64$) and EBL (ECS: 97 vs. OCS: 93 cc, $P = 0.847$). In a sub-analysis of ECS patients, those who underwent laparoscopic hernia repair had a 96 min shorter operative time ($P < 0.001$) and lower EBL (63 vs. 147 cc, $P < 0.001$) than open repair. Patient and demographic/surgical factors were not statistically different between the ECS laparoscopic and open groups; these included age (open: 57 years; laparoscopic: 59 years, $P = 0.62$), BMI (Open: 34 kg/m^2; laparoscopic 35.4 kg/m^2, $P = 0.59$), and defect size (open: 195 cm^2; laparoscopic: 162 cm^2, $P = 0.65$).

Wound complications were lower in the ECS group, 24 % ($n = 10$), compared to the OCS group, 32 % ($n = 11$), although not statistically significant ($P = 0.42$) (Table 4). In total, 7 ECS patients required intervention for the management of these complications: five of these required interventional radiology percutaneous drainage, one required interventional radiology embolization and drainage of hematoma, and the last patient necessitated bedside wound debridement and dressing care. In the OCS group, five patients required percutaneous drainage of complex fluid collections, one patient required bedside incision and drainage of a superficial symptomatic fluid collection, and four patients required operative debridement. There was one midline hernia recurrence identified early in the ECS group (mean follow-up of 8 months, range 0.5–34.5 months) and no hernia recurrences seen in the OCS group (mean follow-up 10 months, range 0.5–30 months). Our median follow-ups for the open and endoscopic groups are approximately 8 and 5.5 months, respectively. Three of the patients in the ECS group developed new lateral abdominal wall hernias post-operatively. The interval to development of these lateral abdominal wall hernias ranged from 24 days to 3 months post-operatively. Two of these lateral abdominal wall hernias were repaired with laparoscopic hernia repair and mesh reinforcement without any further clinical sequelae or surgical site occurrences. The third patient is to be scheduled for surgery in the near future but to our knowledge, he has had no other reported complications.

Discussion

The goal of OCS is to produce a tension-free repair, allowing for unilateral movement of 5 cm at the epigastrium, 10 cm at the waist, and 3 cm at the suprapubic area [6]. Bilateral release can allow up to 20 cm of mobilization from the waistline [6]. Rosen et al. [17] used a porcine model to compare rectus advancement in laparoscopic versus conventional OCS, and the external oblique release technique used in the minimally invasive group is similar to the endoscopic approach used in our series. It was observed that on average, the video-assisted external

oblique release achieved 86 % of the myofascial advancement when compared with the traditional technique [17]. Similarly, in a cadaver model, laparoscopic component separation approached from the peritoneal side of the abdominal wall produced the same amount of release as the conventional component separation method [18]. Lowe et al. [7] presented their experience with seven patients in the first report of ECS, and it was noted that a short but obvious learning curve is involved in becoming comfortable with the technique. Since then, few single institutional studies have compared outcomes on ECS with the conventional open technique, with complications reported in 9–33 % of the endoscopic cases, and 45–57 % of the open cases with mean follow-up of 8–15 months [9, 11, 12]. Harth et al. [9] reported a hernia recurrence rate of 32 % in the open and 27 % in the ECS groups. Giurgius et al. [12] reported no hernia recurrences in the open group of 14 patients, and one hernia recurrence in the endoscopic group of 21 patients, with a mean follow-up of 8 months. Based on these results, the post-operative surgical site occurrences varied markedly between both studies, and hence no definitive concrete conclusions can be made when comparing endoscopic and open techniques. In a study on cost analysis mentioned previously, Harth et al. [10] reported an overall wound morbidity of 28 % in the endoscopic and 46 % in the open groups; however, hernia occurrence post-operatively was not reviewed. In this same study, the total direct costs were similar for the endoscopic and OCS cases [10]. Additionally, the aforementioned studies included contaminated cases, a factor that we eliminated by our exclusion criteria, and the use of mesh was not consistent among all patients cited in these studies, whereas we routinely incorporate a synthetic or biologic prosthesis with our endoscopic technique. Recommendations for biologic graft reinforcement in non-contaminated cases by Ventral Hernia Working Group include Grade 2 hernias, or those patients with comorbidities, as diabetes and tobacco smoking history, which increase the risk of post-operative surgical site occurrences (1). Since these recommendations, there has been much additional interest in the topic of biologic versus synthetic mesh in ventral hernia repair. More recent studies have reported an increased risk of hernia recurrence with the use of biologic prosthetics when compared with synthetic mesh reinforcement, whereas other studies continue to advocate for the use of biologics particularly in high-risk patients, producing similar outcomes and decreased wound morbidity when compared with synthetic mesh repairs [19–22]. Our component separation experience has not demonstrated an association between mesh type and outcome, similar to what has been previously reported in component separation cases [23]. The surgeon should approach each operation on a case-by-case basis, weighing the benefits and risks of biologic versus synthetic reinforcement, while keeping in mind the higher costs associated with the biologic materials. Similarly, large randomized prospective studies controlling for patient factors are needed to help better guide mesh type and method of closure in contaminated and non-contaminated, but high-risk cases.

Following ECS, a laparoscopic approach to the hernia repair can be more challenging, but obviates a large midline incision. Using the same port sites for the laparoscopic hernia repair as were used for the ECS may help prevent morbidity associated with additional incisions and may also decrease operative time, which is equally important, as prolonged operative time has been shown to be associated with increased risk of surgical site infection. An open hernia repair, however, provides the opportunity to remove excess tissue and skin which is typically much more challenging and at times not possible via a minimally invasive technique.

We present a general schematic to help guide technique selection for ventral hernia repair with or without component separation, keeping in mind that there may be exceptions (Fig. 4). A Rives–Stoppa retrorectus dissection was not used in this series. The surgeons did not perform a Rives–Stoppa retrorectus repair in the smaller sized open cases for reasons including the need for mesh explantation from previous ventral hernia repairs, prior failed ventral hernia repairs using a similar technique, and previous abdominal surgeries with concern for distorted rectus/midline anatomy. In patients with complex abdominal wall defects and previous attempts at hernia repair with mesh, such an approach does not permit dissection and mesh overlap beyond the lateral border of the rectus sheath [24]. Fascial relaxation techniques such as component separation should be used in larger complex abdominal wall defects, particularly when considering patients at a high risk for hernia recurrence (obesity, COPD, active smoking, etc.). A history of prior surgery, as open cholecystectomy or appendectomy, requiring incisions that extend lateral to the semilunar line will obliterate the space below the external oblique aponeurosis. Tissue scarring will make endoscopic dissection difficult. Such patients should be evaluated for unilateral ECS, or an open approach which may allow for easier dissection of the scarred plane. Also, a patient who has a large defect with scarred and narrowed rectus with foreshortened external oblique aponeurosis is a poor endoscopic candidate. Aside from dividing the external oblique aponeurosis, an additional component separation, such as a transversus abdominus release, should not be performed concomitantly. This additional component separation will further destabilize the abdominal wall musculature and increase the risk of complications. The type of technique, endoscopic versus OCS with laparoscopic versus open hernia repair, is not the only relevant issue.

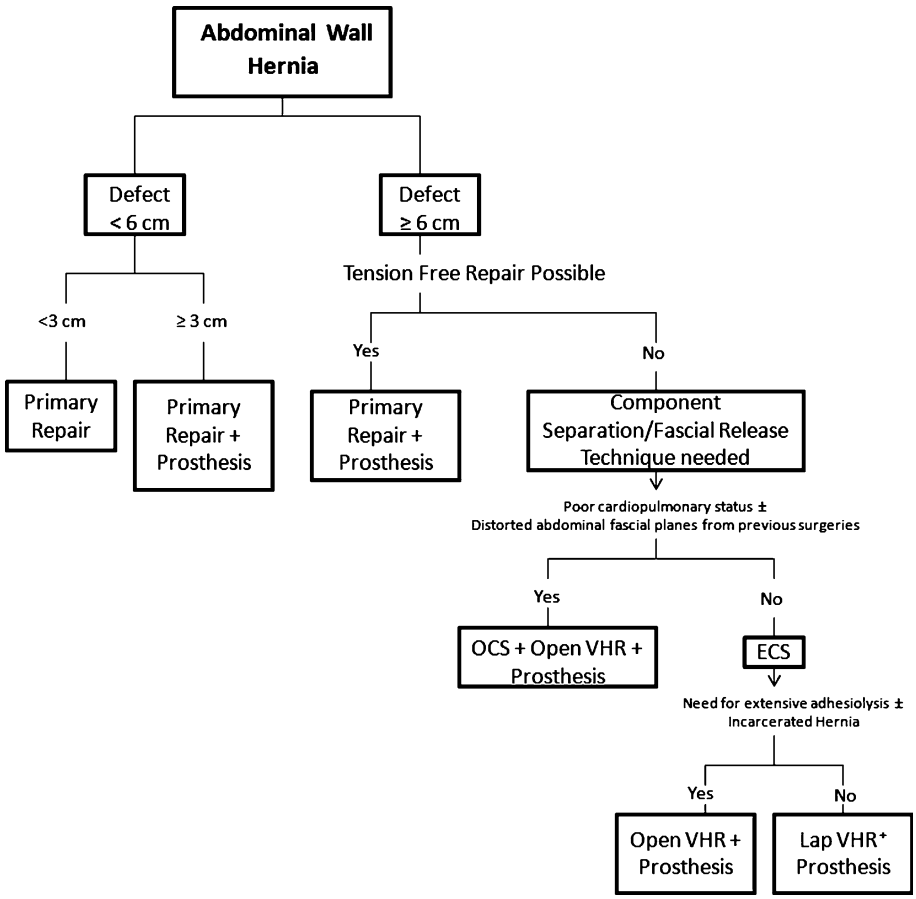

Fig. 4 How to guide technique selection for hernia repair with and without component separation

National Surgical Quality Improvement Program (NSQIP) data analysis on herniorrhaphy show several factors which predispose patients to increased risk of wound infection such as smoking, advanced age, obesity, steroid use, chronic obstructive pulmonary disease, coronary artery disease, poor nutritional markers as low pre-operative serum albumin, prolonged operative time, and synthetic mesh use specifically in a contaminated field [1]. In our study, we reviewed these factors in both groups to find that there was no significant difference, and that the laparoscopic and the open group were comparable. Patient optimization prior to surgery focuses on adequate glucose control in patients with diabetes or pre-diabetes, improved oxygenation in those with pulmonary disease, smoking cessation greater than 4 weeks pre-operatively, weight loss, infection control if present and specifically if affecting operative site, and improved nutritional status as much as possible. As mentioned previously, such measures would be essential in our study patients, as nearly 20 % of the overall number of patients had diabetes at the time of surgery, and approximately 15–17 % of the patients in each group had a history significant for prior cigarette smoking. Pre-operative computed tomography scan is performed to determine not only the dimensions of the hernia and characteristics of the herniated tissue, but also to radiographically visualize the rectus abdominus anatomy and external oblique aponeurosis for operative planning. Ideally, the rectus abdominus is of normal width, with a clearly visible external oblique aponeurosis. Endoscopic component separation may be more challenging if there is significant lateral abdominal wall distortion and scarring from prior surgeries and reconstructions.

Analysis of our institutional early outcomes data showed that wound complications were occurred in 32 % of patients in the OCS group, and 24 % of endoscopic group, with one midline hernia recurrence in ECS group. There were no lateral abdominal wall hernia occurrences in the OCS group. Three lateral abdominal wall hernias occurred post-operatively in the endoscopic group: two in the laparoscopic and one in the open hernia repair groups. Lateral abdominal wall or spigelian hernias have previously been reported as a potential complication after component separation [15]. These hernias in our series occurred early in the senior author's experience with ECS, and hence may be partly related to the learning curve. The lateral abdominal wall hernias in our endoscopic series occurred adjacent to the linea semilunaris, correlating with the destabilization of the fascia from extensive and difficult dissection, or

division of the external oblique that is too close to the semilunar line or perhaps dissection beyond the external oblique causing injury to deeper fascia. Intra-operatively, care is taken to minimize blunt dissection too far medially to minimize the risk of tearing the conjoining fibers of the semilunar line. Additionally, areolar tissue adjacent to the semilunar line is swept down using motions parallel to the semilunar line, again minimizing the potential for any new sites of fascial defects. When small, these lateral abdominal wall hernia defects can be repaired primarily, and mesh reinforcement is needed to repair larger defects.

Advantages of our study include the fact that all endoscopic and open cases were performed at the same institution, and the technique of synthetic/biologic reinforcement was similar between the groups. Additionally, the endoscopic cases were performed by a single surgeon. Comorbidities and ASA class were similar between groups. Also, the database used in our series is prospectively maintained, reviewed periodically by surgeons in surgery and plastic surgery departments, and new patients are accrued up until the final analysis.

There are several limitations to our study. This retrospective review is subjected to selection bias; patients were selected for either endoscopic or OCS based on subjective clinical data. Time of follow-up for the patients studied is an inherent confounder in this retrospective analysis and the prospective nature of the database explains the heterogeneity in follow-up. Continued follow-up of some patients beyond a year may demonstrate additional hernia recurrences not previously identified in our follow-up period [9]. Additionally, though we reviewed a greater number of cases when compared to previous studies, the power of this study would improve further with higher patient enrollment; this may reveal further differences or similarities between endoscopic and OCS. Although we were not able to identify any pre-operative risk factors or comorbidities that potentially contributed to poor outcomes, this analysis was limited given our sample size of patients.

From our early experience, it remains unclear whether the endoscopic technique is better than the conventional technique. Anecdotally, though the complication rate and other peri-operative measures seem to improve with the surgeon's growing experience with the endoscopic technique, further follow-up and more patients are necessary to quantify this observation. To our knowledge, such a study demonstrating the number of cases needed to establish proficiency has yet to be performed and requires particular attention. Surgeons practicing new methods of minimally invasive component separation as ECS should be aware of the potential for lateral abdominal wall hernia occurrences post-operatively at the site of endoscopic dissection. This should be included as part of informed consents and increased awareness may help better guide peri-operative management. Additionally, others studies that included contaminated and clean-contaminated cases have hypothesized and then demonstrated that ECS reduces wound morbidity when compared with OCS [7–12]. This may suggest that there would be a statistically significant improvement in wound complications in the endoscopic group in our series if we explored this same hypothesis in contaminated/clean-contaminated cases as well. Further investigations need to be performed to determine risk association with outcomes specific to the endoscopic technique, and to explore this reconstructive modality in contaminated versus non-contaminated cases, on a controlled, randomized basis.

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