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Featured Article

Robotic intraperitoneal onlay versus totally extraperitoneal (TEP) retromuscular mesh ventral hernia repair: A propensity score matching analysis of short-term outcomes

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ABSTRACT

Background: Short-term outcomes of robotic intraperitoneal onlay mesh(rIPOM) versus robotic totally extraperitoneal retromuscular mesh(rTEP-RM) ventral hernia repair were compared.
Methods: A retrospective review of prospectively collected data of patients was conducted. A one-to-one propensity score matching(PSM) analysis was performed to achieve two well-balanced groups in terms of preoperative variables. A univariate and multivariate analysis were conducted to determine factors influencing post-operative outcomes.
Results: Of 291 rIPOM and rTEP-RM procedures, 68 patients were assigned to each group after PSM. Operative times were longer for the rTEP-RM group. Adhesiolysis was more frequently required in rIPOM. The rTEP-RM allowed for a greater mesh-to-defect ratio. The rate of overall perioperative complications, Clavien-Dindo grades, and surgical site events were higher for the rIPOM group than the rTEP-RM group. The Comprehensive Complication Index® morbidity scores were lower in favor of rTEP-RM group. Adhesiolysis, rIPOM, and craniocaudal defect size were predictors for post-operative complications.
Conclusion: Robotic TEP-RM repair has better early postoperative outcomes for ventral hernias, suggesting that it may be preferable over robotic IPOM repair. Further studies with longer follow-up are needed.

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Introduction

Ventral hernia repair, either primary or incisional, is one of the most commonly performed surgical procedures. The number of ventral hernia repairs (VHRs) was estimated to be over 300,000 annually in the U.S.A.[1] Various VHR techniques have been proposed including onlay, inlay, sublay, and underlay mesh repairs utilizing open or minimal invasive approaches.[2–6] The efficacy of these techniques is evolving rapidly partly due to the corresponding technological advancements in surgery. Therefore, there has been an ongoing debate regarding the optimal surgical approach, mesh position, as well as the initial access in order to achieve better results.[6,7]

Since laparoscopic intraperitoneal onlay mesh (IPOM) was first reported by LeBlanc and Booth,[4] its advantages were rapidly appreciated because of decreased wound complications, improved cosmesis, and faster recovery.[1,8] However, there are both mesh and fixation related complications attributed to IPOM, leading to a number of surgeons to lean towards alternative methods. Extraperitoneal repair techniques are based on the concept of utilizing inner layers of the abdominal wall as a barrier between the mesh and abdominal viscera, and by doing so, intends to avoid the potential adhesive complications.[9] Retromuscular (RM) mesh repair has long been well applied with the open approach[10] and has been successfully adapted to minimally invasive approaches.[5,11,12] In this context, robotic hernia repair has been promising regarding obtaining the same quality of hernia repair that has been achieved through the open technique while eliminating its perioperative morbidity.[7] Recently, RM mesh placement in VHR via totally extraperitoneal (TEP) access has been described for both laparoscopic[12] and robotic[5] approaches.

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The scrutiny of short-term results and investigation of surgical outcomes is paramount for new surgical techniques and technologies for ventral hernia repair. Therefore, we aimed to compare robotic IPOM (rIPOM) and robotic TEP-RM (rTEP-RM) hernia repairs in terms of short-term outcomes. We hypothesize that there may be advantages in retromuscular mesh placement, which can be shown through improved outcomes.

Material and methods

The data of this study were obtained from both a prospectively maintained database and electronic medical records of patients who underwent robotic ventral hernia procedures between February 2013 and August 2019. A researcher validated the quality and completeness of the database externally.

Data were reviewed in terms of preoperative variables, intraoperative, and postoperative variables. Preoperative variables patient demographics [age, sex, body mass index (BMI as kg/m^2)], hernia etiology (primary ventral, incisional, or both), the location of the hernia (grouped as medial, lateral, and both), the American Society Anesthesiologists classification scores (ASA), comorbidities and risk factors [hypertension (HT), myocardial infarction (MI), coronary artery disease (CAD), chronic obstructive pulmonary disease (COPD), smoking (defined as smoking within three months of procedure), immunosuppression (defined as recent chemotherapy or taking immunosuppression medicines), a history of previous wound infections], and procedure setting (elective or emergency).

Operative details included surgical technique (IPOM, TEP-RM with or without transversus abdominis release -TAR-), the performance of adhesiolysis longer than 30 min, primary closure of the hernia defect (yes/no), the type of mesh material [polypropylene, polyester, expanded polytetrafluoroethylene (ePTFE), absorbable], mesh fixation method (no fixation, self-fixation, suture, tacker), the dimensions of the hernia defect (cm) and the dimensions of the mesh itself (cm), the operative time (minutes, console and skin-to-skin), the estimated blood loss (mL, EBL), intraoperative complications. The recommendations of the European Hernia Society (EHS)[13] were followed to classify hernia location and to measure the defect size. The defect area (cm^2), the mesh area (cm^2), mesh overlap, and the ratio of mesh to defect size (M/D ratio) were determined using conventional mathematical formulas, which has been previously described.[9]

Postoperative variables as follows; postoperative pain scores (0-to-10 verbal scale assessed immediately after surgery in post-anesthesia care unit-PACU), the hospital length of stay (LOS-defined as differences between postoperative discharge date and index operation date), hospital readmission within 30-days. As part of routine care, all post-operative patients were clinically evaluated at mainly two intervals post-operatively; the first was performed within three weeks, and the second within three months. For this study, follow-up of a minimum of 90-days was chosen to assure detection of postoperative surgical complications related to index procedures.

All postoperative complications were categorized according to the Clavien-Dindo classification system.[14] The morbidity score was measured using the Comprehensive Complication Index (CCI®, University of Zurich, Zurich, Switzerland).[15] Surgical wound complications were categorized according to the previously published classifications.[16] Briefly, as an umbrella term a surgical site events (SSEs) were defined as surgical site infection (SSI), surgical site occurrence (SSO), and surgical site occurrence requiring procedural intervention (SSOPI). SSIs were further classified as cellulitis, superficial, deep, and organ space infections. SSOs included sterile fluid collection (hematoma, seroma), the dehiscence of the wound, or development of an enterocutaneous fistula. Any SSO or SSI requiring procedural intervention such as percutaneous puncturing to reduce symptoms, bedside wound opening, or reoperation, was described as an SSOPI.

Follow-up of complications within ninety days was performed mainly by reviewing prospectively maintained records and medical records for both in- and outpatient clinic visits. In addition, phone conversation records as well as emergency department visits were reviewed.

Of this cohort of robotic ventral hernia repairs, only patients who had undergone rIPOM or r-RM repair with TEP access were included in the study. Patients who underwent robotic transabdominal preperitoneal (rTAPP) or retromuscular (rTA-RM) mesh repair were excluded from the study.

Surgical technique

For rIPOM technique: the patients were placed in the supine position. Following proper preparation, the trocars were inserted in an appropriate place, and the patient side cart of the da Vinci surgical robotic system (Intuitive Surgical, Sunnyvale, CA, USA) was docked. Adhesiolysis was performed if necessary. The peritoneum surrounding the defect was dissected. After defect measurement, primary closure of the hernia defect was performed by running a long-lasting absorbable suture. The mesh was introduced and secured to the posterior fascia using absorbable sutures. For rTEP-RM technique: initial trocar placement was performed laparoscopically using optical trocar entry. After the other trocars were placed under direct vision, the patient-side cart of the robot was docked and the remainder of the surgery was achieved robotically. Upon completion of the ipsilateral retrorectus dissection, the medial edge of the rectus sheath was incised in order to reach the contralateral rectus sheath. Once the preperitoneal dissection at the posterior aspect of the linea alba was achieved, the medial border of the contralateral rectus sheath was incised to merge the retrorectus spaces together into one compartment (crossover) that is enclosed by the linea semilunaris on both sides. For Rives-Stoppa repair, the mesh was placed retrorectus area. When required, a unilateral or bilateral TAR was added. Neurovascular bundles of the rectus muscle were found and preserved during the TAR. After completion of the dissection, primary closure of the anterior fascial defect was accomplished by running a long-lasting absorbable barbed suture. The opening of the posterior rectus sheath, if occurred, was closed using absorbable suture. The mesh was then deployed. Skin incisions were closed with absorbable sutures.

Statistical analysis

Categorical variables were presented as the frequency with percentage [*n* (%)] and continuous variables as mean ± SD or median (interquartile range, IQR), as appropriate. Categorical variables were analyzed using Pearson Chi-Square or Fisher's Exact Test, and continuous variables using the Independent-Sample *t*-test (for normal distributions) or Mann-Whitney *U* Test (for non-normal distributions).

We expected potential imbalances between groups because of the study design. A propensity score matching (PSM) analysis was planned to reduce potential bias and to attain comparable groups (rIPOM and rTEP-RM). After estimation of the propensity scores using potential confounders such as demographics and preoperative risk factors, participants were matched using a simple 1:1 nearest neighbor matching, with a caliper of .20 of the standard deviation of the logit of the propensity score to obtain similar groups regarding the set of covariates. Standardized differences were examined to compare patient features before and after

matching, with imbalance being defined as an absolute value greater than 0.20 (small-effect size).

Multivariate regression analysis was performed to determine the factors associated with the development of any complication at follow-up visits. Odds ratio (*OR*) with 95% confidence interval (*CI*) was provided for statistically significant predictors.

A post hoc power analysis was performed to calculate the power of the study using the G-Power program (version 3.1.9.4)[17]. Statistical assessments were performed using SPSS software pack (Statistical Package for Social Sciences for Windows version 22 software) and R program (version 2.15.2 for Windows). To incorporate these programs and to perform PSM analysis, a developer-based software providing a custom dialog in the SPSS menu was used.[18] A *p*-value of smaller than 0.05 was considered statistically significant.

Results

From an initial cohort of 566 consecutive patients who underwent robotic VHR (rVHR), 291 patients were included in this study. Of these, 197 (67.7%) patients underwent rIPOM repair, and 94 (32.3%) underwent rTEP-RM repair. A total of 136 patients (68 for each group) have been obtained for the final outcome evaluation after propensity score matching by demographics and preoperative risk factors (Fig. 1). The overall balance test[19] and the relative multivariate imbalance measure *L1*[20] were examined and they indicated that our groups were appropriately distributed. Post-hoc power analysis of 68 patients for each group with a 0.5 effect size demonstrated that the present study has a power of 80.7%.

The rTEP-RM procedures were performed utilizing a Rives-Stoppa technique in 40 (58.8%) patients, unilateral TAR in 20 (29.4%) patients, and bilateral TAR in 8 (11.8%) patients. The comparison of baseline characteristics between the two groups, before and after matching, was given in Table-1. There were no differences in terms of hernia localizations according to the EHS classification[13] (Fig. 2). Accordingly, M3 was the most prevalent hernia location, contributed to by both primary and incisional hernias. To note, some hernias spanned more than one location and the upper limit of cranio-caudal defect size was 20 cm for both groups. With regard to intraoperative findings (Table 2), the requirement of more than 30 minutes of adhesiolysis was statistically higher in the rIPOM group. The rate of defect closure, defect size, mesh size, mesh overlap, and M/D ratio were statistically higher in rTEP-RM group than the rIPOM group. In addition, the types of mesh materials were statistically different between groups; whereas polyester-based meshes were mostly used in rIPOM repair, greater use of ePTFE and polypropylene-based mesh materials was observed in rTEP-RM repair. While all of the rIPOM repairs required mesh fixation by using suture material or absorbable tacker, an interrupted suture fixation was required in only 4(5.9%) rTEP-RM repair. Additionally, console time and skin-to-skin time were statistically longer for rTEP-RM repair. While intraoperative complications occurred in 3 (4.4%) patients who underwent rIPOM repair, there was no intraoperative complication in the rTEP-RM group. All of the intraoperative complications were serosal intestinal injuries occurred during the lysis of dense intraabdominal adhesions. None of these injuries were full-thickness and all were repaired intraoperatively using absorbable sutures. Furthermore, among these patients, none were found to have any late fistulas. A closed suction drain was required in only 1 (1.5%) patient in each group ($p = 1.000$). No patients required conversion to an open or laparoscopic approach. However, a hybrid technique, requiring a skin incision to insert the mesh through the anterior fascial defect, was utilized for 1 (1.5%) patient in each group ($p = 1.000$).

Although the median (IQR) postoperative pain scores that were assessed before leaving the PACU was slightly higher in the rTEP-RM group than the rIPOM group, it did not reach statistical significance [$p = 0.092$; 5(3–6) vs. 4(3–5), respectively]. The LOS did not differ between groups ($p = 0.506$); the median (range) was 0 (0–7) day for rIPOM group and 0 (0–6) day for the rTEP-RM group. Also, the rate of patients who were discharged on the same day of the procedure did not differ between groups ($p = 0.560$; 76.5% vs. 70.6%, respectively). The rate of hospital readmission within 30-days postoperatively did not differ between groups ($p = 0.493$; 8.8% vs. 4.4%, respectively).

The average follow-up time was 24.6 (*range* = 1–77.2) months for the entire cohort. Concerning the primary objective of the study, the overall proportion of patients with any perioperative complication during the first 90 days was higher in the rIPOM group than the rTEP-RM group ($p = 0.005$; 30.6% vs. 10.3%, respectively). Types and severity of postoperative complications were summarized in Table 3. In terms of pulmonary complications, pneumonia occurred in one patient (1.5%) for each group; others were atelectasis. Of cardiovascular complications, all of which occurred in the rIPOM group, two (2.9%) were cardiac arrhythmia treated with β-blocker medication, and one (1.5%) was deep venous thrombosis that occurred at postoperative day (POD) 40. All small bowel obstructions (SBO) or postoperative ileus were observed in the rIPOM group; however, none reached statistical significance ($p = 0.058$). Although median CCI® morbidity scores were similar for both groups, the range was narrower and mean rank statistically lower in the rTEP-RM group, implying more favorable outcomes. There were differences between the two groups when postoperative complications were evaluated regarding their severity, according to the Clavien-Dindo classification; although most complications consisted of minor grades (grade-1 & 2). Two out of four patients with major complications in the rIPOM group experienced a grade-3A complication; a superficial SSI occurred in one patient, and a deep SSI and wound dehiscence occurred in one patient who underwent staged repair in an emergency setting. Both of which were treated with drainage and antibiotic medication. In the rTEP-RM group, one patient required percutaneous abscess drainage

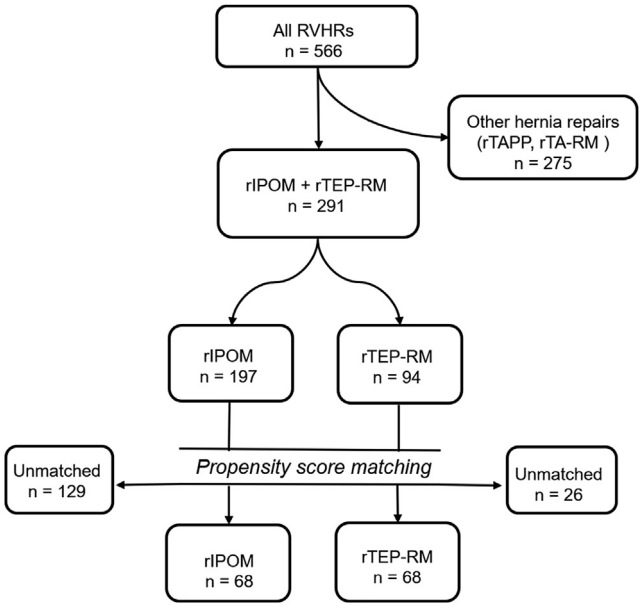

Fig. 1. The flowchart of patient selection.
RVHR robotic ventral hernia repair, *rTAPP* robotic transabdominal preperitoneal, *rTA-RM* robotic transabdominal preperitoneal, *rIPOM* robotic intraperitoneal onlay mesh, r*TEP-RM* robotic totally extraperitoneal retromuscular.

Table 1
The comparison of study groups in terms of preoperative variables before and after matching.

	Unmatched comparisons			Matched comparisons		
	rIPOM ($n = 197$)	rTEP-RM ($n = 94$)	p	rIPOM ($n = 68$)	rTEP-RM ($n = 68$)	p
Age (years), mean ± SD	54.3 ± 14.4	57.8 ± 15	0.952	57.8 ± 12.7	56.5 ± 15.9	0.095
Sex, male, *n* (%)	89 (45.2)	51 (54.3)	0.168	34 (50)	36 (52.9)	0.864
BMI (kg/m^2), mean ± SD	32.5 ± 6.3	31.4 ± 6.6	0.526	31.2 ± 5.7	31.6 ± 7	0.159
ASA Score, median (IQR)	2 (2–3)	3 (2–3)	**0.025**	2 (2–3)	2.5 (2–3)	0.781
HT, yes, *n* (%)	105 (53.3)	42 (44.7)	0.210	34 (50)	33 (48.5)	1.000
CAD, yes, *n* (%)	15 (7.6)	8 (8.5)	0.818	4 (5.9)	4 (5.9)	1.000
MI, yes, *n* (%)	4 (2)	4 (4.3)	0.277	3 (4.4)	2 (2.9)	1.000
COPD, yes, *n* (%)	25 (12.7)	8 (8.5)	0.330	6 (8.8)	8 (11.8)	0.779
Smoking, yes, *n* (%)	38 (19.3)	15 (16)	0.521	13 (19.1)	10 (14.7)	0.648
DM, yes, *n* (%)	32 (16.2)	17 (18.1)	0.738	12 (17.6)	11 (16.2)	1.000
History of wound infection, yes, *n* (%)	15 (7.6)	18 (19.1)	**0.005**	9 (13.2)	8 (11.8)	1.000
Immunosuppression, yes, *n* (%)	1 (0.5)	1 (1.1)	0.542	1 (1.5)	1 (1.5)	1.000
MVHWG grades, median (IQR)	2 (1–2)	2 (2–2)	0.288	2 (1–2)	2 (2–2)	0.976
HPW stages, median (IQR)	2 (1–2)	2 (2-2)	**0.008**	2 (1–2)	2 (2–2)	0.827
Hernia location						
Medial, *n* (%)	191 (97)	82 (87.2)		64 (94.1)	59 (86.8)	
Lateral, *n* (%)	6 (3)	8 (9.6)		4 (5.9)	9 (13.2)	
Both, *n* (%)	0 (0)	3 (3.2)	**0.002**	–	–	0.243
Hernia etiology						
Primary ventral, *n* (%)	108 (54.8)	45 (47.9)		28 (41.2)	40 (58.8)	
Incisional, *n* (%)	87 (44.2)	46 (52.1)		40 (58.8)	28 (41.2)	
Both, *n* (%)	2 (1)	0 (0)	0.301	–	–	0.059
Recurrent hernia, *n* (%)	45 (22.8)	33 (35.1)	**0.034**	20 (29.4)	16 (23.5)	0.560
Procedure setting						
Elective, *n* (%)	181 (91.9)	86 (91.5)		62 (91.2)	61 (89.7)	
Emergency, *n* (%)	16 (8.1)	8 (8.5)	1.000	6 (8.8)	7 (10.3)	1.000

rIPOM robotic intraperitoneal onlay mesh, *rTEP-RM* robotic total extraperitoneal access retromuscular, *BMI* body mass index, *ASA* American society of anesthesiologist, *HT* hypertension, *CAD* coronary artery disease, *MI* myocardial infarction, *COPD* chronic obstructive pulmonary disease, *DM* diabetes mellitus, *MVHWG* modified ventral hernia working group, *HPW* hernia-patient-wound, *SD* standard deviation, *IQR* interquartile range.

because of superficial SSI. The other two patients with major complications in the rIPOM group were grade-3B complications; mesh excision and primary closure of incision was needed in one patient due to mesh infection, and exploratory laparotomy for SBO secondary to an adhesive band was required in the other patient.

With regard to the secondary objective of this study, the overall proportion of patients with SSEs was statistically higher in the rIPOM group. When SSEs were looked at individually as SSIs and

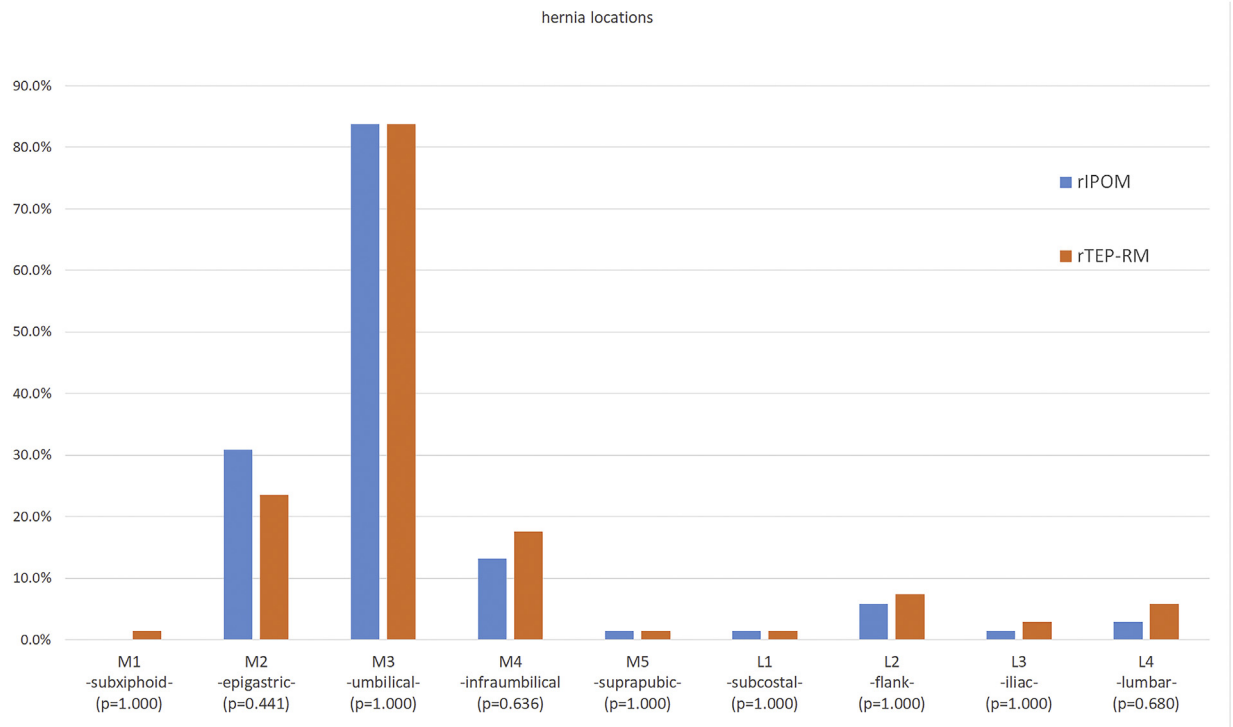

Fig. 2. Comparison of hernia locations between two groups (according to the European Hernia Society classification[13]).
rIPOM robotic intraperitoneal onlay mesh, r*TEP-RM* robotic totally extraperitoneal retromuscular.

Table 2
Comparison of intraoperative variables.

	rIPOM ($n = 68$)	rTEP-RM ($n = 68$)	p
Adhesiolysis (>30 min), *n* (%)	20 (29.4)	2 (2.9)	**<0.001**
Defect craniocaudal size, cm, median (IQR)	4 (2–6.5)	5 (4–6.5)	**0.009**
Defect horizontal size, cm, median (IQR)	4 (2–5)	4 (3–4.5)	0.122
Defect size, cm^2 median (IQR)	12.5 (3.9–24.3)	15.7 (11.7–23.5)	**0.043**
Primary defect closure, yes, *n* (%)	54 (79.4)	68 (100)	**<0.001**
Mesh size, cm^2 median (IQR)	113 (113–176.7)	300 (225–375)	**<0.001**
Cranio-caudal overlap, cm, median (IQR)	4.5 (3.5–5)	6 (5.5–7.5)	**<0.001**
Transverse overlap, cm, median (IQR)	4 (3.5–5)	5.5 (5.5–6)	**<0.001**
Mesh/Defect ratio, median (IQR)	9.4 (7.5–20.2)	16.9 (13.3–24.5)	**0.001**
Mesh materials			
Polypropylene	4 (5.9)	37 (59.7)	
Polyester	58 (85.3)	6 (9.7)	
ePTFE	2 (2.9)	19 (30.6)	
Absorbable	4 (5.9)	0 (0)	**<0.001**
Mesh fixation, yes, *n* (%)	68 (100)	4 (5.9)	**<0.001**
Console time, minutes, median (IQR)	61 (38.5–106)	80.5 (50–127)	**0.019**
Skin-to-skin time, minutes, median (IQR)	80 (51–139.5)	99.5 (68–151)	**0.048**
EBL, mL, median (IQR)	5 (5–5)	5 (5–6.5)	0.561
Intraoperative complication, *n* (%)	3 (4.4)	0 (0)	0.244

rIPOM robotic intraperitoneal onlay mesh, *rTEP-RM* robotic total extraperitoneal access retromuscular, *ePTFE* expanded polytetrafluoroethylene, *EBL* estimated blood loss, *IQR* interquartile range.

SSOs, although the number of each was numerically higher in the rIPOM group, these were not individually significant (Table 3). None of the patients experienced hernia recurrence in the study period, and there was no perioperative mortality.

The comparison of patients with and without complications is presented in Table 4. Multivariate regression analysis, including factors associated with the development of any complication, showed that the development of complications was associated with adhesiolysis ($p = 0.015$; $OR = 5.152$, *95% CI* $= 1.368–19.404$), rIPOM procedure ($p = 0.043$; $OR = 3.632$, *95% CI* $= 1.041–12.670$), and craniocaudal defect size ($p = 0.012$; $OR = 1.417$, *95% CI* $= 1.081–1.856$) corrected for hernia type (incisional), MVHWG grade, hernia area, and skin-to-skin time.

Discussion

In this propensity score-matched study, the rIPOM group compared to the rTEP-RM group, was associated with inferior postoperative outcomes, including a greater rate of higher-grade complications, a higher morbidity score, and a higher rate of SSEs.

Minimally invasive IPOM and IPOM-plus (IPOM with intracorporeal hernia defect closure) have typically been the two options for VHR.[7] However, there is interest in placing the mesh in the extraperitoneal (retromuscular/preperitoneal) space in an attempt to minimize adhesions due to a foreign body and potentially improve outcomes.[21] A recent systematic review revealed that anatomic location of mesh implantation appears to influence outcomes; a retromuscular or underlay (preperitoneal) plane seems to be the more suitable option.[6] In a study comparing open IPOM repair and open RM repair for primary umbilical hernias less than 3 cm in diameter, authors concluded that the latter technique should be preferred due to improved postoperative outcomes.[22]

In the IPOM repair technique, the peritoneal surface of the abdominal wall needs to be cleared from any tissue such as bowel and omentum in order to allow for optimal mesh integration and overlap, especially for the expected mesh landing zone.[23] Adhesiolysis is frequently required for patients who have a history of previous abdominal surgery, as nearly all incisional hernias exhibit various degrees of adhesion to the abdominal wall [24], thus resulting in longer operative times. Additionally, total operative time may be prolonged when the hernia defect is closed.[25] Operative time for robotic retromuscular repair has been found to be significantly longer than standard laparoscopic ventral hernia repair.[26] Likewise, robotic retromuscular repair with TAR significantly increases operative time compared to its open counterpart [27,28]. In a recent study comparing postoperative outcomes of 27 endoscopic TEP procedures with 27 IPOM procedures, it was shown that both techniques have similar complication rates. However, the differences between the two procedures were the reduction in mean postoperative pain score and the longer operative time for TEP-RM repair.[29] In the present study, although the proportion of patients requiring extensive adhesiolysis in the rIPOM group was higher than the rTEP-TM group, the rTEP-RM group had a longer duration of procedure. This likely stems from time-consuming operative steps, such as trocar placement, crossover, and TAR adjunction, which are required to dissect the retromuscular plane. In addition, the closure of the hernia defect may have resulted in prolonged operative time for rTEP-RM repair in the study population, as the rate of defect closure was significantly higher in this cohort. However, this issue could be better interpreted by a study that

Table 3
The comparison of short-term outcomes between groups.

	rIPOM ($n = 68$)	rTEP-RM ($n = 68$)	p
No complication, *n* (%)	47 (69.1)	61 (89.7)	
Clavien-Dindo			
Grade-I, *n* (%)	6 (8.8)	2 (2.9)	
Grade-II, *n* (%)	11 (16.2)	4 (5.9)	
Grade-III (A, B), *n* (%)	4 (5.9)	1 (1.5)	**0.031**
CCI®, median (range)	0 (0–41.5)	0 (0–26.2)	**0.003**
SSEs, yes, n (%)	14 (20.6)	4 (5.9)	**0.021**
SSIs, yes, *n* (%)	6 (8.8)	1 (1.5)	0.115
Cellulitis, *n* (%)	1 (1.5)	1 (1.5)	
Superficial, *n* (%)	3 (4.4)	1 (1.5)	
Deep, *n* (%)	2 (2.9)	0 (0)	
Organ space, *n* (%)	0 (0)	0 (0)	
SSOs, yes, *n* (%)	9 (13.2)	3 (4.4)	0.128
Seroma, *n* (%)	5 (7.4)	2 (2.9)	
Hematoma, *n* (%)	4 (5.9)	1 (1.5)	
Wound dehiscence, *n* (%)	1 (1.5)	0 (0)	
SSO/I-PI, *n* (%)	3 (4.4)	1 (1.5)	0.619

rIPOM robotic intraperitoneal onlay mesh, *rTEP-RM* robotic total extraperitoneal access retromuscular, *CCI®* Comprehensive Complication Index (University of Zurich, Zurich, Switzerland), *SSEs* surgical site events, *SSIs* surgical site infections, *SSOs* surgical site occurrences, *SSO/I-PI* surgical site occurrence or infection requiring procedural intervention.

Table 4
The comparison of the patients with and without complications.

	Complication (+)	Complication (−)	p
Age, years, mean ± SD	59.7 ± 14.6	56.5 ± 14.3	0.311
Sex, male, *n* (%)	14 (50)	56 (51.9)	1.000
BMI, median (IQR)	33.1 ± 8	31 ± 5.9	0.189
ASA Score, median (IQR)	3 (2–3)	2 (2–3)	0.168
HT, yes, *n* (%)	20 (71.4)	47 (43.5)	**0.011**
CAD, yes, *n* (%)	2 (7.1)	6 (5.6)	0.668
MI, yes, *n* (%)	1 (3.6)	4 (3.7)	1.000
COPD, yes, *n* (%)	4 (14.3)	10 (9.3)	0.486
Smoking, yes, *n* (%)	9 (32.1)	14 (13)	**0.023**
DM, yes, *n* (%)	7 (25)	16 (14.8)	0.256
History of wound infection, yes, *n* (%)	7 (25)	10 (9.3)	**0.048**
Immunosuppression, yes, *n* (%)	0 (0)	2 (1.9)	1.000
MVHWG grades, median (IQR)	2 (2–2)	2 (1–2)	**0.017**
HPW stages, median (IQR)	2 (2–2)	2 (1–2)	**0.035**
Hernia location, Medial, *n* (%)	27 (96.4)	96 (88.9)	0.303
Hernia etiology, incisional, *n* (%)	21 (75)	47 (43.5)	**0.005**
Recurrent hernia, *n* (%)	13 (46.4)	23 (21.3)	**0.015**
Emergency hernia repair, *n* (%)	4 (14.3)	9 (8.3)	0.468
Procedure, rIPOM, *n* (%)	21 (75)	47 (43.5)	**0.005**
Adhesiolysis (>30 min), *n* (%)	14 (50)	8 (7.4)	**<0.001**
Primary defect closure, *n* (%)	24 (85.7)	98 (90.7)	0.486
Defect craniocaudal size, cm, median (IQR)	7 (4–10)	4 (3–6)	**0.007**
Defect horizontal size, cm, median (IQR)	4 (3.5–5.5)	4 (3–4.2)	0.051
Defect size, cm^2 median (IQR)	21.2 (12.5–48.3)	12.5 (7–19.6)	**0.009**
Mesh size, cm^2 median (IQR)	212.5 (150–300)	225 (113–300)	0.618
Craniocaudal overlap, cm, median (IQR)	5 (4.2–5.5)	5.5 (4.5–7)	0.151
Transverse overlap, cm, median (IQR)	5 (4–5.7)	5.5 (4.1–6)	0.435
Mesh/Defect ratio, median (IQR)	9.1 (5.7–16)	16 (9.2–22.8)	**0.001**
Mesh materials			
Polypropylene	5 (18.5)	36 (35)	
Polyester	16 (59.3)	48 (46.6)	
ePTFE	4 (14.8)	17 (16.5)	
Absorbable	2 (7.4)	2 (1.9)	0.200
Mesh fixation, yes, *n* (%)	22 (78.6)	50 (46.3)	**0.003**
Console time, minutes median (IQR)	104.5 (56–130)	69 (40–101.5)	**0.024**
Skin-to-skin time, minutes median (IQR)	132.5 (77–173.5)	89 (56–122)	**0.008**
Intraoperative complications	2 (7.1)	1 (0.9)	0.108

BMI body mass index, *ASA* American society of anesthesiologist, *HT* hypertension, *CAD* coronary artery disease, *MI* myocardial infarction, *COPD* chronic obstructive pulmonary disease, *DM* diabetes mellitus, *MVHWG* modified ventral hernia working group, *HPW* hernia-patient-wound, *rIPOM* robotic intraperitoneal onlay mesh, *SD* standard deviation, *IQR* interquartile range.

examines the duration of operative steps separately.

In our previous study, with PSM analysis, comparing short-term outcomes between rIPOM and rTAPP techniques, we found that the development of complications was associated with incisional hernias ($p = 0.040$; $OR = 2.428$, *95% CI* = 1.040–5.664), rIPOM repair ($p = 0.046$; $OR = 2.027$, *95% CI* = 1.013–4.059) and longer procedure duration (console time) ($p = 0.049$; $OR = 1.014$, *95% CI* = 1.000–1.028)[9]. Accordingly, incisional hernias were approximately 2.5-fold more likely to result in early postoperative complications. This is probably secondary to the increased complexity and alteration of virgin tissue planes with incisional hernias. We also found that rIPOM was a significant risk factor for postoperative complications after rVHR in the morbidly obese population[30] ($p = 0.049$; $OR = 4.625$, *95% CI* = 1.006–21.262). Others risk factors included: adhesiolysis ($p = 0.005$; $OR = 16.055$, *95% CI* = 2.270–113.574), BMI ($p = 0.037$; $OR = 1.172$, *95% CI* = 1.010–1.361), and off-console time (the time differences between skin-to-skin time and console time) ($p = 0.033$; $OR = 1.139$, *95% CI* = 1.010–1.285). Although BMI and off-console time emerged as independent risk factors associated with the development of postoperative complications, an odds ratio of 1.1 for both variables suggests that the clinical implication can be negligible. In the current study's regression analysis, while adhesiolysis and rIPOM were found to be predictors for postoperative complications, operative time (skin-to-skin times), and hernia type were not. Interestingly enough, we also found craniocaudal defect size to be a predictor ($p = 0.012$; $OR = 1.417$, *95% CI* = 1.081–1.856). This might present significant implications. Incisional hernias are inherently larger (cranio-caudal length) and are associated with increased adhesion rates. Therefore, even though we found no association between hernia type and post-operative complications in our regression model, cranio-caudal defect size and adhesiolysis might be valid indicators for the higher risk of complications in the presence of incisional hernias.

Adhesiolysis-related adverse events have been well described in the literature.[31–34] Inadvertent intestinal injury is one of the most common intraoperative complication during adhesiolysis in abdominal procedures with a reported incidence of up to 11%.[32–34] Extended adhesiolysis has also been shown to increase the risk of seroma formation.[31] Furthermore, concomitant adhesiolysis has been found as an independent predictor for postoperative morbidity, surgical site infections.[33] We observed serosal intestinal injury during adhesiolysis in 3 (4.4%) patients who underwent rIPOM repair whereas no intraoperative complications during rTEP-RM repair. Theoretically, one might anticipate that there would not be any intestinal injury while performing TEP-RM repair due to the fact that there is a layer of abdominal wall between the dissection plane and abdominal viscera. However, the risk of bowel injury still exists during the crossover maneuver, especially in patients who had a past violation of the midline peritoneum. In this scenario, it is advised that the crossover dissection be initiated in the previously unviolated area.[5]

Minimally invasive IPOM repair has many advantages undeniably, but also the prominent disadvantage of adhesions; direct contact between mesh and visceral contents may increase the possibility of future postoperative gastrointestinal complications such as intestinal erosion, bowel obstruction, or fistula formation.[5,35] In a study in which 1326 laparoscopic IPOM repairs were performed using coated mesh, 126 patients underwent a second-look operation for different reasons and various degrees of adhesion were observed in more than half of these patients.[35] In this study period, we observed that postoperative small bowel obstruction or ileus occurred more frequently after IPOM repair, even though all repairs had been completed with coated mesh. However, the difference did not reach statistical significance. Studies with larger sample size and longer follow-up period could prove helpful to distinguish whether postoperative adhesive complications are preventable with extraperitoneally-placed mesh.

Separation of the abdominal wall layers may provide substantial medial advancement of both anterior and posterior myofascial components,[36,37] thus facilitating the closure of the defect. In the present study, the rate of defect closure was significantly higher in the rTEP-RM group ($p < 0.001$). The primary closure of hernia defects may improve reinforcement and reduce dead space. A meta-analysis has also revealed a decreased-rate of seroma formation with defect closure compared to without defect closure, from 12–27% to 3–11% respectively.[38] However, the development postoperative seroma is affected not only by defect closure but also by various factors, such as mesh types,[39] performing extensive adhesiolysis,[31] and electric cauterization of the hernia sac.[40] Coated meshes are typically associated with seroma formation owing to the impaired drainage of fluids due to the barrier layer.[41] We did not perform a subgroup analysis or a multivariate analysis to investigate risk factors for postoperative seroma formation in the rIPOM group due to the small number of seromas.

Multiple full thickness transfascial sutures, which may contribute to excessive postoperative pain,[42] and circumferential interrupted tacker fixation are often necessary in standard laparoscopic IPOM repair to prevent mesh migration within the abdominal cavity. In rIPOM repair, securing the mesh to innermost layer of the abdomen is usually performed by using circumferential superficial sutures, which may increase the likelihood of inadvertently perforating vessels. While all rIPOM repairs required mesh fixation, only 4 (5.9%) patients in the TEP-RM group required the mesh to be secured using a few interrupted absorbable sutures. In robotic extraperitoneal hernia repair, a reduced amount of mesh fixation or no fixation can be achieved because the mesh is confined within the abdominal wall layers and intraabdominal forces act to hold the mesh in place.[42] Tailoring the mesh to occupy the entire dissected retromuscular plane may help to hold the mesh in place because the borders of the dissected area prevent slippage of the mesh, minimizing the necessity for fixation material. Furthermore, covering the entire retromuscular plane with a mesh may allow for greater mesh overlap as well as a greater mesh-to-defect ratio, as found in this study.

The retromuscular space allows for the use of uncoated synthetic meshes, and thus, tissue ingrowth on both sides of the prosthetic may increase.[43,44] Mesh placement in this well-vascularized bed may attribute to favorable wound morbidity rates, particularly in terms of SSIs.[37] This space, by permitting the use of uncoated synthetic meshes, can offer the advantage of improved bacterial clearance as seen in experimental models in contaminated fields.[37] As mentioned before, concomitant adhesiolysis is one of the risk factors which increase the probability of postoperative surgical site infections.[33] In this study, SSI rates were lower in favor of rTEP-RM repair, with no statistical significance. The use of polypropylene meshes in the majority of rTEP-RM cases, along with less need for adhesiolysis, could be factors contributing to lower SSI rates.

The rTEP-RM technique has yet to be established as reproducible by the surgical community. To the best of our knowledge, there is only one published study by Belyansky et al.[5] where they describe the surgical technique and report early outcomes of rTEP-REM repair, showing minimal complication rates consistent with their prior laparoscopic TEP-RM experience.[12] They observed 2 seromas, requiring procedural intervention, in a total of 37 patients.[5] In the present study, the rTEP-RM repair group has a statistically lower rate of SSEs as compared to the robotic IPOM repair group ($p = 0.021$; 5.9% vs 20.6, respectively). However, when SSEs were considered individually as SSIs and SSOs, the rates were not statistically significant, albeit the number of each was numerically higher in the rIPOM group. The majority of complications, in terms of both Clavien-Dindo classification and CCI® scores, were minor and in favor of the rTEP-RM group.

There are some limitations in this study. Although our data was recorded prospectively, the study's retrospective structure can be considered as a limitation. In order to compensate for potential confounders and significant preoperative imbalances such as patient comorbidities and risk factors between pre-study groups, we performed a PSM analysis. Thus, we aimed to reduce the effect of potential bias and to obtain a well-balanced study population. Another limitation is that this is a single-center study, with one surgeon performing all the procedures. This surgeon has minimally invasive surgery training with a focus on hernia. This may admittedly limit the study's generalizability. Multicenter studies which represent more diverse surgeon experience could provide additional value. Other study limitations include the absence of patient-reported outcomes, such as pain assessment and quality of life. Lastly, this study reflects short-term outcomes associated with these procedures. Our results lack long-term follow-up outcomes, which assess the durability of the repair.

In conclusion, our study shows that robotic TEP-access retromuscular ventral hernia mesh repair appears to have improved early postoperative outcomes compared to robotic intraperitoneal onlay mesh repair. Moreover, TEP may allow for the avoidance of extensive adhesiolysis and its related complications. Lower morbidity scores, less severe complications, and lower rates of surgical site events suggest that this technique could be preferable for the repair of ventral hernias. Further prospective multicenter studies are warranted.

Ethical approval

The database used for this study approved by the Institutional Review Board.

Human and animal rights

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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Informed consent

Informed consent was obtained from all individual participants included in the study.

Declaration of competing interest

Drs. Gokcal and Chang have no conflicts of interest or financial ties to disclose. Dr. Kudsi has received a teaching course and/or consultancy fees from Intuitive Surgical, Bard-Davol and W.L. Gore outside the submitted work.

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