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Comparative review of outcomes: laparoscopic and robotic enhanced-view totally extraperitoneal (eTEP) access retrorectus repairs

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Abstract

Background Building on the principles of eTEP access, described by Dr. Jorge Daes, our group has previously described and standardized a novel minimally invasive approach to restoration of the linea alba and repair of lateral atypical defects of the abdominal wall. The purpose of this report is to present comparative analysis of laparoscopic and robotic eTEP access retrorectus repairs.

Methods A retrospective review was conducted in patients who underwent laparoscopic eTEP (lap-eRS) and robotic-assisted eTEP (robo-eRS) Rives-Stoppa repairs between September 2015 and May 2018 at our institution. We analyzed the preoperative demographics and the perioperative outcomes.

Results Our review identified 206 patients (Lap-eRS 120 vs. robo-eRS 86). The groups were comparable ($p > 0.05$) in gender distribution (47.6% vs. 53% male) and mean age (53.2 vs. 50.8 years), but different ($p < 0.05$) in mean BMI (31.3 vs. 34.4 kg/m^2) and ASA score (2.1 vs. 2.4). The robo-eRS group had a larger defect size (5.5 vs. 7.1 cm, $p < 0.05$), a longer mean operative time (120.4 vs. 174.7 min, $p < 0.05$), and a higher hospitalization cost ($5,091 vs. $6,751, $p = 0.005$) compared to the lap-eRS group. Average length of stay (0.2 vs. 0.1 days), length of drain placement (5.3 vs. 5.7 days), and reoperations (2.5% vs. 2.3%) were similar between lap-eRS and robo-eRS ($p > 0.05$). Patients in both groups (lap-eRS vs. robo-eRS) were followed for an average of 5.7 months vs. 5.5 months ($p = .735$) and showed similar recurrence rates (1.7% vs. 1.2%, $p > 0.05$).

Conclusion We present the largest series to-date of eTEP access laparoscopic and robotic ventral hernia retrorectus repairs. Morbidly obese patients and those with more complex abdominal wall defects were more likely to undergo a robo-eRS. The significantly longer operative time and higher hospital cost associated with the robo-eRS group may be in part due to these factors. Both robotic and laparoscopic eTEP Rives-Stoppa repairs are associated with favorable perioperative outcomes and low recurrence rates.

Keywords eTEP · Rives-Stoppa repair · Ventral hernia repair · Retromuscular repair · Retrorectus repair · Robo-eRS · Lap-eRS

Laparoscopic ventral hernia repair has been a part of the surgeon's armamentarium for nearly 25 years. Traditional laparoscopic ventral hernia repair relies on intraperitoneal onlay mesh placement (IPOM). Compared to open repairs, laparoscopic repair provided shorter length of stay, reduction in surgical site infection, and comparable recurrence rate [1, 2]. However, this technique requires wide overlap of an intraperitoneal mesh directly in contact with the abdominal viscera. In addition, the principles of IPOM repair rely on penetrating the fixation of mesh to the abdominal wall, which has been shown to be associated with decreased quality of life scores [3]. With time, surgeons began exploring other potential abdominal wall spaces for mesh placement in an attempt to eliminate visceral exposure and avoid the rare but significant complications associated with intraperitoneal mesh placement [4]. Placing mesh into extraperitoneal space

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also enables surgeons to minimize the need for penetrating mesh fixation.

In 2012, Dr. Jorge Daes introduced the enhanced-view totally extraperitoneal (eTEP) technique describing laparoscopic access to the retrorectus space [5]. His approach was integral in facilitating innovation in the field of laparoscopic hernia surgery. Initially, eTEP was used for creating a larger operative field during laparoscopic inguinal hernia surgery; its application was expanded to the repair of ventral hernias (VHR) [6]. By combining the eTEP technique with Rives-Stoppa (RS) VHR, we developed a novel minimally invasive approach to abdominal wall reconstruction (AWR) with a wide mesh overlap of the retrorectus space. This dynamic technique enables repair of complex midline and atypical lateral defects, correction of contour abnormalities, elimination of mesh contact with intraperitoneal viscera, and elimination of penetrating fixation. Our institution has published early operative outcomes of robotic eTEP retromuscular abdominal wall reconstruction and has established its feasibility and safety [7]. The purpose of this study is to present the largest series to-date of eTEP access retrorectus repair from our prospectively maintained database and compare operative outcomes between robotic eTEP Rives-Stoppa (Robo-eRS) and laparoscopic eTEP Rives-Stoppa (Lap-eRS) repairs.

Methods

Study design

A retrospective review of a single institution prospectively maintained database was conducted after IRB approval was obtained. Patients who underwent lap-eRS and robo-eRS between September 2015 and May 2018 at Anne Arundel Medical Center in Annapolis, Maryland were identified, including our early robotic learning curve cases. Study data were collected and managed using Research Electronic Data Capture (REDCap) hosted at Anne Arundel Medical Center [7]. Preoperative demographics, intraoperative data and postoperative outcomes including recurrence rates were analyzed. Primary outcomes of interest were perioperative complications, length of stay, 30-day readmissions, and hernia recurrence rates. Quality of life (QOL) assessments were obtained either in-person, via telephone, or by electronic communication between the clinical team and patients who consented for data collection and participation in this research. Quality of life outcomes were assessed for a subgroup of patients within the study population using Carolina Comfort Scale (CCS) prior to surgery, at 1 month, 6 month, and 1-year postoperatively. The CCS is a validated survey instrument that examines functional actions such as laying down, bending over, sitting, activities of daily living, coughing or deep breathing, walking, and exercise on a six-point Likert scale. A score of 2 or greater was considered symptomatic for each of the measured indices [8, 9].

Preoperative workup

The standardized preoperative workup of our patients begins with a detailed history and physical examination. Specific to the hernia patients are the hernia defect size and location, surgical history, presence of ostomy, excess skin, and contour abnormalities. A CT scan of the abdomen and pelvis was routinely obtained for incisional defects to further assess the patient's anatomy, with attention to the hernia defect size and contents, as well as, width of the retrorectus space. Patients then undergo preoperative anesthesia testing at our institution.

Operative technique

Our typical approach to lap-eRS begins with direct entry into the retrorectus space close to the costal margin (Fig. 1A). The space is then developed bluntly (Fig. 1B) until another working port can be placed more inferiorly medial to linea semilunaris and lateral to the epigastric vessels (Fig. 1C). A crossover maneuver is then initiated, connecting the bilateral retrorectus spaces with the preperitoneal space medially (Fig. 2A, B). The hernia sac is then dissected and reduced (Fig. 3). The posterior and anterior fascial defects are approximated with absorbable barbed suture (Fig. 4a, b) and a medium-weight macroporous polypropylene mesh is deployed in the retrorectus space (Fig. 5). We do not use any fixation for mesh. A retromuscular closed-suction drain is then placed and the space is then desufflated. Initial access to the retrorectus space in robo-eRS is performed laparoscopically. Depending on how the robot is docked, the crossover is completed either laparoscopically or robotically. Port placement during eTEP access can be dynamic. Figure 6 represents the most common port set-up that our group uses, however, alternative port configurations have been used by us and can be based on surgeon preference, defect location, and previous surgical history. The relative indications and contraindications for the port positions are shown in Table 1.

Postoperative care

Patients undergoing either lap-eRS or robo-eRS were typically performed on an outpatient basis and discharged the same day or admitted for 23-h observation. Retromuscular closed-suction drains were removed on postoperative day 5 in the outpatient office, with additional postoperative follow-up at 1 month, 6 months, and annually.

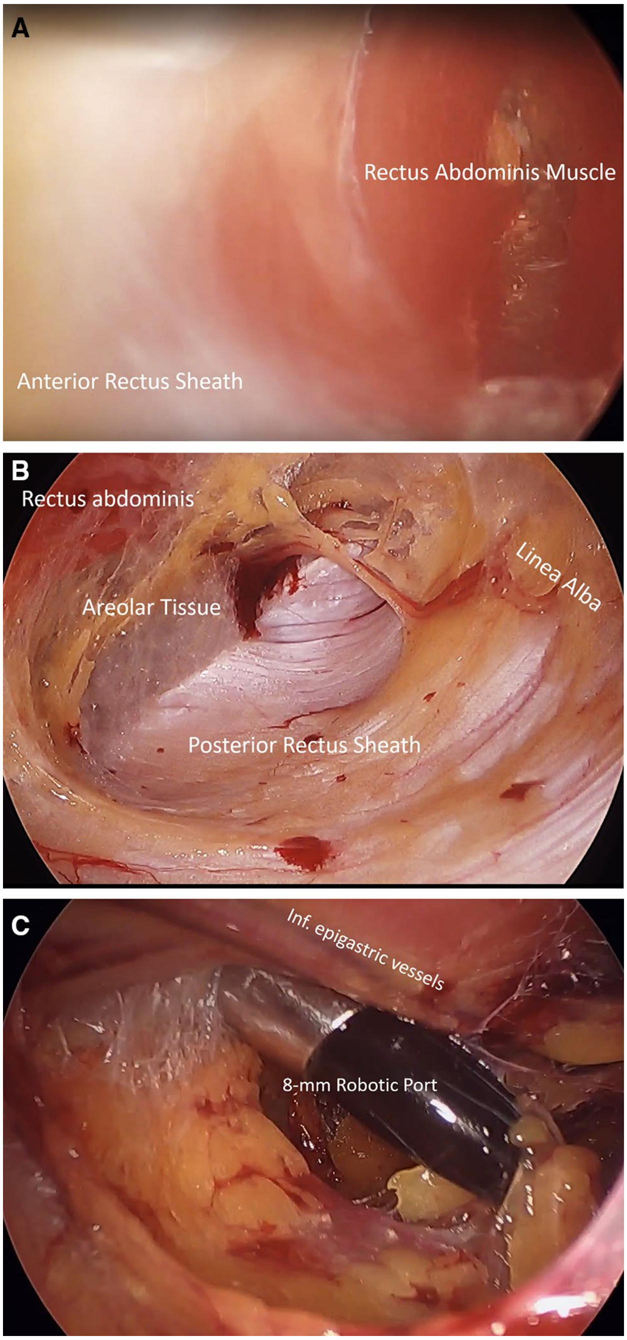

Fig. 1 **A** Initial blunt dissection of retromuscular space. **B** Initial blunt dissection of retromuscular space. **C** Additional placement of robotic ports lateral to epigastric vessels

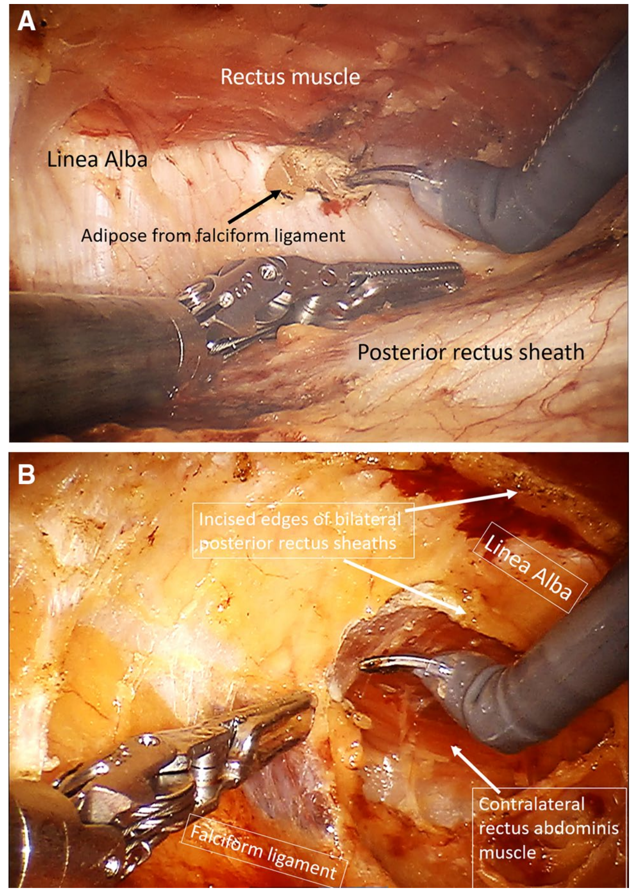

Fig. 2 **A** Crossover maneuver initiated by incising the medial aspect of the ipsilateral posterior rectus sheath. **B** Crossover maneuver completed by entering the contralateral retrorectus space

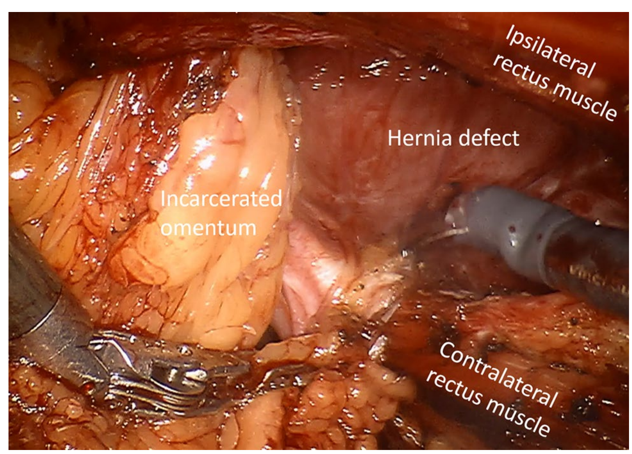

Fig. 3 Reduction of hernia contents

Results

Two-hundred and six consecutive patients were identified in our final analysis, 120 lap-eRS and 86 robo-eRS (Table 2). Gender distribution between the lap-eRS versus robo-eRS were 61.7% male and 38.3% female vs. 47.6% male and 52.4% female, respectively ($p = 0.47$). Mean age, BMI, and ASA score in the lap-eRS and robo-eRS were 53.2 years vs. 50.8 years ($p = 0.24$), 31.3 ± 6.1 kg/m^2 vs. 34.4 ± 7.4 kg/m^2 ($p = .001$), and 2.1 ± 0.52 vs. 2.4 ± 0.52 ($p = <.001$), respectively. The robo-eRS group had larger

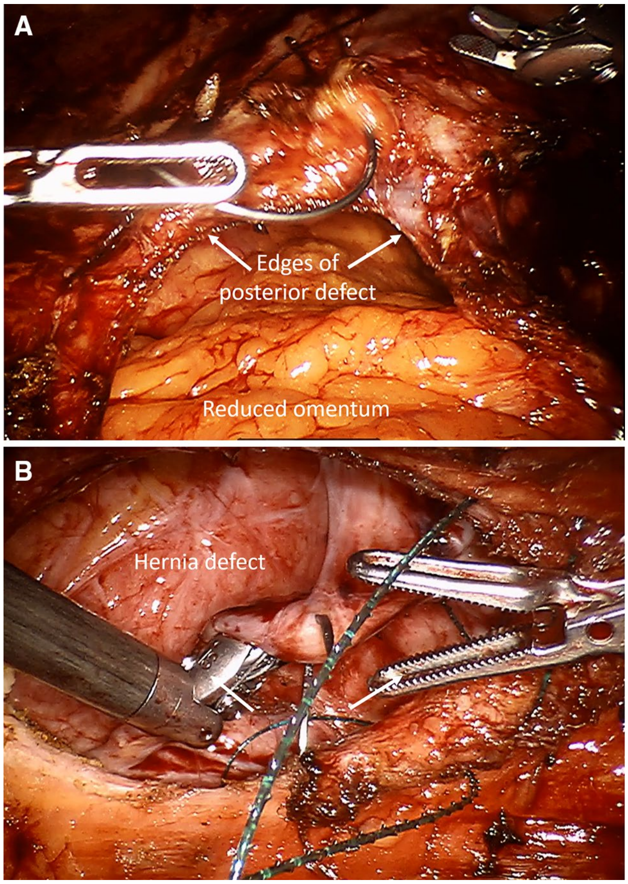

Fig. 4 **A** Closure of the posterior defect. **B** Closure of the anterior defect with plication of the dead space to prevent seroma formation

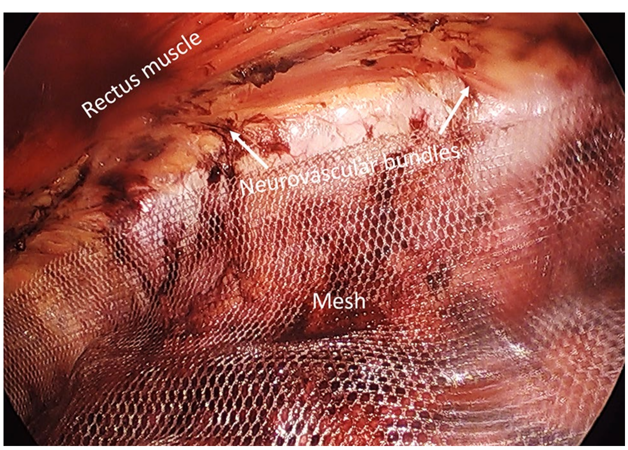

Fig. 5 Placement of medium-weight macroporous polypropylene mesh

hernia defects (7.1 ± 2.6 cm vs. 5.5 ± 1.8 cm, $p < 0.001$) and longer mean operative time (174.7 ± 44.9 min vs. 120.4 ± 35.0 min, $p < .001$) compared to the lap-eRS group. Mean area of the implanted mesh was similar between robo-eRS and lap-eRS (507.5 ± 178.6 cm^2 vs. 526.3 ± 294.7 cm^2, $p = 0.603$). Drains were placed above the mesh in the retrorectus space in 15.8% of lap-eRS cases vs. 25.6% of robo-eRS cases ($p = 0.085$) and were removed on an average of 5 days after surgery at our clinic. The mean length of stay was parallel between the lap-eRS and robo-eRS groups, 0.2 ± 0.9 days vs. 0.1 ± 0.5 days ($p = 0.294$), respectively. The robo-eRS group had a higher total cost compared to the lap-eRS cohort ($6751 ± 4080 vs. $5091 ± 3922, $p = .005$) (Table 3).

Patients were followed for an average of 5.7 ± 4.9 months in lap-eRS versus 5.5 ± 5.9 months in robo-eRS group ($p = .735$). During this timeframe, three patients in the laparoscopic group and two patients in the robotic group returned to the OR ($p = .94$). The 30-day readmission rate for lap-eRS and robo-eRS was 2.5% and 2.3% respectively.

There were significantly more 30-day complications in the laparoscopic group than the robotic group, 9.2% vs. 2.3% ($p = 0.046$) respectively. Four patients developed symptomatic seromas in the lap-eRS group, one was retromuscular and the others were subcutaneous. Only one patient with a subcutaneous seroma required drainage, which was performed in clinic. One lap-eRS patient developed posterior sheath failure, requiring return to OR on postoperative day 10 and was treated with laparoscopic IPOM mesh repair of the posterior rectus sheath. One patient in the robo-eRS group had early repair failure, with strangulation of small intestine requiring bowel resection on postoperative day 26.

Regarding complications greater than 30 days, four patients developed symptomatic retromuscular seromas following lap-eRS repair. Two of these patients underwent percutaneous drainage, both developed infected seromas requiring operative decortication and drainage. The other two patients also failed conservative management and required operative drainage. In addition, three patients in the laparoscopic cohort required operative drainage of retromuscular hematomas. At the latest follow-up, three patients, one in the robo-eRS group and two in the lap-eRS group, had developed recurrences. The patients in the lap-eRS group have since undergone operative correction, while the patient in the robo-eRS had his surgery postponed after suffering a myocardial infarction. Overall, there were significantly more complications, within or beyond 30-days after surgery, observed in the lap-eRS group compared to the robo-eRS group. However, in a subgroup analysis of patients with at least 12 months of follow-up, there were no significant differences in long-term postoperative outcomes, including hernia recurrence, between the two groups (Table 4).

Among patients who completed CCS surveys, 11% reported mesh sensation (from prior hernia surgery), 47% reported discomfort, and 37% had movement limitations prior to surgery. Postoperatively, patients reported significant improvement of QOL outcomes with a decreasing

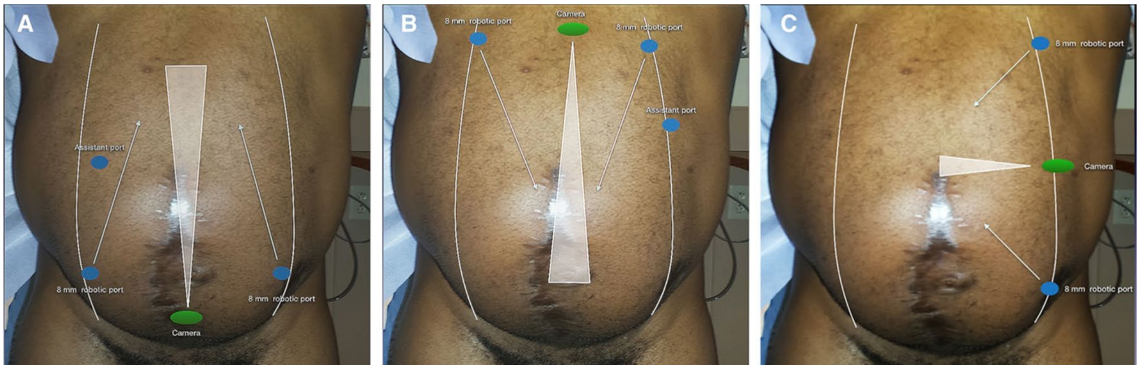

Fig. 6 Variety of robotic docking positions may be used. Port positioning for **A** upper midline defect repair (lower docking), **B** lower midline defect repair (upper docking), and **C** lateral defect repair (side docking)

Table 1 Relative contraindications for types of robotic docking

Defect location	Docking position	Relative contraindications to port placement
Upper midline	Bottom docking below umbilicus/side docking	History of cesarean section, pelvic surgery, or prostatectomy, morbidly obese habitus with large pannus
Lower midline	Upper docking above umbilicus/side docking	History of upper midline surgeries, or Kocher or chevron subcostal incisions
Paraumbilical	Lower/upper/side docking positions	Narrow retrorectus space (specific to side docking)

Table 2 Patient demographics

Values	Lap-eRS		Robo-eRS		*p* value
n	120		86		
Age (years)	53.2 ± 14.6		50.8 ± 12.8		.236
BMI (kg/m^2)	31.3 ± 6.1		34.4 ± 7.4		<.001†
ASA score	2.1 ± 0.52		2.4 ± 0.52		<.001†
Comorbid disease					
Hypertension	40	33.3%	42	48.8%	.437
Hyperlipidemia	19	15.8%	23	26.7%	.401
Chronic lung disease	11	9.2%	18	20.9%	.105
Chronic renal disease	3	2.5%	3	3.5%	.952
Chronic liver disease	0	0.0%	0	0.0%	–
Cardiac disease	8	6.7%	2	2.3%	.070
Diabetes mellitus	10	8.3%	17	19.8%	.074
Hernia characteristics					
Recurrent hernia	22	18.3%	16	18.6%	.695
Diastasis recti	85	70.8%	72	83.7%	.932
Multiple defects	10	8.3%	16	18.6%	.115

Mean ± SD

BMI Body Mass Index, *ASA* American Society of Anesthesiologists

†Statistically significant

trend in mesh sensation, pain, and movement limitation at 1-month, 6-month, and 1-year (Fig. 7).

Discussion

Our group has been performing eTEP access abdominal wall reconstruction since 2015 [2]. Benefits of this approach include versatility in obtaining access for a variety of abdominal wall defects, complete exclusion of mesh from the peritoneal cavity, and obviating the need for penetrating fixation. There is a protective role of minimally invasive techniques when comparing wound-related morbidities with traditional open VHR [1]. Studies have shown complication rates of 20–30% following open AWR, which has been confirmed at our center as well [10–12].

In March 2017, we adopted the robotic platform to perform eTEP ventral hernia repairs and demonstrated good outcomes and technical feasibility [7]. Our study represents the largest published series of this technique to date comparing the outcomes between lap-eRS versus robo-eRS. Patients undergoing robo-eRS were significantly more obese with higher ASA scores and larger defects compared to the lap-eRS group. These results demonstrate that we were able to extend the benefits of minimally invasive reconstructive

Table 3 Perioperative outcomes

Values	Lap-eRS ($n=120$)		Robo-eRS ($n=86$)		p value
Intraoperative					
Operative time (min)	120.4 ± 35.0		174.7 ± 44.9		<.001†
Defect size (cm)	5.5 ± 1.8		7.1 ± 2.6		<.001†
Mesh area (cm^2)	526.3 ± 294.7		507.5 ± 178.6		.603
Drain placed (%)	15.8%		25.6%		.085
Days with drain	5.3 ± 1.2		5.7 ± 2.1		.450
Total cost (USD)	5091 ± 3922		6751 ± 4080		.005†
Length of stay (days)	0.2 ± 0.9		0.1 ± 0.5		.294
Postoperative					
Reoperation	3	2.5%	2	2.3%	.938
30 day readmission	3	2.5%	2	2.3%	.938
30 day complication	11	9.2%	2	2.3%	.046†
Retromuscular seroma	1	0.8%	0	0.0%	.396
Subcutaneous seroma	3	2.5%	0	0.0%	.140
Pneumonia	1	0.8%	0	0.0%	.396
Hematoma	2	1.7%	1	1.2%	.773
Heart attack	1	0.8%	0	0.0%	.396
Pulmonary embolism	1	0.8%	0	0.0%	.396
Fascia dehiscence					
Complete	1	0.8%	1	1.2%	.811
Posterior layer	1	0.8%	0	0.0%	.396
> 30 day complication	11	9.2%	1	1.2%	.016†
Retromuscular seroma	4	3.3%	0	0.0%	.087
Infected seroma	2	1.7%	0	0.0%	.229
Hematoma	3	2.5%	0	0.0%	.140
Recurrence	2	1.7%	1	1.2%	.771
Follow- up (months)	5.7 ± 4.9		5.5 ± 5.9		.735

†Statistically significant

Table 4 Postoperative outcomes of patients with at least 12 months of postoperative follow-up

Values	Lap-eRS		Robo-eRS		p value
n	40		31		
Follow -up (months)	16 ± 4.8		13.1 ± 1.4		.002†
> 30 day complications (n, %)	4	10%	0	0%	.072
Seroma (n, %)	1	3%	0	0%	.383
Hematoma (n, %)	2	5%	0	0%	.212
Recurrence (n, %)	1	3%	0	0%	.383

Mean ± SD (standard deviation)

†Statistically significant

repair to a more complex patient population by utilizing the robotic platform. A recent study suggests that there are ergonomic benefits when utilizing robotic platform as compared to the traditional laparoscopy [13]. These benefits are thought to extend from three-dimensional visualization, improved dexterity from increased degrees of freedom, motions scaling, and tremor filtering [14]. From our personal experience, robotics has enhanced our minimally invasive operative ability in more obese patients with dense abdominal wall, substantially reducing perceived trocar and instrument torque by the operating surgeon. Furthermore, we have noticed that the increased dexterity of robotics facilitates intracorporeal suturing when restoring the linea alba, which may prove difficult even to those with advanced laparoscopic skills [7].

Robo-eRS operative times were significantly higher than lap-eRS. We think that the observed difference in time was at least partially a result of operating on more complex patients and larger defects in the robo-eRS group. Due to the past institutional restrictions, the operating surgeons were not allowed to perform simpler cases on the robot during their learning curve, such as robotic TAPP inguinal hernias or cholecystectomies. It should be anticipated that in early practice (first 50 cases), robotic setup and utilization is less efficient and contributes more to prolonged operative times [15, 16]. We strongly recommend that one is facile with robotics before adopting eTEP access Rives-Stoppa repairs.

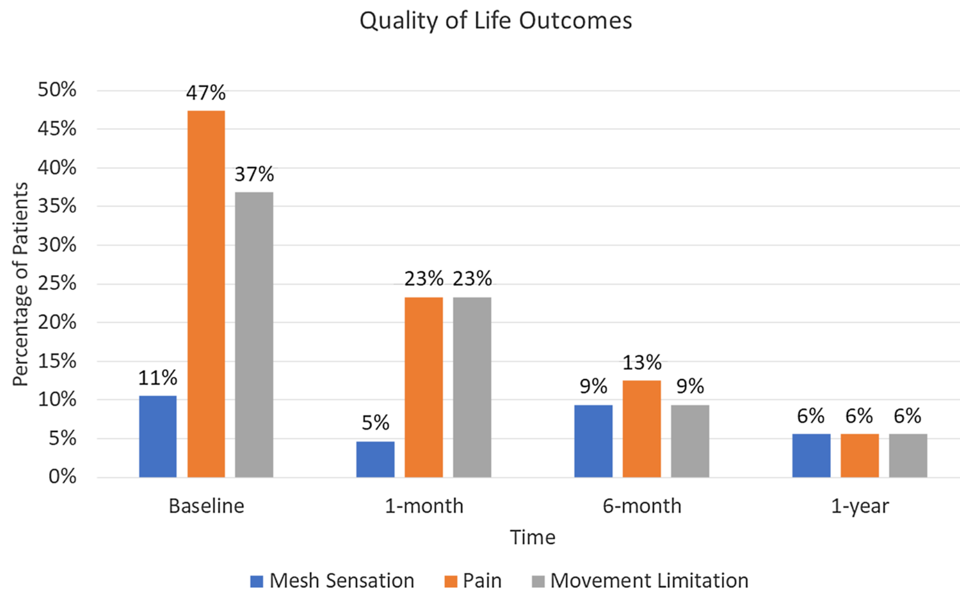

Fig. 7 Quality of life outcomes (QOL) assessed by the Carolinas Comfort Scale (CCS) over time

Attempts to undergo learning curves of robotics and eTEP access simultaneously are likely to result in an increased risk of unfavorable intraoperative and perioperative outcomes.

Overall hospitalization cost was slightly higher for the robotic group compared to the laparoscopic cohort. This cost increase must be analyzed with the perspective that the patient populations were more complex or had more complex disease process in the robo-eRS group, as represented by a significantly larger hernia defect size and higher BMI. In the past, prior to the availability of the robotic platform in our practice, we would have offered open intervention to majority of the patients in the robotic arm, thus prolonging hospitalization and increasing the cost of care. The application of the robotic platform has extended the benefits of minimally invasive retromuscular repair to this patient population, as well as decreasing their overall cost of care. In the past, we have reported on overall decrease in cost when taking cases that were traditionally approached through open intervention and converting these cases to MIS approach [17].

The eTEP approach to VHR has unique complications. As this technique becomes more widespread, the rates of complications will continue to be accurately elucidated. There were significantly more complications, within and beyond 30 days following surgical repair, in the lap-eRS group compared to the robo-eRS group. The most common complication was symptomatic seroma formation. We speculate that the lower seroma rates in robotic cases may be due to the ease of plicating the hernia pseudosac, leading to the reduction of dead space for potential subcutaneous seroma formation. In addition, to decrease the chronic retromuscular seroma rate, we now place 19 French round BLAKE drains in the retrorectus space in all patients with removal on postoperative day 5. The relatively higher complication rate associated with lap-eRS in this cohort needs to be interpreted with care. Retromuscular seromas were more commonly observed in the laparoscopic group. Historically we began performing lap-eRS cases two years prior to robo-eRS cases, and in our recent practice, we have been more aggressive using retromuscular drains. The more frequent use of drains may have decreased the overall risk of potential chronic retromuscular seromas. Because patients undergoing robotic repair were more likely to receive a retromuscular drain, it is difficult to interpret the significance of the higher risk of retromuscular seromas in the lap-eRS group. The robo-eRS group also had a lower rate of hematoma formation compared to the laparoscopic cohort. A possible explanation for this observation is that the enhanced visualization allows for very precise dissection as well as the avoidance of injury to the highly vascularized rectorectus plane. Within 30 days, one patient in the lap-eRS group had posterior layer failure. Intraoperatively, it is imperative for surgeons to be able to judge tension during closure of the posterior layer and to repair any defects made during dissection. Missed defects or dehiscence of the posterior layer can potentially lead to intraparietal hernias and an increased risk of incarceration and strangulation of viscera. If an excessive amount of tension is encountered during closure of the posterior layer, operating surgeon should be equipped to perform a transversus abdominis release (TAR) to relieve tension. In our experience, performing a partial unilateral TAR (release of aponeurotic layers) may provide enough laxity of the posterior layer for tension-free closure. The most devastating complication of this technique is early complete dehiscence of the repair which occurs with simultaneous dehiscence of the posterior and anterior layers. One of our patients who had early complete dehiscence developed strangulation of small bowel requiring resection of ischemic bowel and removal of mesh. We believe that the cause of this was an inadvertent injury to the linea alba during the crossover maneuver, weakening the integrity of the anterior layer resulting in its failure. It is noteworthy to point out that, these dreaded complications occurred during the early learning curve at our institution.

There were three recurrences that occurred after 30 days, two in the laparoscopic group and one in the robotic group. The mechanism of recurrences for these patients were again thought to be a small injury to the linea alba during crossover and inadequate mesh coverage, both of which were not adequately addressed during the initial repair. This again emphasizes the importance of preserving the linea alba and achieving adequate mesh overlap of the entire dissected retromuscular space to ensure the integrity of the repair. In addition to this, missed suture fracture can potentially weaken the repair.

Although lap-eRS was favored in terms of operative cost and intraoperative time, our robo-eRS outcomes were similar. Furthermore, despite actively selecting more complex cases regarding hernia defect size and increased BMI for the robotic platform, it may seem counterintuitive to find that postoperative outcomes are similar between laparoscopic and robotic cases. Given these findings, we believe that the robotic platform is a viable asset in adopting eTEP retromuscular repairs to more complex patients while maintaining good outcomes.

Overall, patients undergoing MIS eTEP access retrorectus repair were satisfied with the procedure. Carolinas Comfort Scale was used to measure QOL outcomes and demonstrated significantly decreasing trend over time of postoperative mesh sensation, pain and movement limitation.

Reproducibility of these outcomes in the surgical community is yet to be established. Abdominal wall reconstruction via eTEP retromuscular repair has proven to be a robust tool in expert hands. This technique is not without its unique complications. Therefore, a strong appreciation of abdominal wall anatomy and attention to detail while operating in the retromuscular space are paramount. Lack, thereof, may result in an irreversible damage to functionality of the abdominal wall [18, 19].

Limitations of our study include those inherent to a single institution retrospective study. Our institution is a high-volume center regarding the eTEP technique, and reproducibility in lower volume centers needs to be evaluated and reported. Our study, although the largest to date of this technique, still has a relatively short follow-up period. Further studies with longer follow-up will continue to elucidate long-term outcomes.

Conclusion

To our knowledge this is the largest series of minimally invasive eTEP Rives-Stoppa repairs to date. This study sought to compare lap-eRS and robo-eRS. In our clinical practice, we actively select patients with higher BMI as well as larger and more complex hernia defects for robotic rather than laparoscopic repair. Despite these factors which could intuitively worsen outcomes, we report equivalent outcomes compared to the laparoscopic approach. Although future studies with longer follow-up may continue to elucidate more accurate outcomes, given our current data, we conclude that robotics is a viable asset in adopting eTEP retromuscular repairs to more complex patients while maintaining acceptable outcomes.

Author contributions All authors certify that they accept responsibility as an author and have contributed to the concept, data gathering, analysis, manuscript drafting, and give their final approval.

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Compliance with ethical standards

Disclosures Dr. Belyansky has received honoraria for speaking engagements and consulting work from Intuitive, Bard Davol and Medtronic; he is an investor into IHC Inc. Dr. Lu, Dr. Addo, Dr. Ewart, Dr. Zahiri, Mr. Broda, Ms. Parlacoski have no conflicts of interest or financial ties to disclose.

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