Reducing Length of Stay Using a Robotic-assisted Approach for Retromuscular Ventral Hernia Repair

A Comparative Analysis From the Americas Hernia Society Quality Collaborative

Alfredo M. Carbonell, DO,* Jeremy A. Warren, MD,* Ajita S. Prabhu, MD,† Conrad D. Ballecer, MD,‡ Randy J. Janczyk, MD,§ Javier Herrera, MD,¶ Li-Ching Huang, PhD,|| Sharon Phillips, MSPH,|| Michael J. Rosen, MD,† and Benjamin K. Poulose, MD, MPH**

Objective: The aim of this study was to compare length of stay (LOS) after robotic-assisted and open retromuscular ventral hernia repair (RVHR).

Background: RVHR has traditionally been performed by open techniques. Robotic-assisted surgery enables surgeons to perform minimally invasive RVHR, but with unknown benefit. Using real-world evidence, this study compared LOS after open (o-RVHR) and robotic-assisted (r-RVHR) approach.

Methods: Multi-institutional data from patients undergoing elective RVHR in the Americas Hernia Society Quality Collaborative between 2013 and 2016 were analyzed. Propensity score matching was used to compare median LOS between o-RVHR and r-RVHR groups. This work was supported by an unrestricted grant from Intuitive Surgical, and all clinical authors have declared direct or indirect relationships with Intuitive Surgical.

Results: In all, 333 patients met inclusion criteria for a 2:1 match performed on 111 r-RVHR patients using propensity scores, with 222 o-RVHR patients having similar characteristics as the robotic-assisted group. Median LOS [interquartile range (IQR)] was significantly decreased for r-RVHR patients [2 days (IQR 2)] compared with o-RVHR patients [3 days (IQR 3), $P < 0.001$]. No differences in 30-day readmissions or surgical site infections were observed. Higher surgical site occurrences were noted with r-RVHR, consisting mostly of seromas not requiring intervention.

Conclusions: Using real-world evidence, a robotic-assisted approach to RVHR offers the clinical benefit of reduced postoperative LOS. Ongoing monitoring of this technique should be employed through continuous quality improvement to determine the long-term effect on hernia recurrence, complications, patient satisfaction, and overall cost.

Keywords: AHSQC, Americas Hernia Society Quality Collaborative, hernia, length of stay, outcomes, retromuscular, robotic, surgery, ventral

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Ventral hernia repair remains 1 of the most common procedures performed by general surgeons. Despite the prevalence, there is little agreement on appropriate operative techniques or ideal outcome measures for patients with ventral hernias. There is considerable variability in costs and outcomes when performing ventral hernia repairs. Subsequently, it can be challenging to determine the value added to patients and hospital systems for specific hernia operations. When new and potentially innovative medical devices are introduced for ventral hernia repair, there is usually additional variability in cost. Given the changing healthcare landscape and the drive towards value-based care, it is important that any additional cost added to the system demonstrates some objective benefit in terms of reducing overall costs or improving patient outcomes. One such example is the robotic-assisted surgical platform, which is currently seeing rapid adoption by general surgeons for hernia repair. This value-based assessment has led our group to examine the value added to hernia repairs with the utilization of the robot for performing retromuscular ventral hernia repairs (RVHRs).

There has been a recent trend in hernia surgery to reconstruct abdominal wall defects by bringing the fascial edges to their normal anatomic position, utilizing a retromuscular approach while avoiding excessive subcutaneous dissection.[1–3] These techniques when performed through an open approach can result in significant patient morbidity, including wound infections, postoperative pain, and extended length of stay (LOS).[4] Several innovative surgeons have recently begun to evaluate the role of the robot in retromuscular repairs.[5] These investigators have replicated the open RVHR (o-RVHR) using robotic assistance (r-RVHR) to allow the prosthetic to be placed in the retromuscular position, with formal reconstruction of the linea alba, as performed in a classic open approach. However, the robotic-assisted platform adds potential cost to the system through capital expenditures in the robot itself, and the expense of the instruments required to perform the procedure. Given these

From the *Department of Surgery, Division of Minimal Access and Bariatric Surgery, Greenville Health System, University of South Carolina School of Medicine, Greenville, SC; †Department of General Surgery, Cleveland Clinic Comprehensive Hernia Center, Cleveland Clinic Main Campus, Cleveland, OH; ‡Department of General Surgery, Center for Minimally Invasive and Robotic Surgery, Abrazo Arrowhead Hospital, Glendale, AZ; §Department of Surgery, Oakland University/William Beaumont School of Medicine, William Beaumont Hospital, Royal Oak, MI; ¶Department of General Surgery, North Florida Surgeons, St. Vincent's Medical Center, Jacksonville, FL; ||Department of Biostatistics, Vanderbilt University Medical Center, 571 Preston Building, Nashville, TN; and **Department of Surgery, Division of General Surgery, Vanderbilt University Medical Center, Nashville, TN.

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Reprints: Benjamin K. Poulose, MD, MPH, Vanderbilt University Medical Center, D-5203 Medical Center North, 1161 21st Avenue South, Nashville, TN 37232. E-mail: benjamin.poulose@vanderbilt.edu.

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issues, we felt it was critical to evaluate the potential advantage of utilizing the robotic-assisted platform in performing RVHR versus the standard open approach in terms of clinical outcomes that are relevant to a patients and hospital systems. The objective of this study was to evaluate the impact of r-RVHR on postoperative LOS compared with o-RVHR using real-world data from the Americas Hernia Society Quality Collaborative (AHSQC).

METHODS

Design Overview

The goal of this study was to evaluate postoperative LOS after r-RVHR and o-RVHR using AHSQC data; we hypothesized that median LOS after r-RVHR was less than o-RVHR. To adjust for confounding factors impacting LOS, a propensity score matching algorithm was used to create 2 similar groups. Performance of this study conformed to Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cohort studies.[6]

Data Source

Data for this analysis were obtained from the AHSQC, a multi-institutional national quality and value improvement effort focused on hernia disease. The AHSQC is comprised of 181 surgeons practicing at 219 hospitals. AHSQC data are characterized by predetermined standard definitions for the preoperative, operative, and postoperative phases of hernia care. Details regarding the AHSQC and its data assurance process have been previously published.[7] The information collected is available to all hospitals and surgical teams in the AHSQC on a real-time basis for quality improvement. For this analysis, a retrospective review of prospectively collected data was performed using AHSQC data between 2013 and 2016. The analysis of this information for research was approved by the AHSQC Data Coordination Center (Vanderbilt University Medical Center) Human Research Protection Program and completed in cooperation with the AHSQC Foundation.

Population

All patients undergoing elective, RVHR with mesh under Centers for Disease Control (CDC) and Prevention wound class 1 (clean), class 2 (clean-contaminated), or class 3 (contaminated) conditions were eligible for analysis. RVHR in the AHSQC was defined as separation of the posterior sheath of the rectus muscle with placement of mesh behind the muscle and anterior to the reapproximated posterior rectus sheath; preperitoneal mesh extension was allowed [usually via transversus abdominis release (TAR)]. Patients undergoing concomitant procedures or parastomal hernia repair were excluded. Patients were identified using standardized AHSQC variables corresponding to these criteria.

Comparison Groups

Of the total number of eligible patients, those identified as undergoing open operations were included in the o-RVHR group, whereas patients undergoing robotic-assisted procedures using the da Vinci Surgical System (Intuitive Surgical, Inc.) were included in the r-RHVR group. Patients undergoing purely laparoscopic procedures were excluded, as were patients undergoing planned ''hybrid'' repairs using both open and minimally invasive techniques. Robotic cases converted to an o-RVHR were included in the r-RVHR group using an intent-to-treat approach. The techniques used for each of the surgical approaches have been previously described.[5,8,9]

Outcome Measures

The primary outcome measure for this study was postoperative LOS after elective RVHR. This was determined by calculating the difference in days between the patient's discharge date after repair and the patient's date of operation.

Secondary outcome measures included perioperative complications, reoperations, and readmissions that occurred within the 30-day postoperative time period. Wound events were divided into surgical site infection (SSI), surgical site occurrence (SSO), and surgical site occurrence requiring procedural intervention (SSOPI). SSI was defined as a superficial, deep, or organ space infection. SSO included any SSI, and also wound cellulitis, nonhealing incisional wound, fascial disruption, skin or soft tissue ischemia, skin or soft tissue necrosis, wound serous or purulent drainage, stitch abscess, seroma, hematoma, infected or exposed mesh, or development of an enterocutaneous fistula. SSOPI was defined as any SSO that required opening of the wound, wound debridement, suture excision, percutaneous drainage, or mesh removal (partial or complete).

Propensity Score Matching Algorithm

To identify comparable groups for analysis regarding preoperative comorbidities and operative technique, a propensity score-based matching algorithm was used. A logistic regression model was used to estimate the propensity score for each patient, defined as the probability of undergoing r-RVHR conditional on selected covariates. These covariates included those having a high likelihood of impacting LOS after operation including body mass index, Ventral Hernia Working Group classification,[10] CDC wound class, American Society of Anesthesiologists class, epidural analgesia, presence of diabetes, sex, age, smoking status, hernia width, use of TAR, hernia type (primary vs acquired), and repair of recurrent hernia. A nearest-neighbor matching method was used to identify the best o-RVHR control matches for each individual r-RVHR patient.

Power, Sample Size, and Statistical Analysis

To estimate sample size, we assumed a 2:1 ratio of o-RVHR patients to r-RVHR patients, based on available patients undergoing RVHR in the AHSQC. We conservatively estimated a difference of 2 days in LOS between groups based on previous work, with standard deviation of 5 days.[5,11] If the true difference between groups is 2 days, this study needed a minimum of 100 r-RVHR patients and 200 o-RVHR patients to reject the null hypothesis that the LOS is equal with power of 90%. After propensity score matching, hypothesis testing was performed using Wilcoxon rank-sum test for LOS and continuous variables. Pearson chi-square analysis or Fisher exact test was used for categorical variables. A 2-tailed P value less than 0.05 was considered significant. The performance of the propensity score-matched comparison was assessed by comparing propensity score distributions and by evaluating homogeneity across propensity score quartiles for the primary outcome measure.[12]

RESULTS

Of the 5602 AHSQC patients, 1250 met inclusion and exclusion criteria. Forty-five of these patients were not included in the matching algorithm due to 14 patients with missing LOS and 31 patients with at least 1 missing value for a matching variable. The resulting 1205 patients were used for the propensity score match, with 111 r-RVHR matched to 222 o-RVHR patients. Four r-RVHR patients required conversion to o-RVHR repair and were included in the r-RVHR group for analysis. The o-RVHR operations were performed by 39 surgeons in the AHSQC (28% private practice, 72% academic practice). For r-RVHR, 14 surgeons performed the procedures (36% private practice, 64% academic practice). The 2 patient groups were similar in terms of demographics, comorbidities, and clinical characteristics (Table 1). A higher proportion of o-RVHR patients underwent regional block analgesia and had a history of

TABLE 1. Preoperative and Operative Characteristics of Open (o-RVHR) and Robotic-assisted (r-RVHR) Retromuscular Ventral Hernia Repair Patients

	o-RVHR (n = 222)	r-RVHR (n = 111)	*P*
Demographics			
Age, yrs (mean ± standard deviation)	55.08±13.76	55.59±12.36	0.8
Women, %	57%	61%	0.5
Non-White, %	18%	14%	0.5
Body mass index, kg/m^2 (mean ± standard deviation)	33.23±7.39	33.88±7.30	0.3
Comorbidities			
Current nicotine use, %	20%	22%	0.4
Diabetes, %	25%	25%	0.9
COPD, %	10%	11%	0.8
Hypertension, %	57%	56%	0.8
Dyspnea, %	7%	2%	**0.04**
Dialysis, %	0%	1%	1
History of abdominal wall infection, %	16%	18%	0.7
History of abdominal aortic aneurysm	2%	2%	1
Recurrent ventral hernia, %	37%	38%	0.9
Current steroid use, %	5%	2%	0.2
Inflammatory bowel disease, %	2%	2%	1
Crohn disease, %	1%	2%	1
Ventral Hernia Working Group hernia grade			0.8
1	15%	14%	
2	67%	65%	
3	18%	21%	
Modified hernia grade			0.9
1	17%	18%	
2	81%	79%	
3	3%	3%	
ASA class			1
1	2%	2%	
2	39%	37%	
3	58%	60%	
4	1%	1%	
Clinical characteristics			
Incisional hernia, %	95%	95%	0.7
Primary ventral hernia, %	5%	5%	0.7
Epidural analgesia used, %	5%	5%	0.7
Regional block analgesia used, %	32%	6%	**<0.001**
Hernia width, cm (mean ± standard deviation)	7.17±3.68	7.51±3.34	0.2
Categorized hernia width, %			0.7
Width <4 cm	13%	10%	
Width ≥4 cm and <10 cm	62%	64%	
Width ≥10 cm	25%	26%	
Hernia length, cm (mean ± standard deviation)	12.00±6.89	13.17±6.58	0.1
Categorized hernia length, %			0.2
Length <8 cm	31%	22%	
Length ≥8 cm and <15 cm	32%	32%	
Length ≥15 cm	37%	46%	
Hernia area, cm^2 (mean ± standard deviation)*	80.13±74.02	87.96±67.57	0.1
Operative details			
Centers for Disease Control wound class, %			1
Class 1 (clean)	97%	97%	
Class 2 (clean-contaminated)	3%	3%	
Class 3 (contaminated)	0%	0%	
Operative time, %			**<0.001**
0–59 min	6.76%	0%	
60–119 min	33.33%	4.50%	
120–179 min	30.63%	18.92%	
180–239 min	16.67%	31.53%	
240+ min	12.61%	45.05%	
Mesh used, %	100%	100%	
Mesh placement, %			**<0.001**
Retromuscular	65%	88%	
Retromuscular and preperitoneal	35%	12%	
Mesh type, %			**<0.001**
Uncoated permanent synthetic	76.58%	95%	
Absorbable barrier composite permanent synthetic	6.31%	5%	
Uncoated absorbable synthetic	8.11%	0%	

TABLE 1. (*Continued*)

	o-RVHR (n = 222)	r-RVHR (n = 111)	*P*
Combination of permanent and absorbable	4.50%	0%	
Other mesh†	4.50%	0%	
Fixation used, %	80%	90%	**0.02**
Fixation type (% if fixation used)			**<0.001**
Sutures only	90%	53%	
Tacks only	2%	38%	
Sutures and tacks	4%	9%	
Other fixation‡	4%	0%	
Transversus abdominis release performed, %	83%	85%	0.7
Drains used, %	70%	21%	**<0.001**
Fascial closure achieved, %	99%	100%	0.6
Fascial closure suture type, %			**<0.001**
Absorbable	92%	67.57%	
Permanent	7%	31.53%	
Absorbable and permanent	1%	0.90%	
Fascial closure suture technique, %			**<0.001**
Running	85%	98%	
Figure of eight	11%	0%	
Simple interrupted	3%	1%	
Running and simple interrupted	1%	1%	

*Hernia area calculated from hernia length and width using formula of an ellipse.
†Other mesh types include biologic, biologic barrier composite permanent synthetic, preformed hernia system, permanent barrier composite permanent synthetic, and unknown mesh type.
‡Other fixation types include combinations of adhesives and sutures.
Bold values signifies statistically significant.

dyspnea versus r-RVHR patients. Patients undergoing o-RVHR had shorter operative times, wider array of mesh products, more uniform use of suture fixation, and a higher proportion of drain usage compared with r-RVHR. Regarding fascial closure, r-RVHR patients had higher use of permanent suture and running closure technique.

Primary Outcome Measure: Length of Stay

The overall median LOS was significantly decreased for r-RVHR patients [2 days; interquartile range (IQR) 2] compared with o-RVHR patients (3 days; IQR 3, $P < 0.001$; Fig. 1). Figure 2 shows the same comparison with outlier values removed (ie, values higher than the third quartile value + 1.5× the IQR). The propensity score-matched comparison for the primary outcome measure was homogenous across propensity score quartiles (Table 2), suggesting good performance of the propensity score matching algorithm.

Secondary Outcome Measures

Table 3 summarizes perioperative complications, reoperations, and readmissions within 30 days of RVHR. There were no differences in recognized intraoperative complications. A partial thickness bowel injury and gastric injury were observed in the r-RVHR group, with 1 partial-thickness and 2 full-thickness bowel injuries occurring in the o-RVHR group. One r-RVHR patient experienced an unrecognized bowel injury requiring reoperation. No differences were observed for SSIs between the 2 groups. A higher proportion of r-RVHR patients experienced SSOs which were mostly seromas not requiring intervention. Reoperation rates, readmission rates, and rates of other complications were similar between the groups.

DISCUSSION

Our study reports the largest collective experience of r-RVHR to date. We found that the robotic-assisted approach resulted in significant postoperative LOS reduction, which was both statistically significant and clinically relevant. The shortened LOS in the robotic-assisted group may be attributable to decreased pain, which may be multifactorial. Some explanations for this may include smaller incision size versus open operations, and also decreased traction on the abdominal wall by retractors, and finally fixation of the mesh using retromuscular suture fixation instead of transfascial suture fixation. Additional investigation is to determine the reasons for the

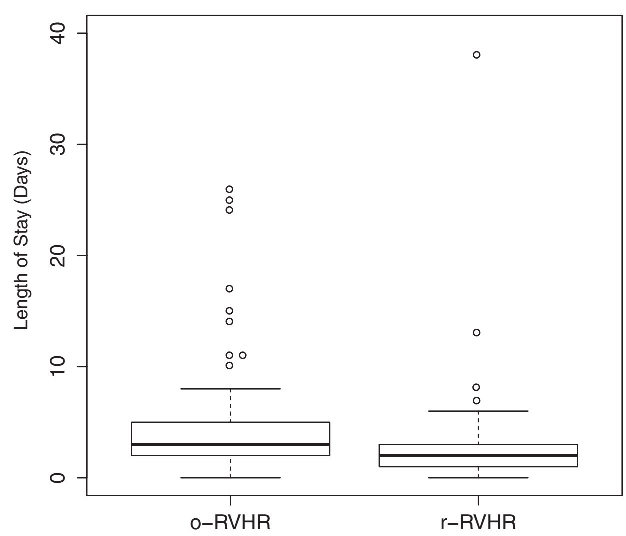

FIGURE 1. Length of stay (days) comparison after open (o-RVHR) and robotic-assisted (r-RVHR) retromuscular ventral hernia repair; each box plot represents data from propensity score matched groups (222 o-RVHR patients and 111 r-RVHR patients). Box plots show the interquartile range (boxes), median, 1.5× the third quartile (upper whisker), minimum value (lower whisker), and outlier values (open circles) for length of stay values. Median length of stay is shown with $P < 0.001$ between the 2 groups.

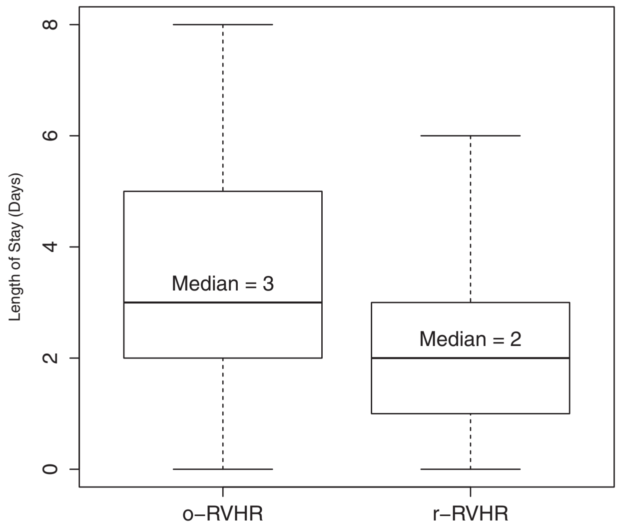

FIGURE 2. Length of stay (days) comparison after open (o-RVHR) and robotic-assisted (r-RVHR) retromuscular ventral hernia repair with outlier values removed (ie, values higher than the third quartile value + 1.5× the interquartile range); each box plot represents data from propensity score matched groups (222 o-RVHR patients and 111 r-RVHR patients). Box plots show the interquartile range (boxes), median, 1.5× the third quartile (upper whisker) and minimum value (lower whisker). Median length of stay is shown with $P < 0.001$ between the two groups.

observed reduction in LOS with the robotic approach, especially in terms of pain. Our study is the first to report a significant reduction in postoperative LOS, while maintaining open operative principles and utilizing robotic assistance. Despite the added cost of the platform, this decrease in LOS demonstrates the possible value of robotic-assisted hernia repairs to patients and hospital systems. These findings should encourage further investigation of this platform for ventral hernia repair regarding reduced postoperative pain, long-term recurrence, and overall cost.

The o-RVHR approach with mesh reinforcement has emerged as an acceptable approach to the repair of incisional hernias. Specifically, TAR allows wide mesh overlap of larger hernia defects in the retrorectus and preperitoneal space lateral to the posterior rectus sheath. This approach also offers a decrease in the wound morbidity typically associated with external oblique release (EOR), which requires the creation of a large subcutaneous flap.[3] Despite reductions in wound morbidity compared with open EOR, the rates of wound events remain significant. In a recent retrospective review of o-RVHR, Cobb et al[4] reported a 35.7% incidence of SSO and a 15.6% incidence of SSI, including a 1.9% mesh explantation rate and 14.9% hernia recurrence rate for CDC class I hernia repairs, the majority of which (97.4%) were in repairs with synthetic mesh as opposed to bioabsorbable or biologic meshes. Our series noted a substantially lower rate of SSIs in o-RVHRs compared with these results. This difference could be due to the smaller and less complex defects repaired in our series versus the Cobb et al experience. Despite that difference, we noted a higher rate of SSOs in our robotic-assisted cohort. These SSOs were mostly due to a higher rate of seroma formation. However, the number of surgical site occurrences requiring procedural intervention was similar between the 2 groups. This suggests that the seromas were not clinically significant and reflect the known issue with minimally invasive approaches to ventral hernia as previously reported.[13]

Evaluating variation in hospital costs related to various hernia repair techniques can be difficult as contract pricing and surgeon practice varies significantly. However, there are some insights into costs of repair that become important as robotic-assisted repairs are utilized. Prosthetic mesh choices can significantly impact the cost of hernia operations. Even synthetic meshes, which are known to be substantially less costly than biologic meshes, can result in dramatically different cost profiles. For instance, an intraperitoneal synthetic mesh with an antiadhesive barrier can cost several thousands of dollars, depending on the size of the mesh, whereas a similarly sized uncoated mesh may cost only several hundreds of dollars. The uncoated sublay mesh, however, should only be placed outside the peritoneal cavity in the retromuscular or preperitoneal position. Historically, this could only be accomplished with an open approach. Our study shows that these inexpensive materials can be placed in the extraperitoneal retromuscular position using robotic assistance. Importantly, these differences in mesh costs could potentially offset the cost of the robotic disposable equipment. Likewise, a standard minimally invasive hernia repair with intraperitoneal mesh often requires mechanical fixation. These devices can cost several hundred dollars each, and may be obviated with robotic-assisted hernia repair, as the mesh can be sutured. Whereas our study did not specifically examine costs associated with r-RVHR, the avoidance of expensive covered meshes and mechanical fixation devices combined with the ability to place the mesh in the retromuscular space while still reproducing the open technique should be taken into account. It remains to be seen if there is overall added value attributable to the robotic-assisted approach to ventral hernia repair versus the open approach, in terms of decreased overall costs or overall improved outcomes. Clearly, the robotic-assisted procedure adds to operative time, as more r-RVHRs took longer than 2 hours compared with o-RVHR. The relationship of this finding to the robotic learning curve is unclear in our study, and likely increases cost. Undeniably, utilization of the robot adds disposable costs, specifically in terms of multiuse instruments and in some cases expensive barbed sutures. However, those costs may be offset by other considerations such as shorter LOS, earlier return to work, or decreased resources directed

TABLE 2. Median Length of Stay After Open (o-RVHR) and Robotic-assisted (r-RVHR) Retromuscular Ventral Hernia Repair by Propensity Score Quartile

	o-RVHR (n = 222)	r-RVHR (n = 111)	*P*
Median length of stay, d [interquartile range (IQR)]			
Propensity score ≤0.25	4 (IQR 3) (n = 56)	2 (IQR 3) (n = 28)	**0.0021**
Propensity score >0.25 to ≤0.5	3 (IQR 3) (n = 56)	2 (IQR 2) (n = 27)	**0.0041**
Propensity score >0.5 to ≤0.75	3 (IQR 2.5) (n = 59)	1 (IQR 3) (n = 24)	**0.0179**
Propensity score >0.75	3 (IQR 2.5) (n = 51)	1 (IQR 1.25) (n = 32)	**<0.001**

Bold values signifies statistically significant.

TABLE 3. Intraoperative and 30-day Postoperative Complications of Open (o-RVHR) and Robotic-assisted (r-RVHR) Retromuscular Ventral Hernia Repair Patients

	o-RVHR (n = 222)	r-RVHR (n = 111)	*P*
Recognized intraoperative complications			
Total recognized intraoperative complications (n)	3	2	1
Partial-thickness bowel injury	1	1	1
Full-thickness bowel injury	2	0	0.6
Gastric injury	0	1	0.3
30-d Postoperative complications			
Surgical site infection, %	4%	2%	0.5
Surgical site infection type (n)			
Superficial	7	1	0.4
Deep	1	0	1
Organ space	0	1	0.2
Surgical site occurrence, %	14%	32%	**<0.001**
Surgical site occurrence type (n)*			
Seroma	9	28	**<0.001**
Cellulitis	6	1	0.4
Hematoma	2	3	0.3
Nonhealing incision, skin necrosis, or ischemia	6	0	0.2
Infected seroma	1	1	1
Other surgical site occurrence	4	3	0.7
Surgical site occurrence requiring procedural intervention, %	5%	4%	0.8
Reoperations, %	3%	2%	0.7
Reoperation reason (n)			
Bowel obstruction	2	1	1
Bleeding	2	0	0.6
Unrecognized bowel injury	0	1	0.3
Unrelated intra-abdominal pathology	2	0	0.6
Readmissions, %	5%	6%	0.6
Readmission reason (n)			
Wound complications	3	0	0.6
Gastrointestinal complications	1	0	1
Pain	1	1	1
Pain and thrombotic complications	0	1	0.3
Interparietal hernia	1	0	1
Obstructing ureteral stone	1	0	1
Shortness of breath	0	1	0.3
Other†	4	4	0.4
Pulmonary embolism (n)	0	0	1
Urinary tract infection (n)	3	0	0.6
Pneumonia (n)	2	0	0.6
Reintubation (n)	2	1	1
Death (n)	2	0	0.6

*Excluding surgical site infections.
†Other unspecified readmission reasons exclusive of those listed.
Bold values signifies statistically significant.

towards pain management, making the cost analysis complex at best. Even a single-day reduction in LOS, as demonstrated in our study, can have a significant impact on costs.[14] Further study related to these outcomes and cost is necessary to determine if the 1-day LOS reduction is an important factor in cost analysis when utilizing the robot in RVHR.

Based on the above noted factors, minimally invasive techniques for RVHR with mesh may be desirable due to reduced wound morbidity, pain, and LOS. A pure laparoscopic approach to retromuscular hernia repair has also been described by 1 group.[15] In this study, the author describes the initial experience with laparoscopic TAR with fascial defect closure and reinforcement with mesh in 3 patients. The average operative time was 329 minutes, with an average inpatient stay of 4.7 days, still twice that of our robotic-assisted series. Whereas the relatively long operative time was attributed to the learning curve, the average LOS was reported as 1 day less than open cases at the same institution. There was no reported morbidity or mortality at 30 days, nor were there wound complications during 6 weeks of follow-up. The defect sizes were not reported, nor were the number of recurrent hernias. Whereas this may suggest that laparoscopic TAR is feasible, it is likely too early to make generalizable conclusions about the appropriate candidates for this operation. In contrast, our experience with r-RVHR is based on 14 surgeons and thus suggests that this approach can be reproduced in advanced abdominal wall reconstructive surgeons' hands. Further study with larger volumes of patients, and also long-term follow-up, is required to determine the role of the purely laparoscopic approach to RVHR.

Additionally, Gonzalez et al[16] have described utilizing the robot to essentially recreate a laparoscopic intraperitoneal onlay mesh (IPOM) repair, with the added facilitation of suturing the defect closed aided by the maneuverability of the robot. The hernia defect sizes were not reported, and a minority underwent additional myofascial release; thus it is difficult to compare with the findings in our study. Despite these limitations, the authors were able to close over two-thirds of the defects primarily and used robotic-assisted suture fixation for the mesh in about 60% of the cases. Whether the robotic-assisted IPOM, as described by Gonzalez et al, or the retromuscular approach, as described here, would result in comparable outcomes in a reasonably matched cohort is unknown and requires further investigation.

The learning curve for achieving proficiency in o-RVHR has not been determined and is similarly unknown for a robotic-assisted approach. Additionally, the robotic-assisted approach introduces more technical challenges; whether our results will be reproducible on a larger scale is unknown at this time. Although performance of TAR was comparable in our propensity score-matched groups, the r-RVHR technique utilizes this release more frequently, increasing the complexity of the procedure with unknown impact on outcomes. Furthermore, the long-term effect of advanced myofascial release techniques still warrants investigation. These issues must be considered before widespread acceptance of this approach.

There are several limitations to this study. Although the data were prospectively collected, the nonrandomized nature of the study likely introduced some selection bias. Efforts to mitigate this involved exclusion of concomitant procedures performed during RVHR and inclusion of patients with CDC wound classes 1 to 3. Inclusion of contaminated cases helped to ensure that serious complications, such as recognized iatrogenic bowel injury, were captured even if the original operation was intended to be a clean case. If a recognized bowel injury was extensive and required resection, these patients would not have been included, potentially missing these complications. These instances, however, tend to be quite rare in our collective experience. All efforts were made to obtain comparable groups using observed variables and propensity score matching, but these methods cannot account for unobserved variables. We were unable to control for surgeon or institution in the propensity score model due to surgeons heavily contributing either to the robotic or open groups separately. Because of this, we could not effectively account for surgeon or institutional characteristics that may have also contributed to changes in LOS. Additionally, enhanced recovered protocols have been instituted in many facilities, which could help reduce LOS in both groups; we could not assess the impact of this. The majority of the surgeons included are highly skilled in performing both o-RVHR and r-RVHR with or without TAR, and most practice in high-volume hernia centers. Of the 14 robotic surgeons, 5 surgeons contributed 5 or more cases to the robotic group (total of 98 cases), with the remaining surgeons contributing a total of 13 cases. It is difficult to determine whether r-RVHR is widely reproducible, as there is some inherent selection bias with the high-volume robotic surgeons included in this study. Importantly, we are reporting on advanced cases performed by high-volume hernia surgeons in both the o-RVHR and r-RVHR groups; this should be viewed as preliminary data with further study needed to support our results. Due to technical complexity of these cases, attempts at r-RVHR should be reserved for surgeons with experience performing open retromuscular dissection and TAR. As has occurred with previous introductions of minimally invasive techniques, surgeons may simply be more likely to send patients home earlier, effectively altering their practice, with a robotic approach compared with open approach.[17] We were unable to include 45 patients in the analysis (before matching) who met inclusion/exclusion criteria due to missing information. Not including these patients with missing data (4% of the eligible pool for matching) may have introduced some selection bias with the o-RVHR group, but the effect was likely minimal, given complete data available for 96% (1205 patients). These issues are recognized limitations of real-world data.[18] As this study is supported by the sole manufacturer of a clinically available robotic-assisted minimally invasive platform in the United States, and all but 2 authors of the study have direct or indirect relationships with the manufacturer, issues concerning publication bias, ascertainment bias, and conflicts of interest must be addressed.[19,20] Steps to minimize these biases included having the analysis performed separately by the authors without conflicts (ie, the biostatisticians), being transparent with respect to the methodology used in the analysis, and ensuring complete disclosure of conflicts of interest with this study. Ultimately, the results of the study should be judged on the data and methodology, the level of transparency presented, and the integrity of the investigators.[21] The conclusions reached should be interpreted appropriately with consideration of these limitations.

CONCLUSIONS

In conclusion, we have demonstrated a reduction in postoperative LOS for a robotic-assisted approach to RVHR compared with similar patients undergoing an open approach. This comparison was performed using real-world data from a multi-institutional quality improvement effort focused on hernia disease. The long-term effect of the robotic-assisted approach on hernia recurrence, patient satisfaction, and overall cost requires further study.

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