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A comparison between robotic-assisted and open approaches for large ventral hernia repair—a multicenter analysis of 30 days outcomes using the ACHQC database

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Abstract

Introduction Over the last few decades, there has been an increase in the use of a minimally invasive (MIS) approach for complex hernias involving component separation. A robotic platform provides better visualization and mobilization of tissues for component separation. We aim to assess the outcomes of open and robotic-assisted approaches for large VHR utilizing the ACHQC national database.

Methods A retrospective review of prospectively collected data from the Abdominal Core Health Quality Collaborative (ACHQC) was performed to include all adult patients who had primary and incisional midline ventral hernias larger than 10 cm and underwent elective open and robotic hernia repairs with mesh from January 2013 to March 2023. Univariate and multivariate analyses were performed comparing Open and Robotic approaches.

Results The ACHQC database identified 5,516 patients with midline hernias larger than 10 cm who underwent VHR. The open group (OG) had 4,978 patients, and the robotic group (RG) had 538. The RG had a higher median BMI (33.3 kg/m^2 (IQR 29.8–38.1) vs 32.7 (IQR 28.7–36.6) ($p<0.001$). Median hernia width was 15 cm (IQR 12–18) in the OG and 12 cm in the RG (10–14) ($p<0.001$). Sublay positioning of the mesh was the most common. The fascial closure was higher in the RG (524; 97% versus 4,708; 95%—$p=0.005$). Median Length of Stay (LOS) was 5 days (IQR 4–7) in the OG and 2 days (IQR 1–3) in the RG ($p<0.001$). The readmission rate was higher in the OG ($n=374$; 7.5% vs $n=16$; 3%; $p<0.001$). 30-day SSI were higher in the OG (343; 6.9%% vs 14; 2.6%; $p<0.001$). Logistic regression analysis identified diabetes (OR 1.6; CI 1.1–2.1; $p=0.006$) and BMI (OR 1.04, CI 1.02–1.06; $p<0.001$) as predictors of SSIs, while the robotic approach was protective (OR 0.35, CI 0.17–0.64; $p=0.002$). For SSO, logistic regression showed BMI (OR 1.04, CI 1.03–1.06; $p<0.001$) and smoking (OR 1.8, CI 1.3–2.4; $p<0.001$) as predictors Robotic approach was associated with lower readmission rates (OR .04, CI 0.2–0.6; $p<0.001$).

Conclusion A robotic approach improves early 30-day outcomes compared to an open technique for large VHR. There was no difference in SSO at 30 days.

Keywords Ventral hernia · Robotic surgery · Open surgery · Incisional hernia · Minimally invasive surgery

Over the last few decades, the surgical approach for hernia repair has two major areas of focus: type of approach (open or minimally invasive)—and anatomic alterations to repair (component separation) [1]. Laparoscopic ventral hernia repair has gained momentum in the past few decades. However, laparoscopic repair faces some challenges, such as intraperitoneal placement of mesh, mesh fixation, inability to close the fascial in large hernia defects, and limited dexterity to perform complex component separation techniques [2].

The emergence of robotic-assisted repairs has challenged the limitations of minimally invasive complex hernia repairs. Abdominal wall reconstruction is a complicated field, and

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the learning curve for robotic surgery is steep. Unlike laparoscopic repairs, both open and robotic-assisted repairs enable the surgeon to close the fascial defect more frequently [1]. Robotic-assisted surgery provides better visualization and mobilization of tissues for component separation with the advantages of the minimally invasive surgical (MIS) approach.

Literature reporting the robotic approach has shown a shorter length of stay and longer operative times when compared to open surgery [3–5]. There is a significant variability between open and MIS approaches for ventral hernia repair which makes it difficult to compare both techniques [2]. Furthermore, no previous study compares robotic and open approach for large ventral hernias. We aimed to compare outcomes from open and robotic-assisted approaches for large ventral hernias utilizing the ACHQC national database.

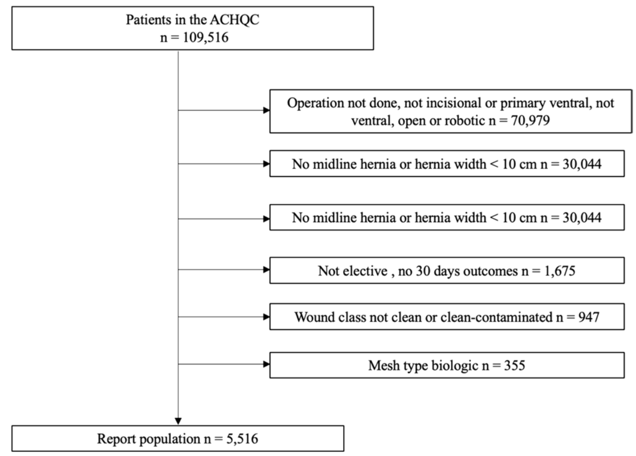

Fig. 1 Flowchart with inclusion criteria

Methods

Data collection

The data for this study originated from the Abdominal Core Health Quality Collaborative (ACHQC) from January 2013 to March 2023. The ACHQC is a nationwide hernia registry; as of now, there are 450 participant surgeons across the United States from academic and private institutions. They prospectively enter the patient's information, which is broadly categorized into demographics, preoperative information, operative details, and postoperative details with patient-reported outcomes (PROs). As of early 2023, there are a total of 118,922 patients listed in the database who underwent ventral, lateral, and inguinal hernia repairs with 30-day and 1-year follow-ups.

Population and comparison groups

The inclusion criteria steps are shown in Fig. 1. We selected all elective open and robotic-assisted ventral hernia repairs with defects equal or larger than 10 cm with mesh placement in the ACHQC. The European Hernia Society (EHS) defines giant/large ventral hernias as hernias larger than 10 cm (W3) [6]. We excluded patients with concomitant hernias, repairs in contaminated and dirty fields, repairs with no mesh or patients with prior mesh. We also excluded patients who had no 30-day follow-up data.

Outcomes

The primary outcome of our study is to assess surgical site occurrences (SSO), such as SSIs, seromas, hematomas, and SSO/I requiring intervention in open and robotic-assisted approaches for large (≥ 10 cm) ventral hernias using the ACHQC database. Secondary outcomes are factors associated with longer LOS or readmission at 30 days after surgery.

Statistical analysis

Categorical variables were presented as frequency and percentage and compared among groups using Person Chi-squared test or Fisher exact test, and continuous variables were presented as median and interquartile range (IQR) and compared among groups using Kruskal–Wallis test or Wilcoxon rank sum tests.

Multivariate analysis

A multivariate model was built to evaluate independent factors associated with wound morbidity (SSO, SSI, Seroma). A backward stepwise procedure was used for the final Cox model with factors with $P < 0.05$. In the multivariate analysis Cox model, the data was reported with hazard ratios (HR) and 95% confidence interval (CI).

Institutional review board

This study was approved by our institutional review board (IRB) number #202,213,764.

Results

ACHQC database identified 5,516 patients with midline hernias equal to or larger than 10 cm who underwent VHR. (Fig. 1). The open group (OG) had 4,978 patients, and the robotic group (RG) had 538. The RG had a higher median BMI of 33.3 kg/m^2 (IQR 29.8–38.1) vs 32.7 (IQR 28.7–36.6) ($p < 0.001$). There was no difference in HTN, DM, and COPD between groups. Smoking was higher in the Robotic group 52 (9.7%). The baseline characteristics are listed in Table 1.

Median hernia width was 15 cm (IQR 12–18) in the OG and 12 cm in the RG (10–14) ($p < 0.001$). M2 and M3 EHS hernia classification [6] were the most common in both groups. (Table 2) Sublay positioning of the mesh was the most common. Retromuscular repair was higher in the OG, 4,322 (94%) versus 414 (79%) in the RG. The intraperitoneal repair was higher in the RG 77 (15%) versus 141 (3.1%) ($p < 0.001$) There was no difference in Trans-versus Abdominis Release (TAR) ($p = 0.055$) or External Oblique release in both groups ($p = 0.3$). Fascial closure was higher in the Robotic group (524; 97% versus 4,708; 95%—$p = 0.005$). Regarding mesh fixation, regular suture was higher in the OG 2,628 (93%) versus 290 (80%) in the RG ($p < 0.001$). Tacks ($p < 0.001$) and barbed suture use ($p < 0.001$) was higher in the robotic group. (Table 2) The RG had more patients with an operative time of 240 + minutes when compared with the OG ($p < 0.001$).

Median Length of Stay (LOS) was 5 days (IQR 4–7) in the OG and 2 days (IQR 1–3) in the RG ($p < 0.001$). (Table 3) Drain use was higher in the OG ($n = 4795$; 96% vs $n = 229$; 435; $p < 0.001$). The readmission rate was higher in the OG ($n = 374$; 7.5% vs $n = 16$; 3%; $p < 0.001$). 30-day SSI was higher in the OG (343; 6.9%% vs 14; 2.6%; $p < 0.001$).

Multivariate analysis

Logistic regression analysis identified diabetes (OR 1.6; CI 1.1–2.1; $p = 0.006$) and BMI (OR 1.04, CI 1.02–1.06; $p < 0.001$) as predictors of SSIs, while the robotic approach was protective (OR 0.35, CI 0.17–0.64; $p = 0.002$). (Table 4) For SSO, logistic regression showed BMI (OR 1.04, CI 1.03–1.06; $p < 0.001$) and smoking (OR 1.8, CI 1.3–2.4; $p < 0.001$) as predictors. Sublay retromuscular or intraperitoneal mesh positioning were not related to increased risk of SSI or SSO. Robotic approach was associated with lower readmission rates (OR 0.04, CI 0.2–0.6; $p < 0.001$). (Table 5).

Discussion

Our study is the first large-scale study to compare open and robotic large ventral hernia repair with mesh. Using the ACHQC database, we found that the robotic approach was associated with increased fascial closure, lower length of stay, readmission rate, and 30-day SSI. Previous studies tried to compare open and laparoscopic approaches for ventral hernia repair but faced challenges due to the heterogeneity of techniques and patient population. [2, 7–9].

The advent of robotic surgery increased the rate of minimally invasive abdominal wall reconstruction [4, 10–12]. The use of the robotic approach brought technical improvements such as increased dexterity and degrees of freedom

Table 1 Sociodemographic characteristics, hernia characteristics and perioperative outcomes

	Open $N = 4{,}978$	Robotic $N = 538$	P-value
Median Age (IQR)	60 (51–68)	61 (52–69)	0.15
BMI (IQR)	32.7 (28.7–36.6)	33.3 (29.8–38.1)	< 0.001
Sex			0.6
Male	2361 (47%)	262 (49%)	
Female	2617 (53%)	276 (51%)	
HTN	2902 (58%)	323 (60%)	0.4
DM	1220 (25%)	139 (26%)	0.5
COPD	410 (8.2%)	46 (8.6%)	0.8
Current Smokers	306 (6.2%)	52 (9.7%)	0.002
Ascites	22 (0.5%)	2 (0.4%)	> 0.9
Dialysis	27 (0.5%)	3 (0.6%)	> 0.9
Anti-platelet medication	722 (15%)	70 (13%)	0.3
Anti-coagulation medication	376 (7.6%)	40 (7.4%)	> 0.9
History of AAA	91 (1.8%)	4 (0.7%)	0.066
CDC Wound class			< 0.001
Clean	4,205 (84%)	510 (95%)	
Clean-Contaminated	773 (16%)	28 (5.2%)	

BMI Body mass index, *IQR* Interquartile range, *HTN* Hypertension, *DM* Diabetes mellitus, *COPD* Chronic obstructive pulmonary disease, *AAA* Abdominal aortic aneurysm, *CDC* Center for disease control

Table 2 Perioperative outcomes

	Open N=4,978	Robotic N=538	p-value
Hernia width	15 (12–8)	12 (10–14)	< 0.001
Hernia length	21 (16–25)	16 (12–20)	< 0.001
Fascial closure	4708 (95%)	524 (97%)	0.005
Incisional Hernia	4931 (99%)	525 (98%)	0.002
EHS Hernia Classification			
M1	1637 (33%)	106 (20%)	< 0.001
M2	4101 (82%)	396 (74%)	< 0.001
M3	4423 (89%)	449 (83%)	< 0.001
M4	3778 (76%)	355 (66%)	< 0.001
M5	1329 (27%)	84 (16%)	< 0.001
External oblique release	108 (2.3%)	7 (1.6%)	0.3
Mesh type			< 0.001
Permanent Synthetic	4764 (96%)	532 (99%)	
Resorbable synthetic	214 (4%)	6 (1.1%)	
TAR	3635 (79%)	358 (83%)	0.055
Mesh type			< 0.001
Permanent Synthetic	4764 (96%)	532 (99%)	
Resorbable synthetic	214 (4%)	6 (1.1%)	
Mesh width	30 (25–31)	26 (20–30)	< 0.001
Mesh length	30 (30–36)	30 (25–35)	< 0.001
Mesh location			< 0.001
Onlay	253 (5.1%)	6 (1.1%)	
Inlay	126 (2.5%)	9 (1.7%)	
Sublay	4599 (92%)	523 (97%)	
Sublay mesh location			
Retromuscular	4322 (94%)	414 (79%)	< 0.001
Preperitoneal	1937 (42%)	131 (25%)	< 0.001
Intraperitoneal	141 (3.1%)	77 (15%)	< 0.001
Fixation type			
Suture	3628 (93%)	290 (80%)	< 0.001
Tacks	240 (6.2%)	56 (16%)	< 0.001
Adhesive	374 (9.6%)	58 (16%)	< 0.001
Barbed Suture	2 (0.4%)	28 (29%)	< 0.001
Operative time (min)			< 0.001
0–59	10 (0.2%)	4 (0.7%)	
60–119	361 (7.3%)	28 (5.2%)	
120–179	1396 (28%)	83 (15%)	
180–239	1401 (28%)	136 (25%)	
240+	1808 (36%)	287 (53%)	

and better visualization of the surgical field [13, 14]. This allowed for more challenging minimally invasive abdominal wall repairs with increased rates of fascial closure, component separation, and retromuscular repairs. A recent meta-analysis demonstrated that robotic VHR is associated with a decreased rate of conversion to open surgery and lower intraoperative bowel injuries when compared to laparoscopy [12].

Table 3 Postoperative outcomes

	Open N=4,978	Robotic N=538	P-value
Median Length of Stay	5 (4–7)	2 (1–3)	< 0.001
Readmission 30 days	374 (7.5%)	16 (3.0%)	< 0.001
Drain	4795 (96%)	229 (43%)	< 0.001
SSI	343 (6.9%)	14 (2.6%)	< 0.001
SSO	733 (15%)	92 (17%)	0.14
Recurrence 30 days	5 (0.1%)	1 (0.2%)	0.5
Infected Seroma	21 (2.9%)	1 (1.1%)	0.5
Hematoma	72 (9.8%)	9 (9.8%)	> 0.9

Table 4 Logistic regression for SSI and SSO at 30 days after surgery

	OR	95% CI	p-value
SSI			
Robotic Surgery	0.35	0.17–0.643	0.002
Wound class clean contaminated	1.7	1.1–2.4	0.007
BMI	1.04	1.02–1.06	< 0.001
Smoking	1.78	1.1–2.74	0.013
Diabetes	1.6	1.1–2.1	0.006
Sublay retromuscular vs intraperitoneal	0.9	0.45–1.7	0.879
SSO			
Robotic Surgery	1.3	0.9–1.6	0.095
Wound class clean contaminated	1.4	1.03–1.8	0.03
BMI	1.04	1.03–1.06	< 0.001
Smoking	1.8	1.3–2.4	< 0.001
Diabetes	1.2	0.97–1.52	0.077
Sublay retromuscular vs intraperitoneal	1.2	0.83–1.75	0.293

Table 5 Logistic regression for Readmission and Hematoma at 30 days after surgery

	OR	95% CI	p-value
Readmission			
Robotic Surgery	0.39	0.22–0.64	< 0.001
Wound class clean contaminated	1.2	1.03–1.54	0.02
BMI	1.04	1.03–1.05	< 0.001
Smoking	1.53	1.16–2	0.002
Diabetes	1.25	1.05–1.47	0.009
Hematoma			
Robotic Surgery	1.18	0.52–2.39	0.65
Wound class clean contaminated	1.6	0.95–2.88	0.06
BMI	0.956	0.92–0.99	0.01
Smoking	0.84	0.31–1.88	0.7
Diabetes	1.5	0.9–2.5	0.08

Data on large ventral hernias is limited, and only one study aimed to compare open versus laparoscopic large ventral hernia repairs [2]. The authors performed a propensity score matching to match defect sizes and found that open repair was associated with longer operative time, more component separation, higher SSI, and longer LOS with equivalent recurrence rates. These results are in accordance with the ones from our study. Collins et al., comparing robotic and open approaches for retromuscular ventral hernia repair in patients older than 65 years-old, found that the robotic approach was associated with increased operative time even though the defects in the open group were slightly wider [15]. These results are in accordance with our study. In our study, the open group had wider defects when compared with the robotic group. The robotic group had longer operative times. This could result from a series of factors such as surgeon experience with the robotic approach, case complexity, or problems with the robotic system. However, it is important to note that our two groups had no difference in TAR or External Oblique release.

The clinical importance of haptic feedback during robotic-assisted surgery is controversial. Early studies on robotic systems in the early 2000s have suggested that inadvertent tissue trauma could be, partly related to the lack of haptic feedback [16, 17]. However, experienced surgeons can use visual cues such as tissue deformation as surrogate for force and lack of haptic feedback [18]. Meccariello et all found that experienced surgeons can recognize the thickness of custom-made membranes without haptic feedback more frequently than junior surgeons [19]. To our knowledge, there is no data regarding the lack of haptic feedback and tissue strangulation in abdominal wall surgery and our findings do not suggest a difference in outcomes related to the lack of haptic feedback in the robotic system.

Studies have shown that postoperative outcomes of the robotic approach are similar to those of the laparoscopic approach for VHR [20]. Therefore, the clinical efficacy of the robotic repair over the laparoscopic approach is still debatable [3, 21]. A recent meta-analysis of RCTs and PSM studies comparing robotic and laparoscopic VHR showed that the Robotic approach was associated with longer operative times and lower conversion to open rates [20]. However, no difference was found in recurrence between the two techniques.

In our study, there was no difference in SSO between the Robotic and Open techniques in the univariate or multivariate analysis. It is not clear the reasons behind this outcome. A previous meta-analysis analyzing the use of drain for incisional hernias showed no differences in seroma formation or protection [22]. The use of drain is associated with increased fluid evacuation from the incision site, however, their efficacy in preventing seroma formation is still uncertain. In our study, the open group had more drain placements when compared with the robotic group and this may influence the SSO outcome. The ACHQC does not record the number of days with drain. A previous study evaluating open and MIS retromuscular hernia repairs showed that the use of drains was associated with lower odds of developing SSO [23]. A systematic review and meta-analysis by Bracale et al. analyzing VHR with TAR comparing open and robotic approaches found lower rates of SSO with the robotic approach [24]. Furthermore, the positioning of the mesh sublay intraperitoneal and retromuscular was also not related to increased odds of SSI or SSO.

In our study, the robotic group had lower rates of SSI, readmission, and lower median LOS when compared to the open group. Despite the open group having more patients with wider defects, the robotic approach was still associated with better postoperative outcomes when adjusting for co-variates in our multivariate analysis. These results are in accordance with the most recent meta-analysis by de'Angelis et al. [12] Bracale et al., analyzing VHR with TAR, also found lower rates of overall complications, LOS, and operative time [24]. Goettman et al. showed lower postoperative SSI rates for the robotic approach [25]. This is in accordance with our results. The lower postoperative rates seem to be due to the MIS nature of the procedure. Open procedures with larger incisions are prone to developing more SSI than the MIS smaller incisions. This was demonstrated by our multivariate analysis that showed that the robotic approach was associated with lower odds of developing SSI. The use of drain has mixed results in the literature regarding the development of SSI [22, 23, 26].

Limitations and strengths of the study

This study has several limitations. It is a retrospective study with prospective data entered by the surgeons who input their data into the ACHQC database. This may lead to recall bias. Second, a performance bias might be present as dedicated abdominal wall repair surgeons are more likely to participate in data collection. Additionally, we lack long-term follow-up data which limits our ability to comment on important factors such as long-term recurrence. Lastly, the data is collected through voluntary self-reporting, so there may be selection bias if participating surgeons input only some of their cases. The strength of our study lies in our large sample size ($n = 5516$) and the multivariate analysis to identify independent factors associated with wound morbidity. Using multivariate analysis allowed for the interpretation of odds ratios of individual events while controlling for other co-variates.

Conclusion

This study is the first to compare open and robotic ventral hernia repair for large ventral hernias. Compared to an open approach, the robotic approach was associated with better short-term postoperative outcomes, such as lower rates of SSI, readmission, and length of stay. Future studies should focus on long-term data such as recurrence to evaluate the efficacy of this MIS approach.

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Declarations

Disclosures Diego L Lima, Raquel Nogueira, Jianing Ma, Shannon Keisling, Mohamad Jalloh, Adel Alhaj Saleh and Prashanth Sreeramoju have no conflicts of interest or financial ties to disclose.

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