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Minimally Invasive Repair of Ventral and Incisional Hernias

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Minimally Invasive Repair of Ventral and Incisional Hernias

Ventral and incisional hernias are a particularly common occurrence impacting millions of patients worldwide. One of the very first applications of minimally invasive surgery in the early nineties has been that of laparoscopic repair of abdominal wall hernias with the intraperitoneal onlay mesh (IPOM) technique. Today, over three decades later, various minimally invasive approaches have been introduced, with the question of the most appropriate one still remaining open.

The goal of this Special Issue is to provide an comprehensive overview of the existing minimally invasive techniques for ventral and incisional hernia repair with regard to their outcome, as an attempt to determine the most appropriate indications for each approach in a given setting.

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Editorial: Minimally Invasive Repair of Ventral and Incisional Hernias

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Keywords: minimally invasive surgery, ventral hernia, trans-abdominal preperitoneal (TAPP), extended view totally extraperitoneal repair (eTEP), intraperitoneal onlay mesh technique (IPOM)

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Editorial on the Special Issue

Minimally Invasive Repair of Ventral and Incisional Hernias

Ventral and incisional hernias are a particularly common occurrence, impacting millions of patients worldwide. The biomechanical complexity of the abdominal wall serves both as the foundation for understanding its pathologies and as a gateway to a range of therapeutic strategies. One of the very first applications of minimally invasive surgery in the early nineties was that of laparoscopic repair of abdominal wall hernias with the intraperitoneal onlay mesh (IPOM) technique. Today, over three decades later, various minimally invasive approaches have been introduced, with the question of the most appropriate one still remaining open. Three out of nine papers included in the present special issue compared the outcome of IPOM to that of other approaches.

Anusitviwat et al. conducted a head-to-head comparison of laparoscopic eTEP-RS/TAR and IPOM techniques, highlighting the advantages of the former in cases with medium- to large-sized hernias. Munjuluri et al. indicated in their cohort that cases treated with laparoscopic ventral TAPP demonstrated lower postoperative pain and reduced costs compared to laparoscopic IPOM plus. Finally, Singh et al. conducted a systematic review and meta-analysis of randomized controlled trials examining the impact of the robotic platform on the outcome of IPOM when compared to the laparoscopic approach, without noting any differences other than higher operational costs for those treated robotically.

Furthermore, a second systematic review and meta-analysis was included, analyzing three studies comparing robot-assisted enhanced-view totally extraperitoneal (eTEP) and transabdominal retromuscular (TARM, aka TARUP) ventral hernia mesh repair. Brucchi et al. did not find any striking differences between the two methods but underlined the need for further trials examining these technically similar techniques and unmasking subtle differences, if any exist. Radu share with us their approach regarding robotic PeTEP for a case with incisional hernia and, in a second paper, demonstrate their personal experience from the first five years conducting eTEP/eTEP-TAR repairs. Vogel et al. share their experience from their first 160 consecutive robotically assisted lateral eTEP and eTAR techniques, providing us with interesting insights regarding that matter. Van Hoef et al. contributed an interesting work focusing on repair of lateral abdominal wall defects with open or robotic unilateral transversus abdominis release, showing a shorter length of stay using the robotic approach in the short-term follow-up.

Last but not least, the rapid rise of Artificial Intelligence and its implications in abdominal wall reconstruction were explored in the final paper of our special issue by Vogel and Mück, shedding light on the rather bright future that lies ahead.

The goal of this Special Issue is to provide a comprehensive overview of the already established, as well as emerging, minimally invasive techniques for ventral and incisional hernia repair with regard to their outcome, as an attempt to determine the most appropriate indications for each approach in a given setting. I would like to personally thank all 32 authors for their thorough work and dedication to this fascinating, ever-evolving field of abdominal wall surgery.

AUTHOR CONTRIBUTIONS

This has been drafted by DP, who acted as the handling editor for all 9 papers.

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REVIEW
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Comparison of Robot-assisted Enhanced-view Totally Extraperitoneal (eTEP) and Transabdominal Retromuscular (TARM aka TARUP) Ventral Hernia Mesh Repair: A Systematic Review and Meta-Analysis

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Background: This systematic review and meta-analysis compares robotic eTEP and TARM/TARUP in terms of complications, operative time, infections, length of stay, seroma, and short-term recurrence rates.

Methods: A systematic review was conducted following PRISMA guidelines, searching MEDLINE, Embase, and CENTRAL until January 30, 2025. Studies comparing r-eTEP and r-TARM/TARUP in adults with ventral hernia were included. Primary outcomes were operative time and postoperative complications. Secondary outcomes included wound complications, length of stay, readmission, pain, and short-term recurrence. A random-effects model was used for meta-analysis, and study quality was assessed via the Methodological Index for Non-randomised Studies (MINORS) score.

Results: Three studies (308 patients: r-eTEP 176, r-TARM/TARUP 132) were included. Overall complications were lower with r-eTEP (RD: -0.17; 95% CI: -0.27 to –0.07; p = 0.001) and as was the case for minor complications (RD: -0.14; 95% CI: -0.22 to –0.06; p = 0.0008). No significant differences were found in major complications, SSI, recurrence, or 30-day readmission. Operative time was shorter with r-eTEP (MD: -25.66 min; 95% CI: -51.18 to –0.14; p = 0.05, $I^2 = 88\%$). Seroma formation was lower with r-eTEP (RD: -0.08; 95% CI: -0.15 to –0.02; p = 0.01). Length of stay was shorter with r-eTEP (MD: -2.64 days; 95% CI: -4.06 to –1.22; p = 0.004, $I^2 = 98\%$).

Conclusion: Evidence remains insufficient to favor one robotic approach over the other. High-quality prospective studies on patient outcomes and long-term recurrence are needed to guide surgical decision-making.

Systematic Review Registration: PROSPERO, identifier CRD420250650879.

Keywords: robot-assisted, robotic, eTEP, TARM, TARUP

INTRODUCTION

The Rives-Stoppa technique has long been the gold standard for open repair of ventral midline hernias and offers a reliable approach to abdominal wall reconstruction [1]. A major advantage of this technique is the retromuscular mesh insertion, which has been associated with a lower recurrence rate, less surgical site infection, and improved abdominal wall function [2, 3].

Over time, laparoscopic adaptation of retromuscular approach evolved [4, 5] and paved the way for the integration of robotic-assisted technology [6], which offers improved precision, visualization and dexterity. Recent data from the Danish Hernia Database supports the use of robotic surgery in ventral hernia repair and demonstrates advantages over both open surgery and laparoscopic intraperitoneal mesh repair [7–9]. The robotic platform allows two primary access methods: the transabdominal (TA) approach, which includes a peritoneal entry, and the totally extraperitoneal (TEP) approach, which preserves the integrity of the peritoneum during access to the retromuscular space [10–12]. For these approaches a lateral docking [13–16] and caudal docking [17, 18] has been described.

While the TA approach is the conventional method for robotic retromuscular hernia repair, recent advances have led to the development of the extended (or enhanced) view totally extraperitoneal (eTEP) technique for robotic ventral hernia repair (VHR) [12, 19]. Despite the increasing acceptance of these techniques, comparative studies remain limited. Although there are numerous studies in the literature evaluating laparoscopic TAPP and extraperitoneal TEP approaches in minimally invasive inguinal hernia repair (IHR) [20], similar comparisons in ventral hernia repair (VHR), particularly using the same trocar approach, are scarce.

Both the robotic eTEP and transabdominal retromuscular (TARM) techniques allow access to the retrorectus space, enabling a minimally invasive alternative of the Rives-Stoppa repair. However, each method offers unique advantages and potential risks, emphasizing the need for direct comparison of their outcomes.

This systematic review and meta-analysis aims to compare the robotic eTEP and TARM/TARUP methods, specifically evaluating overall, major, and minor complications, operative time, surgical site infection rates, seroma formation and short-term recurrence rates.

MATERIALS AND METHODS

Data Sources and Research

The peer-reviewed literature published from January 1, 2000 to January 30, 2025 was searched in the Medline (PubMed), Embase, Scopus, and Cochrane Library databases. The following keywords were used to identify relevant studies: "eTEP," "robotic," "sublay," "retromuscular," "retrorectus," "TARM," "TARUP," "mesh repair," "robotic," "hybrid," "umbilical hernia," "ventral hernia," "epigastric hernia," "incisional hernia." The detailed search strategies can be found in the **Supplementary Material** (**Supplementary Figure S1**). This meta-analysis was conducted in accordance with the PRISMA (Preferred Reporting Items for a Systematic Review and Meta-analysis) [21] and AMSTAR II Statements (**Supplementary Files S1, S2a, S2b**). The planned protocol of this meta-analysis was registered in PROSPERO (PROSPERO 2025: CRD420250650879). In addition, reference lists of retrieved articles were screened to identify further studies.

Selection of the Studies

Two reviewers (FB, RS) independently performed the literature search and data extraction using the Rayyan software for systematic review [22]. They independently assessed the eligibility of all preliminarily identified records first by the title and then by abstract. After screening, the full-text manuscripts of relevant studies were carefully read to confirm eligibility and extract useful information. Disagreements regarding the eligibility of articles were resolved by a third reviewer (GD). Studies were included according to the following criteria: 1) randomized and observational studies in English, 2) adult population diagnosed with ventral hernia, 3) repair using robotic extended view totally extraperitoneal (eTEP) versus transabdominal retromuscular (TARM) ventral hernia repair, 4) detailed description of surgical technique and report of short term results. No geographical restrictions were made. Reviews, editorials, case reports of <5 patients and manuscripts on other minimally invasive techniques were excluded. Patients undergoing concurrent procedures were excluded. Papers reporting duplicate results from the same author group were excluded.

Data Extraction and Quality Assessment

Two authors examined the main characteristics of each article, found and provided the following data: Year of publication, country where the study was conducted and source of population, total number of subjects, sex, age, outcomes, length of primary hospitalisation (LOS), recurrence, duration of follow-up, effectiveness of treatment performed, statistical analysis. The methodological quality of the selected studies was assessed using the criteria of the Methodological Index for Non-randomised Studies (MINORS) [23]. The assessment of the bias of the included studies is listed in the **Supplementary Material** (**Supplementary Table S1**). The overall quality of the evidence was assessed using the GRADE (Grading of Recommendations, Assessment, Development and Evaluations)

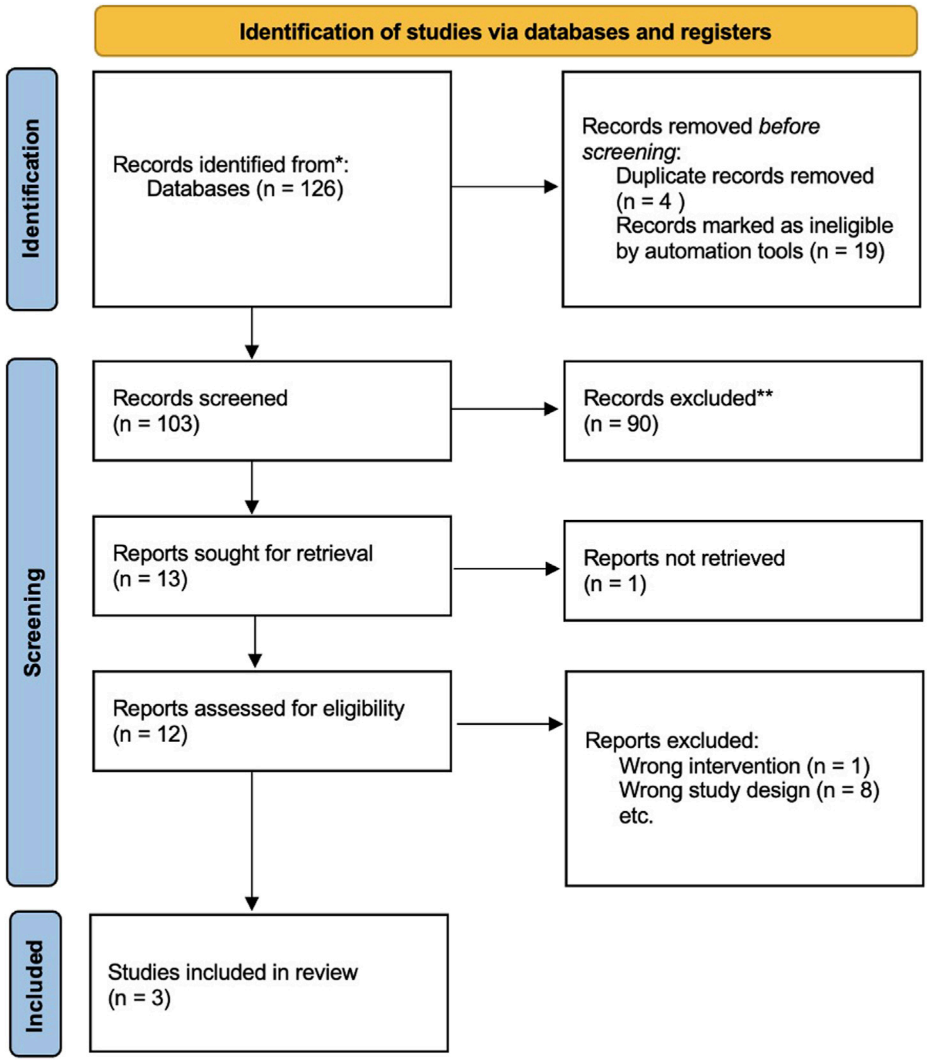

FIGURE 1 | PRISMA flowchart.

approach [24]. Based on the overall assessment the quality of the evidence was categorised into four levels (high, moderate, low or very low). Studies were either downgraded or upgraded in quality depending on whether the criteria of risk of bias, inconsistency, indirectness, imprecision, publication bias, large magnitude, dose dependence or effect of all plausible confounders were met. Authors FB and RS performed the GRADE assessment.

Outcome Measures

Primary outcomes, including:

- Postoperative total, minor and major complications and operative time

Complications were classified as minor or major based on the Clavien-Dindo classification system. Grades I and II were categorized as minor complications, while Grades III and IV were classified as major complications.

Secondary outcomes, including:

- Wound complications (surgical site infection, seroma), length of stay (LOS), short-term recurrence rate, 30-day readmission, postoperative pain.

Data Synthesis and Analysis

Risk Difference (RD) was selected as the effect measure for binary outcomes because of its clinical interpretability and its appropriateness in studies with small sample sizes and low event rates. It was calculated for discrete variables with 95% confidence intervals (c.i.) calculated using a Mantel–Haenszel random-effects model. Mean Difference (MD) were calculated for continuous variables with 95% c.i. using an inverse-variance random-effects model. The random-effects model was applied to all analyses, regardless of I^2 values, in order to account for potential clinical and methodological heterogeneity among studies.

TABLE 1 | Selected studies and patients characteristics reporting the robotic eTEP vs TARM approaches.

Author	Country	Year of Publication	Enrollment (Years)	Type of Study	Total Patients	Patients in eTEP Group	Patients in TARM Group	Approach	MINORS overall score
[25]	USA	2024	2015–2021	Observational (Retrospective)	96	60	36	Both lateral	23
[26]	Belgium	2022	2019–2022	Observational (Retrospective)	48	34	14	eTEP: caudal; TARM: lateral	19
[27]	USA	2020	2013–2019	Observational (Propensity Score Matched)	164	82	82	Both lateral	22

Author	Age eTEP (Mean ± SD)	Age TARM (Mean ± SD)	Sex Ratio (M/F) % eTEP	Sex Ratio (M/F) % TARM	BMI (kg/m^2) eTEP (Mean ± SD)	BMI (kg/m^2) TARM (Mean ± SD)	Primary/Incisional Hernia, n (%) eTEP	Primary/Incisional Hernia, n (%) TARM
[25]	57.35 ± 11.2	57.47 ± 12.0	28 (46.6%)/ 32 (53.3%)	18 (50%)/ 18 (50%)	30.47 ± 4.7	33.24 ± 6.5	28 (46.6)/32 (53.3)	16 (44.4)/20 (55.5)
[26]	62 (20–90)	54 (37–81)	19 (56)/15 (44)	12 (86)/2 (14)	31 (20–42)	30 (26–38)	20 (59)/14 (41)	9 (64)/5 (36)
[27]	57 ± 14.5	56.6 ± 13.2	42 (51.2)/ 40 (48.8)	39 (47.6)/ 43 (52.4)	31.8 ± 7.2	32.5 ± 6.6	32 (39)/50 (61)	28 (34.1)/54 (65.9)

eTEP, extended (or enhanced) view totally extraperitoneal; TARM, transabdominal retromuscular; MINORS, Methodological Index for Non-randomised Studies; SD, standard deviation; M, male; F, female; BMI, body mass index.

Heterogeneity was assessed using Cochran's Q test and the I^2 statistic: I^2 <25% = Low heterogeneity, I^2 25%–50% = Moderate heterogeneity, I^2 >50% = High heterogeneity. All statistical analyses were performed using Revman software, version 5.4.1 (Cochrane Collaboration, The Nordic Cochrane Centre, Copenhagen), with significance set at $p < 0.05$.

RESULTS

Search Results

Figure 1 shows the 2020 PRISMA flowchart, outlining the results of the search strategy. General characteristics of the studies and the groups studied are listed in **Table 1**. Overall MINORS score are shown in **Table 1**. The results of the quality assessment of all included studies based on the GRADE approach are presented in the **Supplementary Material** (**Supplementary Table S2**).

Of the three studies [25–27] included in the review, all were retrospective. Of the 308 patients, 176 were in the robotic eTEP group, while 132 were in the robotic TARM/TARUP group. Study characteristics and patient variables are listed in **Table 1**. Additional details on preoperative and intraoperative patient characteristics are available in **Supplementary Tables S3, S4**.

Meta-Analysis

Primary Outcomes

All studies analyzed the total postoperative complications [25–27]. Data are listed in **Table 2**. The risk difference between the two groups was statistically significant in favor of r-eTEP (RD: -0.17; 95% CI: -0.27 to −0.07; p = 0.001; I^2 = 20%) (**Figure 2**).

All studies examined minor postoperative complications [25–27]. The risk difference between the two groups was statistically significant in favor of r-eTEP (RD: -0.14; 95% CI: -0.22 to −0.06; p = 0.0008; I^2 = 0%) (**Figure 3**).

All studies evaluated major postoperative complications [25–27]. The difference in risk between the two groups was not statistically significant (RD: -0.03; 95% CI: −0.07 to 0.01; p = 0.20; I^2 = 0%) (**Figure 4**).

All studies analyzed the operative time [25–27]. This was 154.31 min [±38.80 min] in the r-eTEP group and 179.75 min [±45.16 min] in the r-TARM/TARUP group. The mean difference between the two groups was statistically significant in favor of r-eTEP (MD: -25.66; 95% CI: −51.18 to −0.14; p = 0.05; I^2 = 88%) (**Figure 5**).

Secondary Outcomes

All studies assessed SSI [25–27]. The difference in risk between the two groups was not statistically significant (RD: −0.03; 95% CI: −0.07 to 0.01; p = 0.15; I^2 = 0%) (**Figure 6A**).

All studies analyzed seromas [25–27]. The difference in risk between the two groups was statistically significant in favor of r-eTEP (RD: −0.08; 95% CI: −0.15 to −0.02; p = 0.01; I^2 = 0%) (**Figure 6B**).

All studies examined the LOS [25–27]. The mean difference between the two groups was statistically significant in favor of r-eTEP (MD: -2.64; 95% CI: -4.06 to −1.22; p = 0.004; I^2 = 98%) (**Figure 6C**).

All studies analyzed short-term recurrences [25–27]. The difference in risk between the two groups was not statistically significant (RD: 0.00; 95% CI: −0.02 to 0.02; p = 1.00; I^2 = 0%) (**Figure 6D**).

All studies analyzed the 30-day readmission [25–27]. The difference in risk between the two groups was not statistically significant (RD: -0.01; 95% CI: -0.05 to 0.03; p = 0.61; I^2 = 0%) (**Figure 6E**).

Two studies evaluated postoperative pain using the VAS scale [25, 27]. The mean difference between the two groups was not statistically significant (MD: −0.49; 95% CI: −1.47 to 0.49; p = 0.33; I^2 = 96%) (**Supplementary Figure S2**). Due to the limited number of studies and the high heterogeneity observed, we therefore decided not to include this analysis in the main manuscript, as the results are not very reliable.

Methodological Quality of Studies

The studies [25–27] achieved a median MINORS score of 22 (range 20.5–22.5). This result indicates a low risk of bias in the

TABLE 2 | Postoperative characteristics and short-term postoperative outcomes.

Author	LOS (days) eTEP, mean (SD)	LOS (days) TARM, mean (SD)	IO complications n (%) eTEP	IO complications n (%) TARM	Drain placement eTEP, n (%)	Drain placement TARM, n (%)	SSI eTEP, n (%)	SSI TARM, n (%)	Seroma eTEP, n (%)	Seroma TARM, n (%)	Hematoma eTEP, n (%)	Hematoma TARM, n (%)
[25]	0 (0–1)*	1 (1–1)*	NR	NR	NR	NR	0	1 (2.7)	5 (8)	4 (11)	NR	NR
[26]	1 (1–3)*	1 (1–5)*	0 (0)	0 (0)	0 (0)	0 (0)	0	0	0	2 (14)	0	0
[27]	0 (0–5)*	0 (0–20)*	0 (0)	4 (4.9)	2 (2.4)	1 (1.2)	1 (1.2)	4 (4.9)	3 (3.7)	11 (13.4)	1 (1.2)	0 (0)

Readmission (30d) eTEP	Readmission (30d) TARM	Tot Compl eTEP	Tot Compl TARM	Minor complication (CD I/II) eTEP	Minor complication (CD I/II) TARM	Major complication (CD III/IV) eTEP	Major complication (CD III/IV) TARM	FU (months) median (range) eTEP	FU (months) median (range) TARM	Recurrence eTEP, n (%)	Recurrence TARM, n (%)
0 (0)	1 (2.7)	24 (40)	14 (38.9)	NR	NR	NR	NR	NR	NR	0	0
0 (0)	0 (0)	3 (8.8)	3 (21.4)	2 (6)	3 (21)	1 (3)	0 (0)	15 (3–29)	35 (29–37)	0	0
4 (4.9)	4 (4.9)	11 (13.4)	31 (37.8)	9 (11)	25 (30.5)	2 (2.4)	6 (7.3)	NR	NR	0 (0)	0 (0)

*LOS, length of stay; *median (range); IO, intraoperative; SSI, surgical site infection; Tot. Compl., total complications; CD, Clavien-Dindo; FU, follow-up; eTEP, extended (or enhanced) view totally extraperitoneal; TARM, transabdominal retromuscular.*

included studies. The complete MINORS scores evaluation for each study are shown in **Supplementary Table S1**.

DISCUSSION

Our meta-analysis revealed statistically significant differences in favor of r-eTEP with respect to several outcomes, including overall complications, minor complications, operative time, seroma rate, and length of stay (LOS). To date, only one other systematic review and meta-analysis has been published on this topic by Tryliskyy et al. [28] Their study included data from Olivier et al. [26] and Kudsi et al. [27], but not the recently published study by Pacheco et al. [25] In contrast to our results, their meta-analysis found no significant differences between robotic eTEP and TARM/TARUP. However, a potential limitation of their analysis was the inclusion of the study by Zaman et al. [29], comparing robotic eTEP with robotic transabdominal hernia repair with preperitoneal mesh (rTAPP, called TASM in their study) and not with a purely retromuscular approach. This methodological discrepancy may have influenced their conclusions and limited the generalizability of their results to the r-eTEP vs. r-TARM/TARUP debate.

Regarding the surgical approach for the two techniques, Kudsi et al. [27] and Pacheco et al. [25] used a lateral approach for both procedures. In contrast, Olivier et al. [26] employed a lateral approach for rTARM/TARUP and a caudal approach for r-eTEP, referred to as inverted TEP (iTEP) in their study. The authors state that the iTEP technique represents a robotic Rives-Stoppa repair, in which access to the retrorectus space is achieved through the suprapubic preperitoneal region, utilizing a single-docking approach.

Our analysis showed a statistically significant reduction in overall and minor complications in favor of r-eTEP, while the incidence of major complications remained comparable between groups. Kudsi et al. [27] reported a complication rate of 13.4% in the r-eTEP group compared to 37.8% in the r-TARM/TARUP group, with seromas accounting for 44% of minor complications in the latter cohort. Several factors may explain this discrepancy. One possible explanation is the learning curve effect, as r-TARM/TARUP was performed earlier in the surgeons' experience, which may have contributed to the higher rate of minor complications. In addition, differences in mesh material may have played a role, as polyester mesh was used in 43.9% of r-TARM/TARUP cases, while polypropylene mesh was used in 61% of r-eTEP cases, which may have influenced complication rates. Another factor could be the extent of adhesiolysis required in the r-TARM/TARUP group. In 45.1% of patients, adhesiolysis lasted more than 30 min, a known risk factor for postoperative complications [27]. These results suggest that the perceived superiority of r-eTEP over r-TARM/TARUP in terms of complications may be study-specific rather than an inherent advantage of the technique. Given these observations, further prospective, standardized studies are needed to gain a clearer understanding of the comparative safety profiles of these procedures.

Our analysis showed a statistically significant reduction in operating time in favor of r-eTEP, a result that is consistent with the studies by Kudsi et al. [27] and Olivier et al. [26] Notably, the iTEP technique used in the latter study involves a suprapubic docking

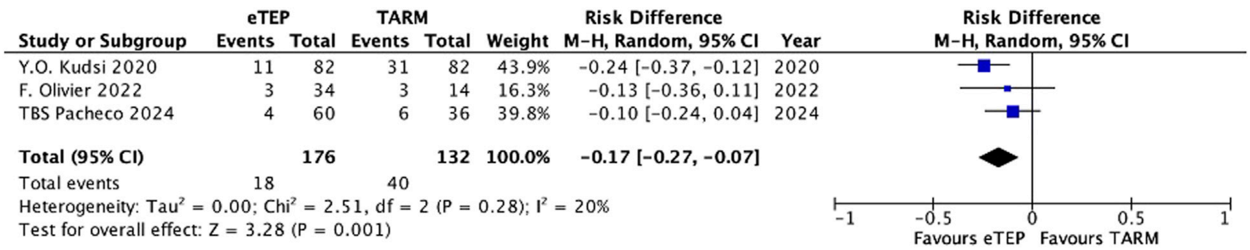

FIGURE 2 | Total complications.

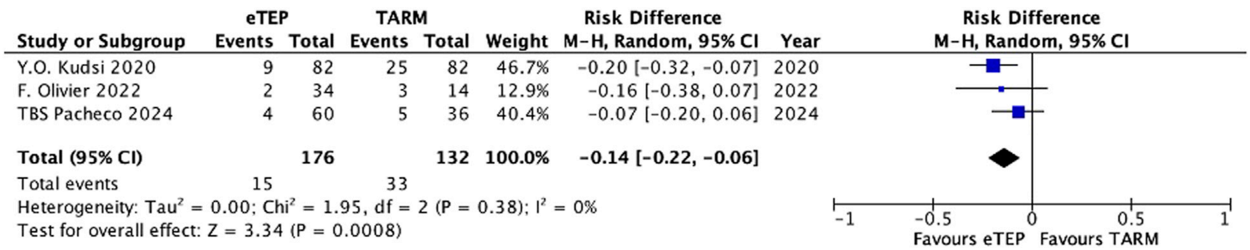

FIGURE 3 | Minor complications.

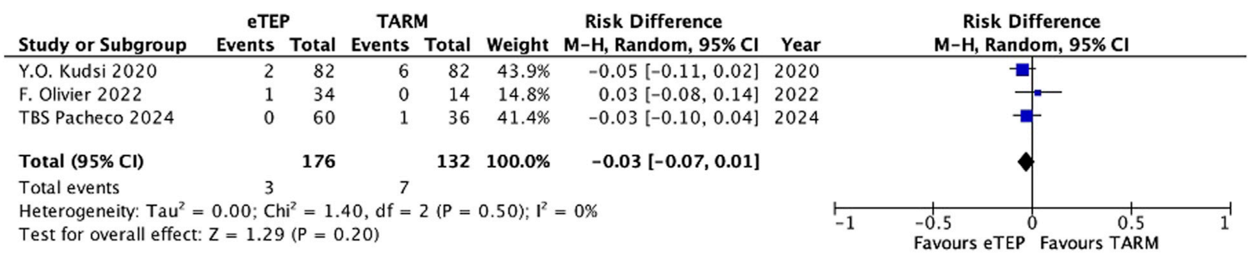

FIGURE 4 | Major complications.

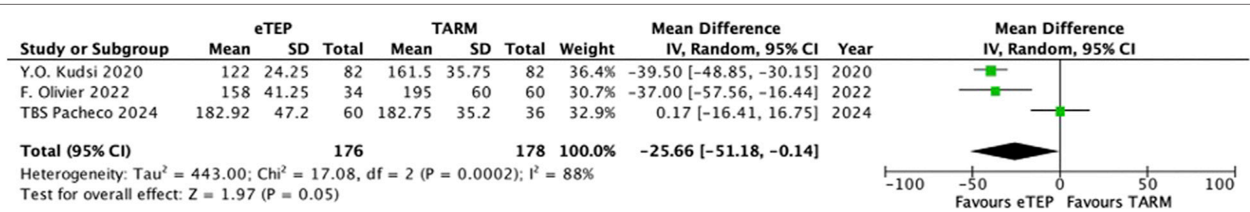

FIGURE 5 | Operative time.

approach, which may differ in efficiency and setup time compared to standard lateral docking. This variation in surgical access could have contributed to the observed differences in operative time and should be considered when interpreting pooled results.

In contrast to r-eTEP, r-TARM/TARUP requires the posterior rectus sheath to be opened and closed, which requires additional steps that prolong operation time. In addition, r-TARM/TARUP was often performed earlier in the surgeons' learning curve, which may have impacted efficiency and technical skills. Previous studies on robotic retromuscular repair support this learning curve effect. Muysoms et al. analyzed robotic transabdominal retromuscular umbilical prosthetic repair (r-TARUP) and reported that the average time for peritoneal closure was initially 21 min, but decreased to 18 min with increased experience [13]. In addition, adhesiolysis, which was more common in the r-TARM/TARUP group, was associated with a median operative time of 20 min, which also contributed to the increased duration observed in this cohort.

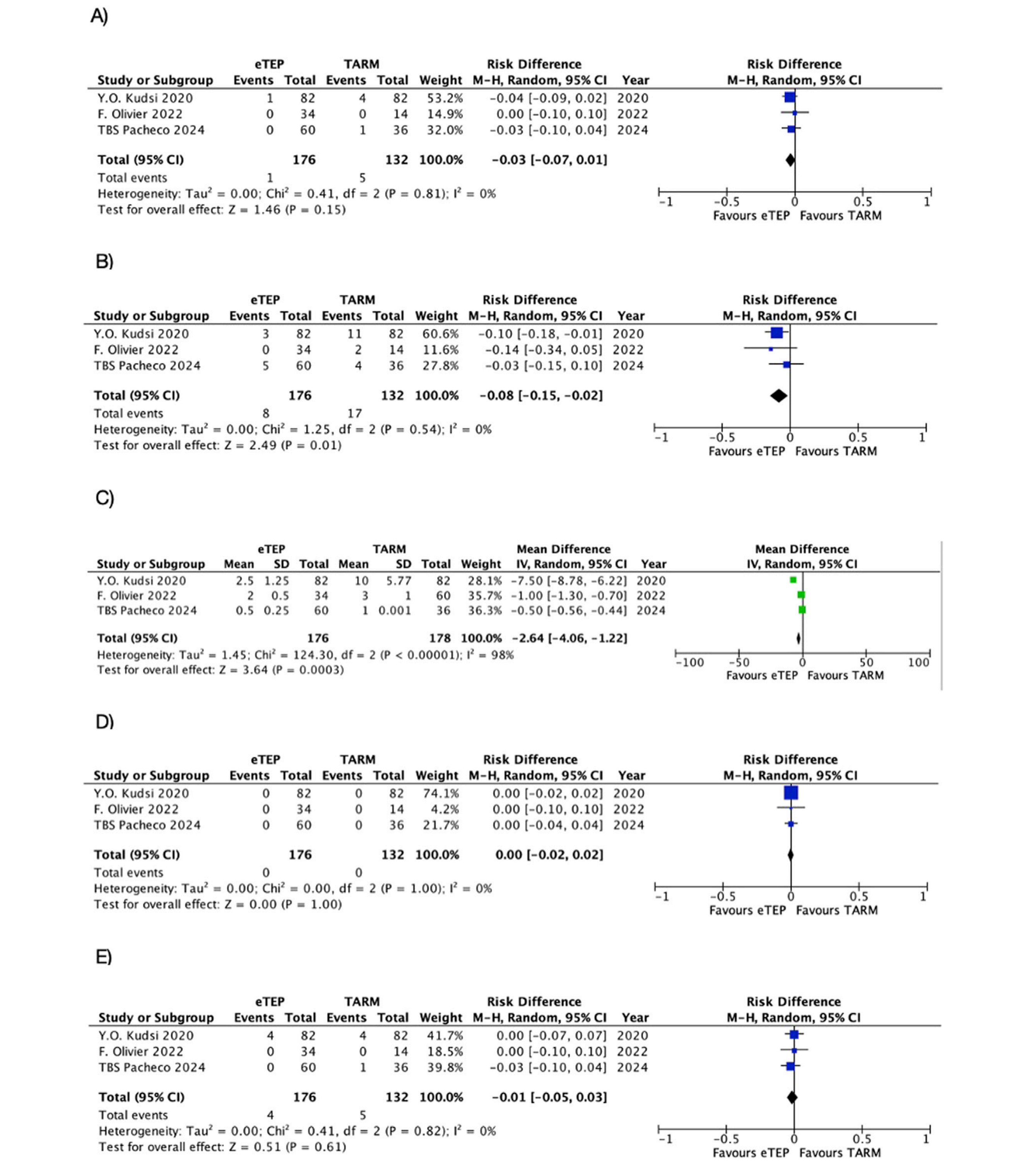

FIGURE 6 | Secondary outcomes. **(A)** SSI. **(B)** Seroma. **(C)** LOS. **(D)** Recurrence. **(E)** Readmission.

Both r-eTEP and r-TARM/TARUP appear to be safe techniques in terms of the occurrence of surgical site infections (SSI), with an overall low incidence of this complication. The highest number of SSIs was reported by Kudsi et al. [27], with one event in the r-eTEP group (1.2%) and four events in the r-TARM/TARUP group (4.9%). This result could be related to the seroma rate and the extent of adhesiolysis, as both factors are known to contribute to an increased risk of infection. Extensive adhesiolysis was identified as an independent predictor of both seroma formation and SSI [30], emphasising the need for careful patient selection and surgical planning when performing robotic retromuscular repairs.

Seroma rates were comparable between the two groups. Kudsi et al. [27] reported a seroma rate of 13.4% in the r-TARM/TARUP group, a finding that may be due to the higher incidence of extensive adhesiolysis in this cohort. Notably, 45.1% of r-TARM/TARUP patients underwent adhesiolysis lasting longer than 30 min, which likely contributed to the increased seroma rate observed [30].

Our meta-analysis showed a statistically significant difference in LOS between the two techniques. In fact, Pacheco et al. reported a shorter hospital stay in patients who underwent r-eTEP, which the authors attributed to less postoperative pain in this group. This finding suggests that differences in pain perception and recovery protocols may influence the length of hospital stay. One possible explanation for this difference is the use of additional ports in r-TARM/TARUP and injury to the parietal peritoneum, which is highly innervated and particularly sensitive to pain [31]. Only two studies in our analysis reported postoperative pain data using the VAS scale, and although our meta-analysis showed no statistically significant difference, the large heterogeneity and limited number of studies make definitive conclusions difficult. Given the conflicting views in the literature [27, 32], further research is needed to clarify the relationship between surgical procedure, postoperative pain and LOS.

Regarding the recurrence, all studies reported the occurrence of events and no statistically significant difference was found. However, only the study by Olivier et al. [26] provided data on long term follow-up, with an approximate duration of 3 years and no recurrences. The study by Kudsi et al. [27] reports a 90-day follow-up, while Pacheco et al. [25] provide 90-day follow-up data for 40% of the study population. Therefore, only short-term considerations regarding recurrence could be deemed reliable. A factor that may influence recurrence rates is the mesh coverage area, as it can affect tissue engagement and mechanical stability, potentially reducing the risk of recurrence. Our results reveal a notable difference between the two studies reporting this data. Kudsi et al. found that both techniques allowed for mesh placement with similar areas (median size of approximately 300 cm^2), whereas Pacheco et al. reported that r-eTEP enabled the placement of significantly larger meshes (mean size of approximately 700 cm^2). The authors of this latter study attribute this disparity to the wider dissection area achieved with r-eTEP, which extends from the subxiphoid region to the Retzius space and, bilaterally to the EIT Ambivium [33]. In contrast, they state that the dissection area in r-TARM/TARUP is more restricted due to the ipsilateral incision, limiting lateral dissection. Several other studies in the literature reporting experiences with robotic eTEP show mesh areas much closer to those reported by Kudsi et al. [14, 17, 34] In principle, despite differences in access methodology, both techniques should allow for the same extent of dissection within the retrorectus space. A significant discrepancy in mesh size and, consequently, in the dissection area may instead be attributed to the fact that r-TARM/TARUP was performed earlier in the surgeon's learning curve, potentially introducing bias into this data [25]. Further studies with longer follow-up periods are needed to confirm whether these differences translate into significant long-term benefits.

This meta-analysis is limited by the number of studies included and their retrospective design, introducing selection bias and variability in surgical technique, patient selection, and perioperative management. The lack of randomized trials limits the ability to draw definitive conclusions. It should be noted that the anatomical location of seromas (retromuscular vs. subcutaneous) was not reported in the included studies. This lack of granularity limits the ability to fully interpret the clinical significance of this complication, particularly in the r-TARM/TARUP group where higher rates were observed. Significant heterogeneity was observed in operative time and LOS, likely influenced by surgeon experience, institutional protocols, and the learning curve effect, as r-TARM/TARUP was often performed earlier. Differences in mesh coverage area across studies raise concerns about standardization in technique.

Given the existing uncertainty and clinical balance, there is currently insufficient evidence to definitively recommend one technique over the other for robotic abdominal wall surgery. Further high-quality, prospective studies focusing on patient-reported outcomes and long-term recurrence rates are needed to inform surgical decisions and optimize patient care.

AUTHOR CONTRIBUTIONS

FB and RS wrote the paper, AD made figures and tables, GD and FM reviewed the manuscript. All authors contributed to the article and approved the submitted version.

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CONFLICT OF INTEREST

Outside the present study, AD benefitted from a fellowship grant from Intuitive Surgical. Outside the present study, FM has been awarded research funding from Medtronic, Intuitive Surgical, and FEG Textiltechnik. Additionally, FM has received speaking fees from Medtronic, BD Bard, Intuitive Surgical, and WL GORE, as well as consulting fees from Medtronic, CMR Surgical, and has provided expert testimony for Sofradim. FM also serves as a proctor for Intuitive Surgical, Medtronic, and is an advisory board member for Medtronic.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

GENERATIVE AI STATEMENT

The author(s) declare that no Generative AI was used in the creation of this manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontierspartnerships.org/articles/10.3389/jaws.2025.14723/full#supplementary-material

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Comparative Study Between Laparoscopic Transabdominal Preperitoneal Repair Plus and Laparoscopic Intraperitoneal Onlay Repair Plus of Umbilical and Paraumbilical Hernia

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Laparoscopic ventral hernia repair has evolved to minimize the morbidity and recurrence rates associated with traditional open repairs. As laparoscopic expertise grows and newer mesh materials are developed, these techniques have become increasingly accepted due to the advantages of minimally invasive surgery. In laparoscopic hernia repair, mesh placement can either be intraperitoneal or preperitoneal. Intraperitoneal Onlay Mesh (IPOM+) placement brings the mesh into direct contact withabdominal contents, potentially leading to complications such as chronic pain, intestinal obstruction, fistula formation, infertility, and adhesions. To counteract these issues, composite meshes combining polypropylene with inert substances like collagen or cellulose have been introduced, though their high cost remains a challenge. An alternative approach, Transabdominal Preperitoneal (TAPP+) repair, uses a less expensive polypropylene mesh placed in the preperitoneal space, minimizing adhesion formation and mesh-related complications. However, the TAPP+ procedure is technically more demanding and can result in longer operative times. This study compares the safety and efficacy of TAPP+ and IPOM+ techniques in repairing umbilical and paraumbilical hernias, with emphasis on economical aspects.

Keywords: laparoscopic, umbilical hernia, TAPP+, IPOM+, paraumbilical hernia

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INTRODUCTION

The adoption of laparoscopic techniques in ventral hernia repair aims to mitigate the heightened morbidity and recurrence rates associated with traditional open repair methods. Over time, as laparoscopic expertise has grown and newer meshes have been developed, this approach has gained acceptance and has the potential to become the preferred procedure because of the benefits of minimally invasive surgery [1–3]. During laparoscopic repair, the mesh is positioned either intraperitoneally or in the peritoneal/retromuscular spaces. The uniform distribution of intra-abdominal pressure across each square inch of the mesh, rather than along suture lines, as in conventional repair, contributes to the strength of the repair and reduces recurrence rates [1].

In intraperitoneal onlay mesh (IPOM+) placement, direct contact between the mesh and the abdominal contents cannot be avoided. Although a polypropylene mesh is cost-effective and integrates well into the abdominal wall, it triggers significant inflammatory reactions and adhesions. These complications, including chronic pain, intestinal obstruction, fistula formation, infertility, and surgical challenges, have led to the development of new-generation composite meshes [3–5]. These composite meshes combine conventional materials, such as polypropylene, with inert substances, such as collagen or cellulose, reducing bowel adhesions and the risk of fistulas. However, their high costs present challenges. As an alternative, transabdominal preperitoneal (TAPP+) repair using a less expensive polypropylene mesh was proposed [6, 7].

Preperitoneal retromuscular placement of a polypropylene mesh minimises adhesion formation and postoperative complications, leveraging the peritoneum as a protective barrier between the mesh and bowel. This approach ensures effective abdominal wall reinforcement due to immediate mesh fixation under intra-abdominal pressure while also avoiding intraperitoneal mesh-related complications and fixation device issues. Despite its advantages, the preperitoneal approach may require longer operative times for dissection and the development of the pre peritoneal plane for mesh placement [8].

Umbilical hernias are relatively common in Western countries and affect up to 2% of the adult population. Despite its prevalence, the most commonly performed technique for repair is the open anterior approach. This preference is largely due to the ability to make a small incision in the skin and the relatively short duration of the surgical procedure. However, this method may pose a higher risk of hernia recurrence, particularly because it often lacks reinforcement of defects with synthetic materials [1–4].

For small umbilical hernias measuring 1–2 cm, the risk of recurrence is three times higher when mesh implantation is not utilised. The likelihood of recurrence also rises with the size of the hernia orifice and patient's body mass index. Given the increasing number of overweight and obese individuals in the population, the demand for umbilical hernia treatments is expected to rise. These patients, who are at a higher risk of diastasis recti (separation of the abdominal muscles), are also more prone to midline hernia recurrence [5].

Surgeons should consider reinforcing the hernia defect with synthetic mesh if recti divarication is confirmed. Additionally, overweight and obese patients face a higher risk of complications, particularly surgical site infections, which further increase when using an anterior approach with mesh. Laparoscopic hernia repair is recommended to mitigate the risk of infection and prevent recurrence.

This study aims to evaluate the efficiency, postoperative pain management, duration of recovery, and potential complications between Transabdominal Preperitoneal Repair Plus (TAPP+) and Laparoscopic Intraperitoneal Onlay Mesh Repair Plus (IPOM+) for umbilical and paraumbilical hernias, specifically comparing the duration of surgery, postoperative pain and requirement of analgesics, duration of hospital stay, seroma formation and cost of surgery.

METHODOLOGY

Study Design

This prospective observational study was conducted at the Department of General Surgery, Sri Ramachandra Institute of Higher Education and Research, Porur, Chennai. The study period spanned for a period of 3 years and involved patients with umbilical and paraumbilical hernias.

Aim and Objectives

To compare the outcome of Transabdominal preperitoneal repair plus (TAPP+) and laparoscopic intraperitoneal onlay repair plus (IPOM +) of umbilical and paraumbilical hernia with regards to

1. Duration of Surgery
2. Postoperative pain on Day 0, 1, 7, 14 and 30
3. Duration of stay in hospital
4. Seroma formation
5. Cost of Surgery

Study Population

Inclusion Criteria

The study included patients aged more than 18 years who presented with a defect size of 4 cm or less, with single primary umbilical or paraumbilical hernias, and were scheduled for elective surgery. Patients who met the inclusion criteria were enrolled after obtaining informed consent.

Exclusion Criteria

Exclusion criteria included defect sizes greater than 5 cm, multiple defects, recurrent hernias, muscular repairs, and cases requiring emergency intervention or concomitant procedures. Patients who were medically unfit for general anaesthesia were also excluded.

Data Collection

The study involved 50 patients, of which 33 underwent intraperitoneal onlay meshplasty plus (IPOM+) and 27 underwent transabdominal preperitoneal repair (TAPP+).

Basic information such as age, sex, and hernia defect size was recorded for all volunteers. Detailed medical histories, clinical examinations, and relevant investigations were documented and recorded.

Surgical Technique

Patients underwent either transabdominal preperitoneal repair plus (TAPP+) or Laparoscopic Intraperitoneal Onlay Repair Plus (IPOM+). The outcomes of these two techniques were compared based on several parameters.

Outcome Measures

The primary outcomes were as follows.

1. Duration of Surgery: Measured from the start time to the end of surgery in minutes.
2. Postoperative Pain: Assessed on days 0, 1 and 7 using the Visual Analogue Scale (VAS). All patients received standard postoperative analgesia protocol, and additional requirement of analgesics was recorded. Post operative pain was further assessed using VAS on follow-up on day 14, and day 30, and on outpatient basis upto a duration of 3 months postoperatively.
3. Seroma Formation: This is defined as the development of a serous pocket of fluid, and was assessed clinically, in patients who presented with swelling at the site of surgery postoperatively. If present this was managed conservatively with compression dressings.
4. Duration of Hospital Stay: From the time of admission till discharge from the hospital.
5. Cost of Surgery: Includes the mesh and tackers used for the procedures.

Follow-Up and Data Analysis

Patients were followed-up to monitor the duration of hospital stay and postoperative pain. Seroma formation was also clinically assessed and recorded. All collected data were analysed to establish the percentage of outcomes related to TAPP+ and laparoscopic intraperitoneal onlay repair. This analysis aimed to compare the efficacy and safety of the two surgical techniques.

Statistical analysis was performed using SPSS software, version 16.0. Continuous variables were tested for normality using the Shapiro–Wilk test. Variables following a normal (Gaussian) distribution were summarized as mean ± standard deviation (SD), while those not normally distributed were expressed as median with interquartile range (IQR). Categorical variables were presented as frequencies and percentages. Comparisons between the two groups were conducted using the independent samples t-test for normally distributed continuous variables, and the Mann–Whitney U test for non-normally distributed data. Categorical variables were compared using either the Chi-square test or Fisher's exact test, depending on the expected cell counts. A two-tailed p-value of less than 0.05 was considered statistically significant.

Ethical Considerations

This study was conducted in compliance with ethical standards. Informed consent was obtained from all participants and the study protocol was reviewed and approved by the institutional review board.

Surgical Technique

TAPP+: The procedure begins with access to the peritoneal cavity. After establishing a Pneumoperitoneum of 15 mmHg, an overview of the abdominal cavity was also obtained. Adhesions are released. The peritoneum is grasped at least 7 cm from the hernia defect and incised at the left paramedian line, this is done using monopolar scissors. The hernia sac with the herniated tissue is released and retracted into the intra-abdominal cavity. To facilitate the mesh placement over the defect, a pre-peritoneal area of at least 5 cm in all directions is raised and prepared. Primary closure of the hernia defect is performed using non- absorbable barbed sutures. For this step, intra-abdominal pressure is reduced to 8–10 mmHg. Next, the mesh is positioned between the posterior rectus sheath and peritoneum. Like the mesh placement in inguinal TAPP+ repair, no securing sutures to the mesh are necessary. And if the peritoneum is injured during the preparation, these are repaired with absorbable

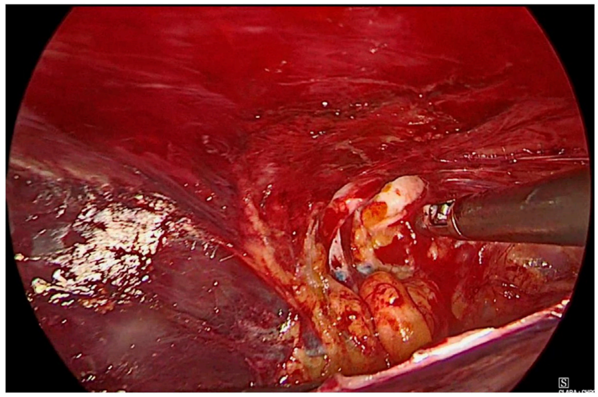

FIGURE 1 | Hernial sac with content.

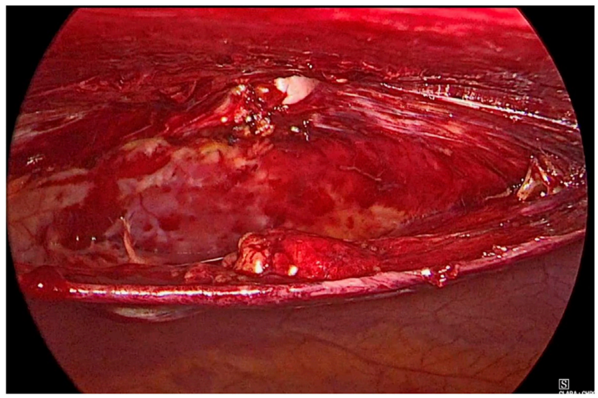

FIGURE 2 | Hernial content reduced.

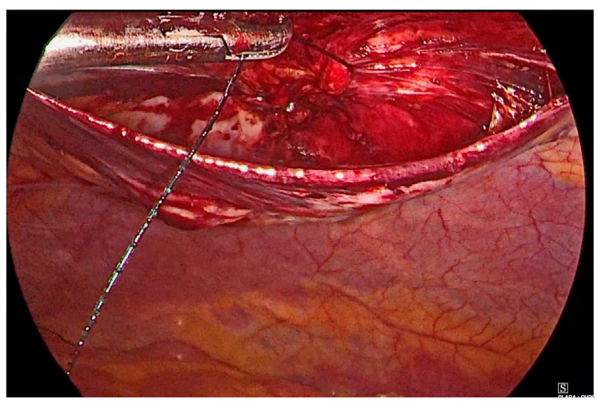

FIGURE 3 | Defect closure using barbed suture.

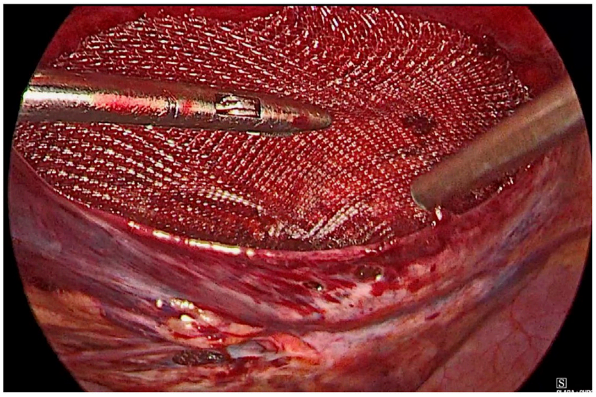

FIGURE 4 | Mesh placed inside pre peritoneal space.

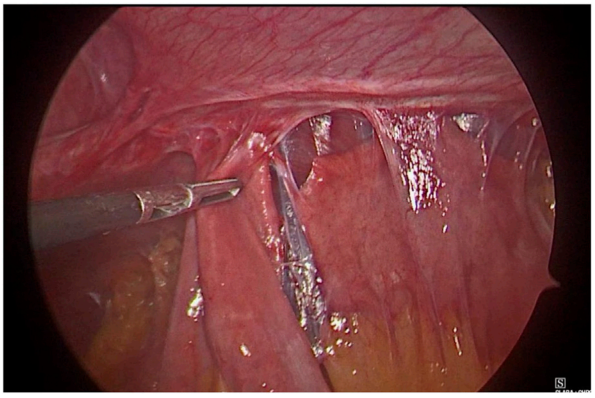

FIGURE 5 | Adhesiolysis.

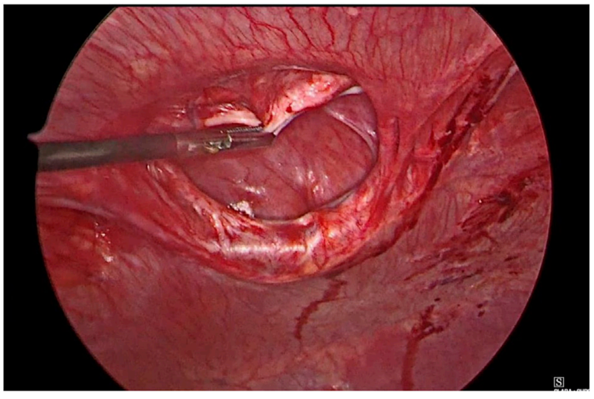

FIGURE 6 | Hernial defect with sac.

sutures. After the mesh is adequately positioned, the peritoneal flap is closed with an absorbable barbed suture or tackers. The trocars are removed under visual and the pneumoperitoneum is reduced (**Figures 1–4**).

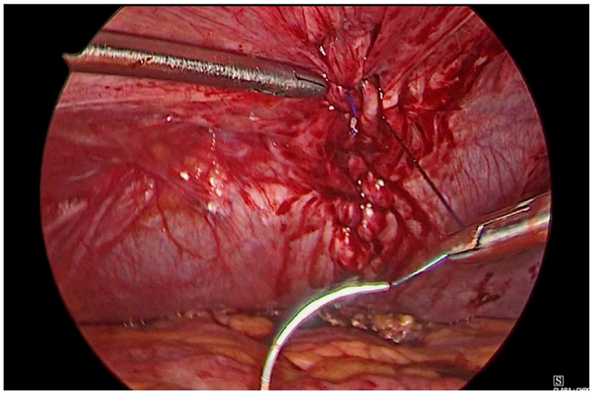

FIGURE 7 | Defect closure using barbed sutures.

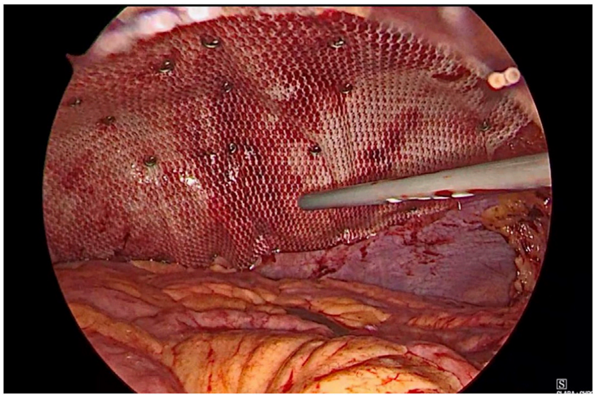

FIGURE 8 | Composite mesh fixation using tackers.

IPOM+: The patient is positioned supine, and pneumoperitoneum is established. A 30° laparoscope is used to access the hernia defect. After 360° inspection of the abdominal cavity, all abdominal wall adhesions, if present, are released. After identifying, the hernia contents are reduced into the abdominal cavity. Structures surrounding the defect and possibly obstructing mesh placement, such as the peritoneum or the umbilical and falciform ligaments, are dissected. The fascial defect is measured under vision. The primary closure of the hernia defect is performed with non-absorbable barbed sutures, constitutng the "plus" technique. The mesh is then deployed and fixed intraperitoneally using absorbable staples in a "double crown" technique, with a minimum of 5 cm overlap to reduce recurrence risk (**Figures 5–8**).

RESULTS

The distribution of patients by age group showed no statistically significant difference between the IPOM+ and TAPP+ groups ($p = 0.376$). In the IPOM+ group, 6.1% were under 30 years,

TABLE 1 | Comparison of various factors between TAPP+ and IPOM+ groups.

Factors assessed	TAPP+ Group	IPOM+ Group	P-value
Duration of surgery (minutes)	70.21	79.26	0.002
Pain score day 0 (mean VAS)	3.48	4.21	0.002
Pain score day 1 (mean VAS)	1.52	1.91	0.002
Seroma	0	6.1%	0.193
Cost of mesh (RS)	7,444.44	27,878.79	<0.0001
Cost of tackers (RS)	15,444.44	22,121.21	<0.0001

24.2% were between 31 and 40 years, 39.4% were between 41 and 50 years, 18.2% were between 51 and 60 years, and 12.1% were over 61 years of age. In the TAPP+ group, 3.7% were under 30 years old, 40.7% were between 31 and 40 years, 22.2% were between 41 and 50 years, 11.1% were between 51 and 60 years, and 22.2% were over 61 years old.

There was a significant difference in the sex distribution between the IPOM+ and TAPP+ groups (p = 0.013). In the IPOM+ group, 75.8% of the patients were female and 24.2% were male. In the TAPP+ group, 44.4% were female and 55.6% were male.

The mean defect size was recorded taking the largest diameter of the defect into consideration, based on which the overlap of mesh required was also decided. The mean defect size was slightly larger in the IPOM+ group with largest diameter of 2.35 cm (SD = 0.92), as compared to the TAPP+ group with 2.06 cm (SD = 0.73), but this difference was not statistically significant on analysis (p = 0.18).

Duration of Surgery

The duration of surgery was significantly longer in the TAPP+ group than that in the IPOM+ group. The mean duration was 79.26 min (SD = 8.55) for TAPP+ and 70.21 min (SD = 11.90) for IPOM+, with a p-value of 0.002 (**Table 1**).

Duration of Hospital Stay

The mean duration of postoperative hospital stay was 1.8 ± 0.6 days in the TAPP+ group and 2.3 ± 0.7 days in the IPOM+ group. The difference was not statistically significant (p = 0.12), suggesting comparable recovery profiles between the two approaches.

Post Operative Pain Scores

Patients were assessed on postoperative days 0, 1, 7, 14 and 30 using the Visual Analogue Scale (VAS). All patients received standard postoperative analgesia protocol, with local anaesthesia infilatration at the port sites intraoperatively, and intravenous paracetamol injections three times a day until postoperative day 1. Any additional requirement of intravenous analgesics was recorded. Chronic pain was further assessed on outpatient basis upto a duration of 3 months postoperatively.

Patients in the IPOM+ group reported higher pain scores on postoperative day 0 than those in the TAPP+ group did. The mean pain scores were 4.21 (SD = 0.86) for the IPOM+ and 3.48 (SD = 0.89) for the TAPP+, with a statistically significant p-value of 0.002 (**Table 1**). On postoperative day 1, pain scores remained significantly higher in the IPOM+ group with a mean of 1.91 (SD = 0.58) compared to 1.52 (SD = 0.58) in the TAPP+ group, with a p-value of 0.012. On postoperative day 7, the pain scores were comparable between the two groups, and thereafter completely resolved by postoperative day 14. There were no cases of chronic pain or neuralgia in either group.

Seroma Formation

Seroma was assessed clinically, in patients who presented with swelling at the site of surgery postoperatively. This was only managed conservatively with compression dressings, and on further follow up, completely resolved. Aspiration was not attempted in any patient developing a seroma. There were no hematomas and none of the patients developed surgical site infections. Seroma formation was not significantly different between the groups (p = 0.193). In the IPOM+ group, 6.1% of the patients developed seroma, whereas none of the patients in the TAPP+ group developed seroma (**Table 1**).

Cost of Mesh and Tackers

The cost of mesh was significantly higher in the IPOM+ group with a mean of 27,878.79 INR (SD = 2011.80) than in the TAPP+ group, with a mean of 7,444.44 INR (SD = 4,660.25), with a p-value of <0.0001 (**Table 1**). Similarly, the cost of tackers was significantly higher in the IPOM+ group with a mean of 22,121.21 INR (SD = 2,858.73) compared to the TAPP+ group with a mean of 15,444.44 INR (SD = 9,254.24), with a p- value of <0.0001 (**Table 1**).

Recurrence and Surgical Site Infections

At the 6-month follow-up, no cases of surgical site infection, seroma or hematoma were observed in either the IPOM+ or TAPP+ group. No short-term recurrences were noted.

DISCUSSION

Studies comparing TAPP+ and IPOM+ for umbilical and paraumbilical hernias have shown that the TAPP+ technique for umbilical hernia repair allows for the placement of a larger mesh than the anterior open approach, aligning more closely with current recommendations. This is particularly beneficial for patients with additional risk factors, such as obesity or diastasis recti. The TAPP+ method places the mesh in the preperitoneal space, avoiding direct contact with the bowel. Although the laparoscopic TAPP+ method is safe, it requires a longer operation time than open methods because of the dissection of the preperitoneal space and the hernial sac. Despite the longer procedure time, there were no significant differences in hospitalisation time, postoperative pain, or early recurrence between the TAPP+ and open ventral patch repair methods. Patients reported better cosmetic results with the ventral patch method but were highly satisfied with both treatments. Further analysis is required to determine the long-term effectiveness of these methods in preventing recurrence [9–11].

A prospective randomised trial by Sarli et.al, involving 115 patients with 148 hernias compared the TAPP+ and IPOM+ techniques for laparoscopic hernia repair. The study found that TAPP+ took significantly longer than IPOM+, but there were no intraoperative complications, conversions to open repair, or postoperative deaths in either group. Postoperative complications occurred in 16.9% of the TAPP+ patients and 25% of the IPOM+ patients, with neuralgia occurring more frequently in the IPOM+ group. Recurrences were reported in 11.1% of IPOM+ hernias but not in TAPP+ hernias. Another study highlighted the advantages of the TAPP+ technique in umbilical hernia repair, allowing for the placement of a larger mesh than anterior approach surgery, which aligns with current recommendations, especially for patients with additional risk factors like obesity or diastasis recti [12].

A comparative study of transabdominal preperitoneal versus intraperitoneal onlay mesh repair for laparoscopic ventral hernia repair found that both techniques are feasible and safe, but the TAPP+ method allows for the placement of a larger mesh and avoids direct contact between the mesh and intestines. This study suggested that the TAPP+ method might be more effective in preventing recurrence, especially in obese patients. These studies suggest that both the TAPP+ and IPOM+ techniques are safe and effective for umbilical and paraumbilical hernias, with TAPP+ offering advantages in terms of mesh size and placement, especially for patients with additional risk factors. However, TAPP+ has a longer operation time than IPOM+, and the choice of technique may depend on the surgeon's experience and individual patient's needs [13].

Our study reports that the analysis of TAPP+ and IPOM+ for umbilical and paraumbilical hernias demonstrated that TAPP+ is associated with lower postoperative pain and reduced costs for mesh and tackers, despite a longer operative time. A similar study finding was also reported by Megas et al., who reported that Ventral-TAPP+ procedures represent an alternative technique to laparoscopic IPOM+ repair to reduce the risk of complications associated with the intraperitoneal positioning of mesh and fixation devices. Additionally, their study showed that the postoperative pain levels, material costs, and hospital stay of the Ventral-TAPP+ cohort were significantly lower than those of the laparoscopic IPOM+ cohort [14].

There were no significant differences in the age distribution between the two groups (p = 0.376), indicating a balanced demographic spread. In the IPOM+ group, 6.1% were under 30 years, 24.2% were between 31 and 40 years, 39.4% were between 41 and 50 years, 18.2% were between 51 and 60 years, and 12.1% were over 61 years of age. In the TAPP+ group, 3.7% were under 30 years old, 40.7% were between 31 and 40 years, 22.2% were between 41 and 50 years, 11.1% were between 51 and 60 years, and 22.2% were over 61 years old. This shows that both techniques were applied across a wide range of age groups without significant bias.

A significant difference in sex distribution was observed, with a higher percentage of females in the IPOM+ group (75.8%) than in the TAPP+ group (44.4%), and a higher percentage of males in the TAPP+ group (55.6%) than in the IPOM+ group (24.2%) (p = 0.013). This gender imbalance could potentially influence outcomes and warrants further investigation. In contrast to our study findings, Megas et al. did not report any significant association between age and sex distribution in either procedure. In addition, the study reported findings comparing laparoscopic IPOM+ and Ventral-TAPP+ procedures. The age of patients in the laparoscopic IPOM+ group (n = 30) was 55.83 ± 11.6 years, while in the Ventral-TAPP+ group (n = 34) it was 54.94 ± 14.70 years, with a p-value of 0.791 [14].

The mean defect size was slightly larger in the IPOM+ group at 2.35 cm (SD = 0.92) compared to the TAPP+ group at 2.06 cm (SD = 0.73), but this difference was not statistically significant (p = 0.18). This indicates that both techniques were used for hernias of comparable size. In unmatched comparisons, the mean hernia size for the laparoscopic IPOM+ group (n = 30) was 3.45 cm^2 (SD = 1.18), whereas the Ventral- TAPP+ group (n = 34) had a mean hernia size of 2.747 cm^2 (SD = 0.98), with a p-value of 0.012. Propensity-matched comparisons showed a mean hernia size of 3.35 cm^2 (SD = 1.17) for the laparoscopic IPOM+ group (n = 27) and 2.98 cm^2 (SD = 0.945) for the Ventral-TAPP+ group (n = 27), with a p-value of 0.206. Few guidelines have proposed the use of the laparoscopic IPOM+ technique for defect sizes up to 10 cm [15, 16].

The diagnosis type did not differ significantly between the two groups (p = 0.297). In the IPOM+ group, 18.2% had paraumbilical hernias and 81.8% had umbilical hernias. In the TAPP+ group, 29.6% had paraumbilical hernias and 70.4% had umbilical hernias. This similarity suggests that the type of hernia did not influence the choice of the surgical technique. Megas et al. reported similar findings, where epigastric hernias were present in two patients (6.7%) in the laparoscopic IPOM+ group and one patient (2.9%) in the Ventral-TAPP+ group. In addition, combined epigastric and umbilical hernias, there were 2 patients (6.7%) in the laparoscopic IPOM+ group and 4 patients (11.8%) in the Ventral-TAPP+ group. Umbilical hernias were reported in 14 patients (46.7%) in the laparoscopic IPOM+ group and 21 patients (61.8%) in the Ventral-TAPP+ group. In the other cohort, 13 patients (48.1%) in the laparoscopic IPOM+ group and 18 patients (66.7%) in the Ventral-TAPP+ group had umbilical hernias [14].

The duration of surgery was significantly longer in the TAPP+ group than in the IPOM+ group, with a mean duration of 79.26 min (SD = 8.55) for TAPP+ and 70.21 min (SD = 11.90) for IPOM+ (p = 0.002). The longer surgery duration in the TAPP+ group could be attributed to the complexity of the procedure, which requires meticulous dissection and mesh placement in the preperitoneal space. A contrasting finding was reported by Megas et al., with a shorter operating time for the TAPP+ procedure than for IPOM+. Regarding operating time, unmatched comparisons indicated a mean duration of 65.33 min (SD = 25.39) for the laparoscopic IPOM+ group and 57.61 min (SD = 18.36) for the Ventral-TAPP+ group, with a p-value of 0.169. In propensity-matched comparisons, the mean operating time was 65.19 min (SD = 26.43) for the laparoscopic IPOM+ group and 58.65 min (SD = 18.43) for the Ventral-TAPP+ group, with a p-value of 0.303 [14]. However, similar to our study, Sarli et al. reported that TAPP+ took a significantly longer duration to complete the procedure than IPOM+ [12].

Patients in the IPOM+ group reported higher pain scores on postoperative day 0 than those in the TAPP+ group did. The mean pain scores were 4.21 (SD = 0.86) for the IPOM+ and 3.48 (SD = 0.89) for the TAPP+ (p = 0.002). On postoperative day 1, pain scores remained significantly higher in the IPOM+ group, with a mean of 1.91 (SD = 0.58) compared to 1.52 (SD = 0.58) in the TAPP+ group (p = 0.012). These findings suggest that patients undergoing TAPP+ experienced less immediate postoperative discomfort, which could be attributed to the less invasive nature of the preperitoneal approach. Megas et al. reported similar findings regarding postoperative pain assessment. Specifically, they analysed the mean pain scores on the first postoperative day (POD0) at rest and during movement using a 0–10 scale system. In the laparoscopic IPOM+ group, VAS scores were 2.28 ± 1.275 at rest and 3.32 ± 1.49 on movement [14].

The ventral-TAPP+ group exhibited lower pain scores with VAS scores of 1.33 ± 1.18 at rest and 2.26 ± 1.75 on movement. Statistical analysis revealed significant differences in pain levels between the two groups (p = 0.008 at rest and p = 0.023 during movement). Furthermore, the study investigated the maximum pain sensation during hospital stay and found significant differences between laparoscopic IPOM+ and ventral-TAPP+ patients. The maximum VAS score was notably higher in the laparoscopic IPOM+ group (3.76 ± 1.45) than in the ventral-TAPP+ group (2.48 ± 1.58), with a p-value of 0.004, indicating a statistically significant disparity in pain experienced by patients undergoing the procedures [14].

Ruíz et al. suggested that ventral TAPP+ may emerge as the preferred approach for incisional hernia repair. Their study, which involved 59 patients, demonstrated minimal complications. Of the seven patients experiencing complications, one case involved recurrence, another presented with chronic pain, and five cases were classified as complications according to the Clavien-Dindo classification. Additionally, they highlighted extraperitoneal hernia repair as a cost- effective technique, a finding corroborated by the results of our study [15]. Seroma formation was not significantly different between the groups (p = 0.193). In the IPOM+ group, 6.1% of the patients developed seroma, whereas none of the patients in the TAPP+ group developed seroma. This indicates that while seroma formation is a concern, it does not differ significantly between the two techniques. Bittner et al. reported that or eventration of the mesh, seromas, recurrences, and non-restoration of abdominal muscle function [9, 10].

The cost of mesh was significantly higher in the IPOM+ group with a mean of 27,878.79 INR (SD = 2011.80) than in the TAPP+ group, with a mean of 7,444.44 INR (SD = 4,660.25) (p < 0.0001). Similarly, the cost of tackers was significantly higher in the IPOM+ group with a mean of 22,121.21 INR (SD = 2,858.73) compared to the TAPP+ group with a mean of 15,444.44 INR (SD = 9,254.24) (p < 0.0001). This significant cost difference is a crucial factor in clinical decision making, especially in resource-limited settings. Megas et al., in their study, reported significantly lower material costs associated with the preperitoneal method (p = 0.001). Additionally, patients in the ventral- TAPP+ group had a notably shorter length of stay, which was attributed to reduced postoperative pain, decreased reliance on pain medication, and, consequently, faster patient mobilisation. This outcome translated to an indirect cost reduction, encompassing savings on both material and personnel expenditures [14].

Kumar et al. [17] presented findings aligning with the advantages of preperitoneal mesh placement. Although the hernia sizes in their study were similar to ours, the operation times for the e-TEP method were nearly twice as long as those for ventral-TAPP+ in our study (107.52 ± 23.44 min versus 57.61 ± 18.36 min). Ventral-TAPP+ provides surgeons with a clearer view of the surgical site, thus facilitating quicker tissue preparation and defect closure. Furthermore, Kumar's study using the e– TEP method for small-to-medium-sized ventral hernias reported two recurrences out of 46 cases, highlighting the advantage of TAPP+ as proposed in our study.

At the 3-month follow-up, no cases of seroma or recurrence were observed in either group, indicating good short-term outcomes for either surgical technique. The ventral-TAPP+ cohort, the most contemporary group, was evident in the follow-up duration, averaging 14.70 months, which was relatively shorter than that of the laparoscopic IPOM+ group. However, this timeframe still allows for 1 year of observation, providing insightful results for a promising technique. Throughout this follow-up period, our findings, along with the existing literature, revealed the absence of hernia recurrence [13, 18, 19].

Implications

These findings suggest that while TAPP+ may involve a longer operative time, it offers the benefits of reduced postoperative pain and lower costs for mesh and tackers. These factors could make TAPP+ a more favourable option in certain clinical scenarios. However, the significant sex imbalance between the groups and its potential impact on outcomes should be considered in future studies. The lower cost associated with TAPP+ also supports its use, particularly in healthcare settings, where cost-effectiveness is a priority.

Limitations

The significant difference in sex distribution between the two groups could have influenced the results, particularly regarding pain perception and recovery. The study was conducted at a single centre, which may limit the generalisability of the findings. Additionally, the follow-up period was limited to 3 months, which may not capture long-term outcomes, such as recurrence rates and chronic pain. Further multicentre studies with longer follow-up periods are required to validate these findings.

CONCLUSION

In conclusion, a comparative study between TAPP+ and IPOM+ for umbilical and paraumbilical hernias demonstrated that

TAPP+ is associated with lower postoperative pain and reduced costs for mesh and tackers despite a longer operative time. Both techniques showed no significant differences in seroma formation and had good short-term outcomes, with no recurrences at 3 months. The choice of technique should consider patient-specific factors, including the potential benefits of reduced pain and the costs associated with TAPP+. Further research is needed to explore the long-term outcomes and account for the impact of demographic differences on surgical results.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving humans were approved by Institutional Research Ethics Committee (For PG Students of Medical College) DHR/ICMR Registration No: EC/NEW/INST/2023/TN/0320. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

KM Conducted the study, contributed to data collection, statistical analysis, and manuscript review. AR Collected data, performed data analysis, and was the primary author of the manuscript. NA Served as the primary operating surgeon, supervised the clinical aspects of the study, and provided critical revisions to the manuscript. All authors contributed to the article and approved the submitted version.

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CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

GENERATIVE AI STATEMENT

The author(s) declare that no Generative AI was used in the creation of this manuscript.

PUBLISHER'S NOTE

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Comparison of Laparoscopic eTEP-RS/TAR and IPOM Techniques for Ventral Hernia Repair

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Background: The laparoscopic intraperitoneal onlay mesh (IPOM) technique has been widely used for ventral hernia repair; however, concerns regarding mesh-related complications have led to the development of alternative approaches. The enhanced-view totally extraperitoneal (eTEP) technique has emerged as a promising alternative, offering improved anatomical restoration and reduced postoperative morbidity. This study compares the clinical outcomes of eTEP and IPOM for ventral hernia repair.

Methods: A retrospective cohort study was conducted at a tertiary referral centre in Thailand. Patients who underwent laparoscopic ventral hernia repair using either eTEP or IPOM between January 2016 and December 2021 were included. Demographic data, hernia characteristics, perioperative variables, and postoperative outcomes were analysed. Statistical comparisons were performed using parametric and non-parametric tests, with a significance threshold of $p < 0.05$.

Results: A total of 70 patients were included, with 32 undergoing eTEP and 38 undergoing IPOM. Both groups were comparable in baseline characteristics, with most cases classified as incisional hernias. The mean operative time was significantly longer in the eTEP group (360 vs. 240 min, $p < 0.001$). Subgroup analysis showed significantly lower postoperative pain scores at 12 and 24 h in the eTEP-RS and eTEP-TAR groups compared to the IPOM group ($p < 0.001$). The mean VAS scores at 12 h were 4 (eTEP-RS), 3 (eTEP-TAR), and 7.5 (IPOM), while at 24 h, they decreased to 2 (eTEP-RS), 2 (eTEP-TAR), and 4 (IPOM). Complication rates were comparable between groups; however, minor bowel injury was reported in some IPOM cases. The one-year recurrence rate was 3.1% for eTEP and 7.9% for IPOM (p = 0.620), increasing to 6.2% and 15.8% at 2 years, respectively (p = 0.275).

Conclusion: Laparoscopic eTEP is a safe and effective alternative to IPOM for medium to large ventral hernias, demonstrating lower postoperative pain and recurrence rates. However, its technical complexity and longer operative time highlight the importance of careful patient selection and surgical expertise. Further prospective studies with larger sample sizes are needed to validate these findings and optimise clinical outcomes.

Keywords: eTEP, enhanced-view totally extraperitoneal, ventral hernia repair, retromuscular repair, IPOM, recurrence

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INTRODUCTION

The laparoscopic intraperitoneal onlay mesh (IPOM) technique has become the standard approach for ventral hernia repair following the seminal work of LeBlanc et al. in 1993. This method has been shown to facilitate enhanced recovery and a reduction in wound-related complications [1, 2] However, it also has some drawbacks. The placement of intraperitoneal mesh can lead to adhesions, fistula formation, and migration, which may cause serious complications. Additionally, mesh fixation methods, while necessary for stability, have been linked to higher levels of postoperative pain and an increased need for reoperations, raising concerns about its long-term effectiveness and patient outcomes [2, 3].

Ventral hernia repair has undergone significant advancements over the past two decades, with minimally invasive techniques increasingly favouring the intraperitoneal onlay mesh (IPOM) approach. More recently, there has been a paradigm shift towards a patient-centred model, prioritising quality of life and mitigating surgery-related morbidity. This evolution encompasses strategies aimed at restoring abdominal wall function, reducing recurrence rates, and minimising postoperative complications, including seroma formation, bulging, and chronic pain [4–7]. To minimise the risks associated with intraperitoneal mesh placement, several minimally invasive techniques have been developed, including the enhanced-view totally extraperitoneal (eTEP) approach, Mini- or Less-Open Sublay Operation (MILOS), and laparoscopic subcutaneous onlay mesh (SCOM) [8–11]. Among these, the eTEP technique has emerged as a widely favoured alternative, providing enhanced anatomical visualisation and a lower incidence of postoperative complications, thereby improving surgical outcomes and patient recovery.

The enhanced-view totally extraperitoneal (eTEP) technique was first introduced in 2012 for laparoscopic inguinal hernia repair and later refined for ventral hernia reconstruction. This approach was developed to mitigate the risks associated with intraperitoneal mesh placement and to optimise surgical outcomes. By positioning the mesh within the retro-rectus space, eTEP enables abdominal wall reinforcement while preserving the integrity of the peritoneal cavity, thereby reducing the likelihood of mesh-related complications [12] The integration of the enhanced-view totally extraperitoneal (eTEP) approach with transversus abdominis muscle release has yielded highly favourable outcomes. This technique promotes the restoration of abdominal wall anatomy and function while minimising the risk of mesh-related complications by preventing direct contact with intra-abdominal organs [11, 13].

The enhanced-view totally extraperitoneal (eTEP) approach is increasingly utilised for abdominal wall hernia repair. However, early evidence remains limited, with most studies focusing on short-term outcomes and the learning curve [11, 14] Current literature predominantly originates from high-volume centres, highlighting the need for multicentre studies to establish long-term efficacy [11, 15]. Despite the shift towards minimally invasive techniques, eTEP remains largely limited among specialised centres. Comparative studies evaluating eTEP against IPOM and IPOM Plus are primarily based on small sample sizes and focus on patients with smaller hernias. Most analyses compare early postoperative recovery and short-term outcomes [16–18].

The adoption of laparoscopic enhanced-view totally extraperitoneal (eTEP) repair is increasing across Southeast Asia; however, the available literature predominantly comprises reports on initial experiences [19]. In Thailand, laparoscopic hernia repair is primarily conducted by minimally invasive surgeons or within tertiary healthcare institutions. As this paradigm shift progresses, further high-quality research is required to develop evidence-based guidelines for the optimal selection between laparoscopic eTEP and intraperitoneal onlay mesh (IPOM) in clinical practice.

This study assesses our initial experience and postoperative outcomes of laparoscopic ventral hernia repair, comparing the enhanced-view totally extraperitoneal (eTEP-RS/TAR) approach with the intraperitoneal onlay mesh (IPOM) technique. All procedures were performed over a five-year period at a single tertiary centre.

MATERIALS AND METHODS

A retrospective cohort study was conducted at Prince of Songkla University, a tertiary referral centre for hernia management in southern Thailand. The study included patients diagnosed with ventral hernia (both primary and incisional) [20] who underwent laparoscopic retromuscular repair using either the enhanced-view totally extraperitoneal (eTEP) approach or the intraperitoneal onlay mesh (IPOM) technique between January 2016 and December 2021. Ethical approval was obtained from the hospital's ethics committee prior to patient enrolment. A total of 70 patients were included and stratified into two groups based on the surgical approach: laparoscopic eTEP and IPOM.

Surgical Technique

eTEP Approach

The enhanced-view totally extraperitoneal (eTEP) procedure was conducted using a standardised dual-surgeon setup. The patient was positioned in a supine posture, with the arms aligned alongside the body. Depending on the hernia location, slight extension of the back or hips was applied to optimise surgical exposure. Access to the retrorectus space was facilitated using a balloon spacemaker, with port placement determined based on the hernia defect size, location, and any previous surgical scars. Midline crossover was performed through an intact anatomical region, and transversus abdominis release (TAR) was undertaken in cases where adequate mesh overlap was unachievable or when defect closure resulted in excessive tension. Preservation of the linea alba and neurovascular bundles was prioritised throughout the procedure. The hernia defect was meticulously repaired, followed by reconstruction of the linea alba using 0 Stratafix^{TM} absorbable sutures, with additional suture reinforcement applied along pre-existing scar lines. The posterior fascial defect was subsequently closed prior to mesh placement, ensuring a minimum overlap of 5 cm in all directions.

Histoacryl® glue was utilised for mesh fixation, and surgical drains were routinely placed in accordance with postoperative management protocols.

IPOM Approach

The conventional intraperitoneal onlay mesh (IPOM) technique was performed by surgeons with a minimum of 5 years' experience in laparoscopic surgery. The patient was positioned in a supine position, with the arms placed bilaterally along the body. The key procedural steps included establishing pneumoperitoneum, performing adhesiolysis, and placing a composite mesh with a minimum overlap of 5 cm beyond the hernia defect, without primary defect closure. The mesh was secured using sutures at 2–4 fixation points, with tackers providing additional reinforcement to ensure stability.

Variables

- Patient Demographics: Age, gender, body mass index (BMI, kg/m^2), American Society of Anesthesiologists (ASA) classification, comorbidities and hernia risk factors, which assesses the patient's overall health status and perioperative risk.
- Hernia Symptoms: The presence of pain, urinary disturbances, obstructive symptoms, and general discomfort.
- Radiological Data: Imaging findings from computed tomography (CT) scans, including hernia classification as per the European Hernia Society (EHS), rectus hernia defect size (cm^2), and abdominis muscle dimensions.
- Perioperative Variables: The assessed parameters included operative time (minutes), total blood loss, placement of drains, mesh type, and mesh area (cm^2).
- Postoperative Variables: Postoperative pain was evaluated using the Visual Analogue Scale (VAS), ranging from 0 to 10, with pain scores recorded at 4 h intervals up to 12 h postoperatively and every 6 h up to 24 h. Multimodal analgesia, comprising oral analgesics, non-steroidal anti-inflammatory drugs (NSAIDs), and opioids, was administered in all cases unless contraindicated. Postoperative complications included wound morbidities, such as surgical site infection, wound dehiscence, haematoma, and symptomatic seroma. Length of hospital stay and hernia recurrence were systematically monitored over a one-year follow-up period.

Statistical Analysis

All statistical analyses were performed using R software (R Core Team, 2024). Categorical variables were summarised as frequencies and percentages and compared between groups using either the Chi-square test or Fisher's exact test, as appropriate. Continuous variables were presented as mean ± standard deviation or median with interquartile range (IQR), depending on the data distribution. Independent t-tests or Mann-Whitney U tests were employed for two-group comparisons, whereas one-way ANOVA was applied for analyses involving three groups. A p-value of < 0.05 was considered indicative of statistical significance.

RESULTS

Patient and Hernia Characteristics

Between January 2016 and December 2021, a total of 70 patients were enrolled in the study, with 32 undergoing the eTEP procedure and 38 undergoing the IPOM procedure. Within the eTEP group, 15 patients underwent eTEP-RS, while 17 underwent eTEP-TAR.

Patient demographics, as summarised in **Table 1**, demonstrated no significant differences between the groups in terms of gender, age, BMI, or ASA classification. The mean (SD) age of the cohort was 62.3 (12.5) years, with a median BMI of 27 kg/m^2 (IQR: 24–32). The majority of patients (67.1%) were classified as ASA class II. Comorbidities, similarly revealed no statistically significant differences between the groups for most variables. Hypertension (46.9% in the eTEP group versus 63.2% in the IPOM group) and dyslipidaemia (46.9% versus 28.9%) were the most frequently reported comorbid conditions. Diabetes mellitus, acknowledged both as a comorbidity and a recognised risk factor for hernia recurrence, was observed in 25.0% of patients in the eTEP group and 23.7% in the IPOM group. Cardiovascular disease was present in 6.2% of patients undergoing eTEP and 2.6% of those in the IPOM group. Notably, liver disease was significantly more prevalent in the eTEP group (18.8%) compared to the absence of cases in the IPOM group (p = 0.007). Other variables, including previous wound infection, smoking status, steroid use, renal insufficiency, and chronic lung disease, did not demonstrate statistically significant differences between the two groups. Incisional hernias were observed in 55 patients (78.6%), while 14 patients (20%) presented with recurrent ventral hernias. With regard to hernia-related symptoms, pain was the most frequently reported complaint, affecting 40.6% of patients in the eTEP group and 42.1% in the IPOM group.

All hernias were classified according to the European Hernia Society (EHS) guidelines [21]. There were no statistically significant differences between the groups in terms of hernia location, size, or mean defect area. The most frequently observed hernia location in both groups was M3 (umbilical), followed by M4 (infraumbilical) and L2 (flank). According to the EHS hernia defect classification, the majority of hernias were categorised as W2 (4–10 cm) in both groups (78.1% in eTEP vs. 78.9% in IPOM, p = 0.763). The median hernia defect size was comparable, with a length of 6.5 cm (IQR: 5.0–8.2) in the eTEP group versus 6.0 cm (IQR: 5.0–8.0) in the IPOM group (p = 0.458) and a width of 5.0 cm (IQR: 5.0–7.0) vs. 5.0 cm (IQR: 4.0–7.0) (p = 0.676). Similarly, the median hernia area was 34.0 cm^2 (IQR: 20.0–56.0) in eTEP and 35.0 cm^2 (IQR: 17.0–53.5) in IPOM, with no significant difference (p = 0.516). The mean rectus abdominis muscle size measured 4.0 ± 1.8 cm (right) and 4.8 ± 1.3 cm (left) in the eTEP group, compared to 4.8 ± 1.6 cm (right) and 4.4 ± 2.0 cm (left) in the IPOM group, with no statistically significant differences (p = 0.058 and p = 0.338, respectively).

TABLE 1 | Patient demographics and hernia classification.

Variables	eTEP (n = 32)	IPOM (n = 38)	*p* value
Patient Demographics:			
Gender, n (%)	8 (25.0)	7 (18.4)	0.707
Male (n = 15, 21.4%)	24 (75.0)	31 (81.6)	
Female (n = 55, 78.6%)			
Age (years), Mean ± SD	62.0 ± 12.7	62.7 ± 12.5	0.820
BMI (kg/m^2), Median (IQR)	29.5 (23.8, 31.0)	27.0 (24.0, 33.8)	0.832
ASA score, n (%)			1.000
I	1 (3.1)	1 (2.6)	
II	21 (65.6)	26 (68.4)	
III	10 (31.2)	11 (28.9)	
Comorbidities and Risk factors:			
Hypertension (%)	15 (46.9)	24 (63.2)	0.261
Dyslipidemia (%)	15 (46.9)	11 (28.9)	0.194
Diabetes (%)	8 (25.0)	9 (23.7)	1.000
Previous chemotherapy (%)	5 (15.6)	3 (7.9)	0.455
Smoking/passive smoker (%)	2 (6.2)	0 (0)	0.205
Steroid therapy (%)	1 (3.1)	0 (0)	0.457
Cardiovascular disease (%)	2 (6.2)	1 (2.6)	0.457
Renal insufficiency (%)	9 (28.1)	4 (10.5)	0.115
Immunosuppression (%)	1 (3.1)	0 (0)	0.457
Chronic lung disease (%)	2 (6.2)	1 (2.6)	0.589
Liver disease (%)	6 (18.8)	0 (0)	0.007
Previous wound infection (%)	5 (15.6)	2 (5.3)	0.234
Hernia Characteristics:			
Symptoms, n (%)			1.000
Asymptomatic	19 (59.4)	22 (57.9)	
Symptomatic	13 (40.6)	16 (42.1)	
Type, n (%)			0.649
Primary	1 (3.1)	0 (0)	
Incisional	24 (75.0)	31 (81.6)	
Recurrent	7 (21.9)	7 (18.4)	
Location (EHS classification), n (%)			0.922
M1	0 (0)	0 (0)	
M2	1 (3.1)	3 (7.9)	
M3	15 (46.9)	18 (47.4)	
M4	7 (21.9)	9 (23.7)	
M5	1 (3.1)	1 (2.6)	
L1	0 (0)	0 (0)	
L2	8 (25.0)	7 (18.4)	
L3	0 (0)	0 (0)	
L4	0 (0)	0 (0)	
Defect size (EHS classification), n (%)			0.763
W1	3 (9.4)	5 (13.2)	
W2	25 (78.1)	30 (78.9)	
W3	4 (12.5)	3 (7.9)	
Hernia Defect Measurements:, Median (IQR)			
Length (cm)	6.5 (5.0, 8.2)	6.0 (5.0, 8.0)	0.458
Width (cm)	5.0 (5.0, 7.0)	5.0 (4.0, 7.0)	0.676
Area (cm^2)	34.0 (20.0, 56.0)	35.0 (17.0, 53.5)	0.516
Rectus abdominis size (cm), Mean ± SD	4.0 ± 1.8	4.8 ± 1.6	0.058
Right	4.8 ± 1.3	4.4 ± 2.0	0.338
Left			

Perioperative Outcomes

Perioperative outcomes are summarised in **Table 2**. The mean operative time was significantly shorter in the IPOM group (240.0 min) compared to the eTEP group (360.0 min, $p < 0.001$). However, there were no statistically significant differences between the groups in terms of blood loss. A total of six types of mesh were utilised. In the eTEP group, both composite and uncoated meshes were employed, with a lower mean mesh area of 225.6 cm^2. Conversely, the IPOM group predominantly utilised composite mesh, which had a larger mean area of 300.0 cm^2.

Subgroup analysis, as outlined in **Table 3**, indicated that the operative time for eTEP-RS remained longer than that of IPOM (320 min vs. 240 min). Blood loss during TAR procedures was minimal, ranging between 5 and 10 mL. In accordance with our institutional protocol, routine drain

TABLE 2 | Perioperative data and mesh characteristics.

Variables	eTEP (n = 32)	IPOM (n = 38)	*p* value
Perioperative data:			
Operative time (min), Median (IQR)	360.0 (247.5, 497.5)	240.0 (180.0, 300.0)	<0.001
Blood loss (mL), Median (IQR)	10.0 (5.0, 16.2)	10.0 (10.0, 18.8)	0.222
Placement of drain, n (%)	30 (93.8)	3 (7.9)	<0.001
Mesh Characteristics:			
Type of mesh used, n (%)			<0.001
Parietex™	2 (6.2)	28 (73.7)	
Physiomesh™	0 (0)	6 (15.8)	
Other composite mesh	2 (6.2)	3 (7.9)	
Versatex™	12 (37.5)	0 (0)	
Prolene mesh™	8 (25)	0 (0)	
Other Polypropylene soft mesh	8 (25.0)	1 (2.6)	
Mesh size, Median (IQR)			0.631
Length (cm)	16.5 (15.0, 24.2)	20.0 (15.0, 20.0)	0.731
Width (cm)	14.5 (11.5, 15.0)	15.0 (10.0, 15.0)	
Mesh area (cm^2), Median (IQR)	225.0 (165.8, 341.2)	300.0 (150.0, 300.0)	0.976

TABLE 3 | Subgroup Analysis of Hernia Repair Techniques: Perioperative data and Mesh characteristic.

Variables	eTEP-RS (n = 15)	eTEP-TAR (n = 17)	IPOM (n = 38)	*p* value
Perioperative data:				
Operative time (min), Median (IQR)	320 (275, 420)	360 (240, 600)	240 (180, 300)	0.002
Blood loss (mL), Median (IQR)	10.0 (7.5, 20.0)	5.0 (5.0, 10.0)	10.0 (10.0, 18.8)	0.107
Placement of drain, n (%)	13 (86.7)	17 (100)	3 (7.9)	<0.001
Mesh Characteristics:				
Mesh type, n (%)				<0.001
Parietex™	0 (0)	2 (11.8)	28 (73.7)	
Physiomesh™	0 (0)	0 (0)	6 (15.8)	
Other composite mesh	2 (13.3)	0 (0)	3 (7.9)	
Versatex™	4 (26.7)	8 (47.1)	0 (0)	
Prolene mesh™	5 (33.3)	3 (17.6)	0 (0)	
Other Polypropylene soft mesh	4 (26.7)	4 (23.6)	1 (2.6)	
Mesh size, Median (IQR)				
Length (cm)	15 (12.5, 16.5)	20 (15, 28)	20 (15, 20)	0.007
Width (cm)	12 (10, 15)	15 (13, 15)	15 (10, 15)	0.415
Mesh area (cm^2), Median (IQR)	169 (150, 240)	280 (225, 450)	300 (150, 300)	0.070

placement was performed in the eTEP group, particularly in eTEP-TAR cases.

Postoperative Outcomes

The postoperative variables are summarised in **Table 4**. In terms of postoperative pain, the IPOM group recorded significantly higher VAS scores at both 12 and 24 h postoperatively compared to the eTEP group (7.5 vs. 4.0 at 12 h and 4.0 vs. 2.0 at 24 h, $p < 0.001$). However, there were no statistically significant differences between the groups regarding hospital stay duration or overall complication rates. Subgroup analysis, as detailed in **Table 5**, further demonstrated that the IPOM group exhibited significantly higher mean pain scores at 12 and 24 h compared to the eTEP-TAR group, with values of 7.5 vs. 3.0 at 12 h and 4.0 vs. 2.0 at 24 h, $p < 0.001$ respectively. Regarding postoperative complications, the overall incidence was low. In the eTEP-RS group, 2 cases (13.3%), and in the eTEP-TAR group, 1 case (5.9%), were reported as symptomatic seromas requiring drainage. No significant surgical site occurrences requiring specific treatment were recorded in either group. In the IPOM group, two cases of serosal tears occurred without full-thickness bowel injury, while three cases of pseudo-recurrence were documented.

Over the one-year follow-up period, no significant differences in hernia recurrence rates were observed between the groups. In the eTEP-TAR subgroup, one recurrence was reported in a complex mirror L incision, where laparoscopic suturing was insufficient for defect closure. The majority of recurrence cases in both the eTEP and IPOM groups were identified at the two-year follow-up, though statistical comparison was constrained by the small sample size.

DISCUSSION

This study presents a comparative analysis of the eTEP and IPOM techniques for ventral hernia repair, emphasising distinctions in perioperative and postoperative outcomes. The findings indicate

TABLE 4 | Comparison of Postoperative Outcomes Between eTEP and IPOM.

Variables	eTEP (n = 32)	IPOM (n = 38)	*p* value
Post operative pain (VAS score), Median (IQR)			
at 12 h	4.0 (3.0, 5.2)	7.5 (5.0, 8.0)	<0.001
at 24 h.	2.0 (1.0, 2.0)	4.0 (2.2, 5.0)	<0.001
Hospital stays (days), Median (IQR)	4 (3, 7)	4 (2, 5)	0.209
Complications, n (%)	3 (9.4)	5 (13.2)	0.719
Recurrent Rate, n (%)			
At 1 year	1 (3.1)	3 (7.9)	0.620
At 2 years	2 (6.2)	6 (15.8)	0.275
Follow up time (months)			0.294
Median (IQR)	17.1 (5.8, 39.4)	10.9 (3.6, 28.3)	
Min-Max	1.08–52.63	0.03–88.44	

TABLE 5 | Subgroup Analysis of eTEP-RS, eTEP-TAR, and IPOM Outcomes.

Variables	eTEP-RS (n = 15)	eTEP-TAR (n = 17)	IPOM (n = 38)	*p* value
Post operative pain (VAS score), Median (IQR)				
At 12 h	4.0 (4.0, 5.0)	3 (3.0, 5.0)	7.5 (5.0, 8.0)	<0.001
At 24 h	2.0 (1.5, 2.0)	2 (1.0, 2.0)	4.0 (2.2, 5.0)	<0.001
Hospital stays (days), Median (IQR)	4 (3.5, 6.5)	4.0 (3.0, 7.0)	4.0 (2.0, 5.0)	0.423
Complications, n (%)	2 (13.3)	1 (5.9)	5 (13.2)	0.780
Recurrent Rate, n (%)				
At 1 year	0 (0)	1 (5.9)	3 (7.9)	0.804
At 2 years	1 (6.7)	1 (5.9)	6 (15.8)	0.605
Follow up time (months)				0.539
Median (IQR)	18.8 (5.7, 38.9)	11.7 (5.9, 38.6)	10.9 (3.6, 28.3)	
Min-Max	1.31–48.23	1.08–52.63	0.03–88.44	

that eTEP was associated with significantly lower postoperative pain scores at both 12 and 24 h compared to IPOM, likely attributable to differences in mesh fixation techniques. Furthermore, eTEP exhibited a lower recurrence rate at both one and two years, reinforcing its efficacy in ventral hernia repair. However, the mean operative time was markedly longer in the eTEP group, reflecting the technical complexity and learning curve associated with the procedure. While complication rates were comparable between the groups, minor bowel injuries were observed in some IPOM cases. These findings suggest that eTEP may offer distinct advantages over IPOM, particularly in reducing postoperative pain and recurrence rates, thereby positioning it as a promising alternative for medium to large ventral hernias.

In Thailand, the increasing prevalence of incisional hernias following previous open surgeries has led to a substantial rise in follow-up cases. Consequently, our study underscores incisional hernia as a significant clinical challenge in southern Thailand. Given the documented advantages of eTEP-TAR, this technique offers a promising approach for optimising surgical outcomes and improving patient care [16, 22, 23]. Laparoscopic eTEP has emerged as a superior alternative to IPOM, particularly for large hernia defects and recurrent cases following previous IPOM repair. Our findings indicate that IPOM was associated with a longer operative time compared to other studies, potentially due to the larger hernia size and the high prevalence of incisional hernias, with recurrence rates reported at 18.4% [24, 25] eTEP-TAR has increasingly superseded IPOM in the management of medium to large hernias, as it enables the placement of a larger mesh area, thereby enhancing surgical outcomes and optimising long-term patient recovery [7, 17, 18, 23, 26] The mean operative time for eTEP-RS and eTEP-TAR was longer than that reported in previous studies, likely reflecting the early learning phase associated with the technique. The eTEP approach requires a highly specialised skill set, encompassing retrorectus space creation, midline crossover, transversus abdominis release (TAR), and laparoscopic suturing, all of which contribute to a steeper learning curve. Consequently, the mean operative times for eTEP-RS and eTEP-TAR were significantly longer than those for IPOM, a trend that is consistent with findings from earlier research [7, 16–18, 22, 27].

Several studies have evaluated postoperative pain following eTEP and IPOM procedures. Existing evidence indicates that mean VAS scores at 12 and 24 h postoperatively were highest in the IPOM group. [4, 7, 18, 22, 27] In our study, although variations in fixation devices were noted, all patients underwent combined fixation, which may have been a contributing factor to increased postoperative pain [4]. Moreover, IPOM was associated with the most prolonged persistence of postoperative pain, a trend that is consistent with our findings [3, 4, 16, 18, 22, 27] Existing literature indicates that mesh fixation techniques may contribute to lower postoperative pain levels in the eTEP-RS and eTEP-TAR groups. This is primarily due to the avoidance of traumatic or aggressive mesh fixation and the strategic positioning of the mesh within the retromuscular layer, which reduces the likelihood of adhesion formation and fistula development [17, 23, 28].

The mean length of hospital stay in the eTEP group was longer than that reported in previous studies [4, 7, 18, 22, 27] This prolonged admission may be attributed to the relative novelty of the eTEP technique at the time of the study. Furthermore, as a significant proportion of patients resided in rural areas, hospitalisation was extended until drain removal and until patients were sufficiently prepared for independent self-care management prior to discharge.

Two cases of serosal injury were identified in the IPOM group, primarily as a consequence of extensive adhesiolysis. However, no major bowel injuries, such as full-thickness perforations, were observed. Postoperative seroma formation has been reported in up to 30% of cases [23, 29]. In our study, seroma was diagnosed in 25% of eTEP-RS cases and 12% of eTEP-TAR cases, which may be attributed to the creation of an extensive retromuscular space during the procedure. Furthermore, the incidence of seroma could be influenced by the choice of mesh, particularly polyester-based variants such as Parietex™ and Versatex™. Mild seroma-related symptoms generally resolved over time without the need for surgical intervention. Based on our observations, seroma regression occurred within 3–5 days in eTEP-TAR cases, and routine drain placement did not appear to prevent postoperative seroma formation. Given the low risk of bleeding associated with the eTEP technique, routine drain placement may not be necessary. Moreover, variations were noted in the administration of prolonged oral prophylactic antibiotics in selected cases; however, no significant postoperative infections or requirements for additional interventions were documented. It is important to acknowledge that the data concerning this practice are limited, due to the inherent constraints and potential inconsistencies associated with retrospective data collection.

Although eTEP presents a steep learning curve, its complication rates were lower than those reported for IPOM, consistent with findings from previous studies [30]. This may be attributed to surgeons' prior experience with open TAR procedures and their proficiency in eTEP for groin hernia repair. Additionally, cadaveric training and a structured dual-surgeon approach have proven invaluable in facilitating the safe adoption of laparoscopic eTEP-TAR, particularly during the early learning phase.

The recurrence rate of IPOM in our study was 7.9% at 1 year and 15.8% at 2 years. Reported recurrence rates for IPOM vary between 3.5% and 24%, depending on factors such as defect closure, mesh type, and fixation technique [31–33]. Several factors may have contributed to the recurrence rate observed in our study, including defect size, the extent of mesh overlap, and the specific type of mesh used. In cases of medium to large defect sizes, IPOM demonstrated a slightly higher recurrence rate compared to eTEP-RS and eTEP-TAR. A review of operative records indicated that recurrences were most frequently observed in W2 (medium) and W3 (large) defect sizes, suggesting that a 5 cm mesh overlap may be insufficient for preventing recurrence, particularly in larger defects, as outlined in **Supplementary Table S1** [34]. Larger defects necessitate increased mesh overlap; however, they also pose challenges, such as shrinkage and folding due to restricted intraperitoneal space, which may compromise mesh integration and long-term durability. At the two-year follow-up, the increased recurrence rate in the IPOM group may be attributed to factors such as tissue remodelling and suboptimal mesh integration. Notably, Parietex™, a non-absorbable polyester mesh with a collagen coating, features a medium to large pore size that facilitates tissue ingrowth; however, experimental animal model studies have associated Parietex™ with an increased risk of shrinkage [35]. Additionally, the recall of Physiomesh™ in 2016, which occurred during the study period, may have contributed to the elevated recurrence rates observed [36]. Furthermore, the fixation method plays a crucial role in long-term surgical outcomes. Evidence suggests that fascial closure can significantly reduce recurrence rates and postoperative bulging, emphasising its importance in enhancing the durability of hernia repair compared to conventional IPOM [28, 37]. Nevertheless, due to the limited sample size, establishing a definitive causal relationship remains challenging.

In low- to middle-income countries, open hernia repair remains widely utilised, often leading to larger defect sizes and, in some cases, hernia formation in atypical anatomical sites. The laparoscopic eTEP-RS and eTEP-TAR approaches provide significant advantages in managing these complex cases, demonstrating superior effectiveness compared to IPOM, as they are associated with reduced postoperative pain, fewer complications, and comparable or potentially improved recurrence rates. [18, 22] A notable advantage of eTEP-RS and eTEP-TAR over IPOM is the ability to employ non-barrier mesh, which serves as a more cost-effective alternative to the composite mesh required for intraperitoneal placement. While eTEP procedures are associated with longer operative durations, a steeper learning curve, and increased technical complexity, their clinical benefits make them a valuable approach for ventral hernia repair [38].

STRENGTHS AND LIMITATION

This study offers a comparative analysis of the enhanced-view totally extraperitoneal (eTEP) and intraperitoneal onlay mesh (IPOM) techniques, addressing the limited literature on their clinical outcomes. A five-year data collection period strengthens the evaluation of long-term patient outcomes and recurrence rates. Conducted in a real-world tertiary care setting, the findings hold broad clinical relevance. However, limitations include a small sample size of laparoscopic eTEP cases due to the introduction of robotic eTEP in December 2021 and the retrospective nature of the study, which may limit the ability to fully assess the impact of specific risk factors on outcomes. To further validate these findings and refine clinical decision-making, future research should incorporate larger cohorts, propensity-matched analysis, and extended follow-up periods.

CONCLUSION

This study indicates that laparoscopic eTEP may serve as a safe and effective alternative to conventional laparoscopic IPOM for medium- to large-sized hernias, offering advantages such as reduced postoperative pain and a lower incidence of mesh-related complications. However, the eTEP technique presents notable technical challenges and necessitates a steep learning curve, requiring a thorough understanding of anatomy alongside advanced surgical expertise. Furthermore, eTEP is associated with a prolonged operative duration compared to IPOM, underscoring the need for meticulous patient selection to optimise outcomes. For small-sized hernias, IPOM plus is a preferable option for experienced laparoscopic surgeons compared to standard IPOM, given its relatively straightforward approach and acceptable recurrence rates. Key modifiable elements, such as defect closure, a comprehensive understanding of mesh properties, and continuous advancements in surgical techniques, play a crucial role in optimising surgical outcomes.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving humans were approved by Human Research Ethic Committee, Faculty of Medicine, Prince of Songkla University. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because the study was a retrospective cohort study utilizing existing medical records, with no direct patient intervention or interaction. The data was anonymized to protect patient privacy, and the study was approved by the institutional review board/ ethics committee.

AUTHOR CONTRIBUTIONS

YA was responsible for study conception and design collected and analyzed the data. SC, KY, SM, and SL provided critical revisions and contributed to manuscript drafting. PW supervised the project and ensured the integrity of the data analysis. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontierspartnerships.org/articles/10.3389/jaws.2025.14176/full#supplementary-material

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CASE REPORT
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Case Report: Robotic PeTEP for Totally Extraperitoneal Repair of Incisional Hernia

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The development of minimally invasive surgical techniques for ventral hernias has significantly progressed, evolving from IPOM and IPOM + to advancements like eTEP/eTEP-TAR. These newer techniques have demonstrated their effectiveness by delivering excellent postoperative outcomes, despite being introduced less than a decade ago. Recreating traditional procedures, which are considered the "gold standard" in ventral hernia surgery, through minimally invasive methods—such as the Rives-Stoppa repair—could represent the next frontier in abdominal wall surgery. This publication focuses on replicating ventral incisional hernia repair using an extraperitoneal approach, as outlined by Todd Heniford, and taking inspiration from the PeTEP technique for primary ventral hernias, whether associated with diastasis recti or not, as described by Hector Valenzuela.

Keywords: PeTEP, incisional hernia extraperitoneal repair, robotic pre-peritoneal repair, robotic PeTEP, incisional hernia robotic extraperitoneal repair

INTRODUCTION

The minimally invasive surgical treatment of ventral hernias has come a long way, from IPOM by Karl Leblanc [1]and IPOM+ by Jan Kukleta [2], eTEP/eTEP-TAR by Belyansky [3]. The latter techniques, although published less than 10 years ago, have proven their effectiveness through excellent postoperative results [4]. The replication of classical operations, which have become the "gold standard" in ventral hernia surgery, using minimally invasive approaches—such as the Rives-Stoppa [5, 6] procedure—may be the key to advancements in parietal surgery. In this context, replicating the ventral incisional hernia repair using an extraperitoneal approach, as published by Todd Heniford [7]and inspired by the PeTEP approach for primary ventral hernias associated or not with diastasis recti, as described by Valenzuela [8, 9], is the focus of this publication.

SURGICAL TECHNIQUE

In the following, I will present the technique for repairing an M1-M3W2 incisional hernia (considering the EHS classification) [10], using the minimally invasive robotic P-eTEP approach.

Abbreviations: eTEP, Enhanced view of totally extraperitoneal; TAR, transversus abdominis release; PeTEP, pre-peritoneal eTEP; IPOM, intra-peritoneal onlay mesh.

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FIGURE 1 | Position of the patient.

Key-stages of the procedure (https://youtu.be/eK1t-ZnADM0):

The positioning of the patient on the operating table is very important. The patient's trunk should be in hyperextension, with the legs supported on stands, to avoid conflict between the robot arms and the patient's thighs (**Figure 1**).

1. Development of the pre-peritoneal space and ports placement.

An optical trocar coupled to an insufflator is used. The insufflation pressure is set to 15 mmHg, and the insufflator is set to maximum flow rate.

Access is achieved by placing the trocar on the midline immediately above the pubic region.

Blunt dissection of the pre-peritoneal space is then performed using the telescope in both the left and right inguinal regions.

The working trocars are placed laterally to the inferior epigastric vessels (**Figure 2**).

2. Dissection of the pre-transversalis/pre-peritoneal space.

The dissection begins in the pre-transversalis space, on the flanks, to avoid penetrating the peritoneum. The progression of the initial dissection from the Retzius space in a cranial direction reveals the arcuate line on each side. This approach avoids dissecting the retro-rectus space, as we do in the retro-muscular eTEP approach. The dissection progresses from lateral to medial. Only after achieving the pre-transversalis space on both flanks does the median dissection begin with the reduction of hernia sacs. The goal is to maintain the working space even in the event of peritoneal opening (**Figure 3**).

Depending on the hernia's location, the dissection may continue retro-diaphragmatic or retro-xiphoid (for M1 locations) to ensure effective coverage of the defect.

3. Measurement of the defect and the dissected pre-peritoneal space.
4. Closing the openings in the peritoneum with absorbable 2/0 or 3/0 barbed suture and reconstructing the linea alba.
5. Placement of the mesh/prosthesis. The mesh covers the entire dissected area (**Figure 4**).

RESULTS AND DISCUSSION

The post-operative course was favorable, with the patient experiencing early active mobilization, reduced pain, and early return of bowel movement. The patient was discharged the day after the surgery, but not more than 20 h postoperatively.

Postoperative follow-up was conducted at 2 weeks and 3 months. The patient did not experience pain or any other issues. Recovery was quick, and they were able to resume physical and sports activities after 1 month without any further problems.

To ensure continued wellbeing and monitor the progress of recovery, it's advisable for the patient to attend an annual check-up, similar to how all patients operated in our center are monitored.

DISCUSSION

Repairing ventral incisional hernias using a totally extraperitoneal approach was first published by Todd Heniford. Recently, Hector Valenzuela published a technique for totally extraperitoneal repair of primary ventral hernias, whether associated with diastasis recti or not, using laparoscopic or robotic approaches. The combination of these two principles has led to the possibility of repairing midline incisional hernias using a totally extraperitoneal approach.

The novelty of the procedure lies in the ability to repair ventral hernias without cutting any musculo-fascial structures by dissecting the layers of the abdominal wall—in particular, the pre-peritoneal plane—closing the hernia defect and placing the parietal prosthesis in this space.

An important detail of surgical anatomy that is extremely useful in this procedure is "the fatty trident" — the distribution of the pre-peritoneal fat described by Miguel Angel Ureña [11]. Only by starting the dissection in the pre-transversalis space on the flanks and progressing toward the midline can we maintain the working space even in the situation of opening the peritoneal cavity. The operation continues with the reduction of hernia sacs, closure of any holes in the peritoneum, restoration of the linea alba, and pre-peritoneal parietal prosthesis placement.

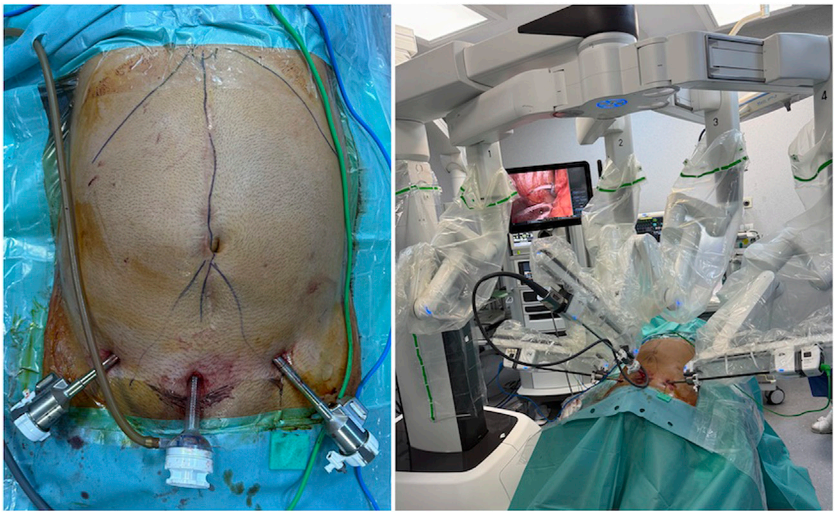

FIGURE 2 | The ports settings.

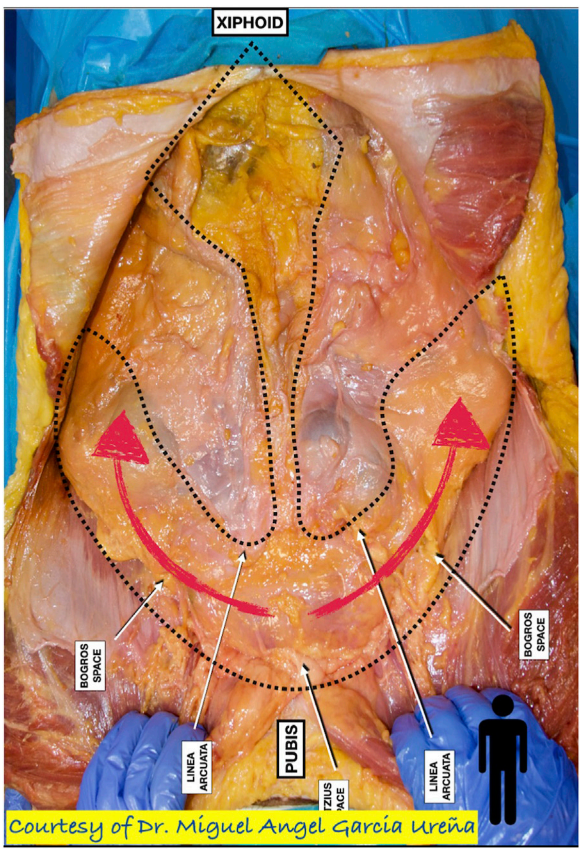

FIGURE 3 | Dissection of the pre-transversalis/pre-peritoneal space (Courtesy of Miguel Angel Ureña).

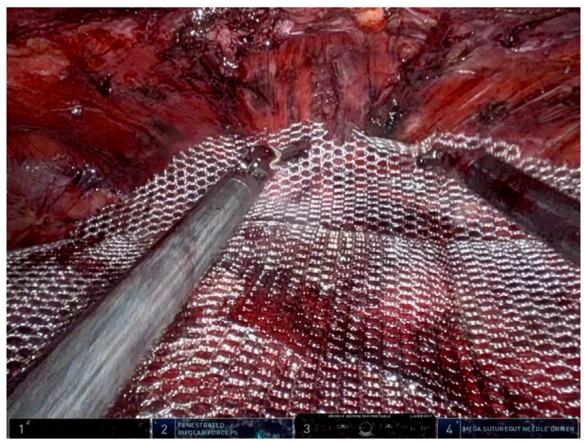

FIGURE 4 | Placement of the mesh.

Although it is a challenging technique and not easy to reproduce without rigorous training, the preperitoneal approach offers many advantages: the restoration of the abdominal wall architecture without needing to cut any structures (muscles, fascia, etc.). The procedure relies exclusively on the dissection of anatomical planes. This leads to other benefits, such as minimal risk of bleeding or nerve damage. Keeping the peritoneum intact serves as a natural barrier between the mesh and the viscera. As a result, postoperative recovery is quick, with very low levels of pain. The difficulty lies in maintaining the integrity of the peritoneum, which is often very thin and fragile. For this reason, dissection must progress from lateral to medial, as previously described.

The minimally invasive preperitoneal approach to ventral hernias has been recently published. Experience is still limited and cannot yet form the basis of practice guidelines. However, the concept of restoring the abdominal wall architecture as close to normal as possible makes this procedure revolutionary. The limitation is due to the difficulty in dissecting a very thin peritoneum, as well as certain patient-specific particulars, such as previous surgeries in the lower abdominal region, which, through scarring, make extraperitoneal access difficult or impossible.

It should be noted that, in the event of a failure of the preperitoneal dissection, there is a backup plan: the retromuscular dissection, similar to eTEP. Of course, these aspects will be presented to the patient for informed consent.

CONCLUSION

If the minimally invasive replication of the Rives-Stoppa operation and TAR (eTEP/eTEP-TAR) was possible having very good results, an advanced technique, like Todd Heniford's, which successfully repaired primary and incisional ventral hernias through a preperitoneal approach without cutting myofascial structures, has been proven by Hector Valenzuela in primary hernias, laparoscopically and robotically repair, and can be successfully extended to incisional hernias as well.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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Comparing Open and Robotic Unilateral Transversus Abdominis Release in Incisional Hernias With a Lateral Component: A Single Center Retrospective Study

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Introduction: Lateral hernias are often more challenging to correct when compared to midline defects, due to the anatomic boundaries of the bony pelvis, retroperitoneum, and costal margin. With the insurgence of robot assisted abdominal wall surgery, these defects have been found more manageable through a minimal invasive repair. In this study, we aim to present our short-term results of incisional hernia repair with a lateral component requiring a unilateral transversus abdominis release, through open surgery versus robot assisted.

Methods: A retrospective analysis was performed of our robotic and open abdominal wall repairs of lateral hernias, where a unilateral transversus abdominis release was performed, between January 2017 and December 2023. Patient, hernia and perioperative details are reported.

Results: 54 patients in the open group versus 10 patients in the robotic group were included. Hernia width and hernia surface area were higher in the open group, but not significant. Operation time was similar between open and robotic procedures. In-hospital complications, surgical site infection and clinical seroma rate during the first 30 postoperative days were similar in both groups. There was a clear difference in length of stay, in favor of the robotic group.

Discussion: In our limited series, a robotic approach seems safe and feasible when faced with large lateral hernias. Short-term results show a shorter length of stay using the robotic approach, with no significant difference in short term complications, specifically SSI-rate. However, conclusions are limited due to the low number of patients and additional studies should be performed to account for long term recurrence and increase included patient number.

Keywords: hernia, robotic abdominal wall repair, TAR, comparative analysis, lateral abdominal wall

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INTRODUCTION

Lateral hernias, as defined by the European Hernia Society [1], are often more challenging to correct when compared to midline defects. Repair is technically demanding due to anatomic boundaries of the bony pelvis, retroperitoneum, and costal margin. They are predominantly secondary to prior subcostal or flank incisions, ostomy sites, traumatic abdominal wall injury, or trocar sites. True congenital lateral wall defects are exceedingly rare, with very few reported cases [2, 3]. These defects can be repaired through both an open or minimally invasive fashion, with mesh placement either intra-peritoneal, pre-peritoneal or onlay, bearing in mind the principles of tension free fascial approximation and adequate mesh overlap. To achieve this, frequently component separation is required, especially if combined with a midline defect. Originally devised by Novitsky in 2012 [4], the transversus abdominis release (TAR) builds seamlessly on the known Rives-Stoppa retromuscular plane, and provides not only medial advancement of the anterior fascia in the midline, but also opens the pre-peritoneal plane for a wide mesh overlap.

The introduction of minimally invasive tools in abdominal wall reconstruction has led to, as in other surgical specialties, reduced length of stay, earlier return to work and fewer wound complications [5]. However, due to its technical complexity and poor ergonomics, laparoscopic repair never found its way into complex abdominal wall repair [6]. With the increased availability of robotics, this has changed, and more and more difficult abdominal wall defects, with large fascial defects and hard to reach areas, are repaired by a robot assisted technique. Other series have already shown that the robotic approach is safe and feasible, showing good short term outcomes [6–10]. However, these are mainly based on midline hernias. To see whether these findings are also applicable for lateral hernias, we retrospectively reviewed our own series.

METHODS

We retrospectively reviewed our robotic and open abdominal wall repairs of lateral hernias, with or without medial component where a unilateral TAR was performed. All the procedures were performed between January 2017 and December 2023, by 3 dedicated hernia surgeons. Informed consent was obtained from all patients. The study was approved by UZ Gent Ethics committee under number BN-09636. Medical records were examined for patient characteristics, hernia characteristics, perioperative and postoperative details, and short-term post-operative outcome. Patient data included age, body mass index (BMI), gender, diabetes, smoking status, presence of pulmonary disease, use of immunosuppressants or corticosteroids, history of aortic aneurysm of collagen related disease and American Society of Anesthesiologist (ASA) class. The included hernia characteristics were prior hernia surgery, hernia defect size (width and surface area), mesh size, type of hernia repair, and hernia location based on the European Hernia Society (EHS) classification. Perioperative details included wound class, mesh type, mesh position, mesh size (width – length – surface area) and intraoperative surgical complications. Post-operative details included length of stay (LOS), in hospital complications and 30-day morbidity (seroma, SSI, recurrence).

The statistical analysis included a univariate analysis performed on categorical variables to elucidate risk factors for hernia recurrence. Chi-squared test was used to determine the significance of each risk factor and to delineate complications by type of repair. Continuous variables were compared using an independent-samples t-test or ANOVA test in cases of non-normal distribution. Significance was defined as $p < 0.05$. Standard deviation was calculated for hernia defect, mesh size, operation time and LOS. Pre-, peri- and post-operative data was prospectively maintained in a RedCap database. Data analysis was carried out with SPSS® Statistics (IBM, Armonk, New York, United States).

The robotic-assisted surgical procedures were performed with the DaVinci Xi or X system (Intuitive Surgical, Sunnyvale, California, United States). The surgical procedure is similar as previously described by others [8].

RESULTS

A total of 54 patients in the open TAR group and 10 patients in the robotic TAR group were included. Patient demographics are summarized in **Table 1**. No significant differences between patient groups were noted regarding age, sex, BMI, smoking status, diabetes, chronic use of corticosteroids, history of aortic aneurysm and collagen related disease. There were significantly more patients with a higher ASA-score in the open TAR-group as well as patient on immunosuppressants.

Hernia characteristics are shown in **Table 2**. No differences between groups were seen regarding hernia width, hernia surface area, prior hernia surgery, EHS classifications, CDC wound class, mesh type or position. Mesh size was significantly larger in the open TAR group. There were no intra-operative complications in the robotic group, there were two bowel lesions and one ureteral injury in the open TAR group.

Outcome data are displayed in **Table 3**. Operation time was similar between open and robotic procedures. In-hospital complications, surgical site infections (SSIs) and clinical seroma rate during the first 30 postoperative days were similar in both groups. There was a clear difference in LOS, where the robotic group had a significant shorter LOS compared to the open group (Open group: 6.94 ± 5.07 vs. Robotic group: 1.50 ± 0.97, $p = 0.001$). Only one major postoperative complication occurred (Clavien–Dindo grade III and above), in the open group. In the 30-day follow-up period there were no mesh removals, nor early recurrences.

DISCUSSION

The impact of minimally invasive approach during abdominal wall repair on LOS has already been shown with the introduction

TABLE 1 | Patient demographics.

	Open TAR	Robot TAR	*p*-value
N	54	10	
Age, years (mean ± SD)	61 ± 12	62 ± 7	0.782
Gender			
Male	31 (57.4%)	5 (50.0%)	0.664
Female	23 (42.6%)	5 (50.0%)	
BMI (mean ± SD)	28.51 ± (4.62)	29.55 ± (5.42)	0.529
ASA-score			
1	0	0	0.056
2	21 (38.9%)	8 (80.0%)	
3	32 (59.2%)	2 (20.0%)	
4	1 (1.9%)	0	
Smoking			
Never smoked	19 (35.1%)	5 (50.0%)	0.304
Ex-smoker (>12 months stopped)	28 (51.9%)	4 (40.0%)	
Occasional smoker	1 (1.9%)	1 (10.0%)	
Daily smoker	6 (11.1%)	0	
Pulmonary disease	9 (16.7%)	1 (10.0%)	0.594
Diabetes			
Type I	1 (1.9%)	0	0.664
Type II	12 (22.2%)	1 (10.0%)	0.378
Immunosuppressants	25 (46.3%)	1 (10.0%)	**0.032**
Corticosteroids (chronic)	2 (3.7%)	0	0.536
History of aortic aneurysm	1 (1.9%)	0	0.664
Collagen related disease	1 (1.9%)	0	0.664

Values marked in bold are statistically significant.

TABLE 2 | Hernia characteristics.

	Open TAR	Robot TAR	*p*-value
N	54	10	
Hernia Width	11.82 ± 6.11	9.83 ± 7.65	0.366
Hernia Surface Area	166.26 ± 141.74	104.79 ± 110.51	0.199
Recurrent Hernia	16 (29.6%)	2 (20.0%)	0.534
EHS Classification[a]			
M1	7 (13.0%)	0	0.228
M2	22 (40.7%)	3 (30.0%)	0.523
M3	18 (33.3%)	3 (30.0%)	0.837
M4	8 (14.8%)	1 (10.0%)	0.687
M5	5 (9.3%)	0	0.316
No midline component	23 (42.6%)	5 (50.0%)	0.546
L1	10 (18.5%)	1 (10.0%)	0.512
L2	33 (61.1%)	7 (70.0%)	0.595
L3	15 (27.8%)	3 (30.0%)	0.886
L4	14 (25.9%)	1 (10.0%)	0.275
CDC[b]			
I	46 (85.2%)	10 (100.0%)	0.429
II	4 (7.4%)	0	
III	4 (7.4%)	0	
Mesh Size			
Width	32.22 ± 8.76	21.90 ± 8.35	**<0.001**
Length	38.52 ± 10.72	23.90 ± 12.07	**<0.001**
Surface Area (cm^2)	1302.19 ± 679.38	597.30 ± 462.27	**0.003**
Intraoperative Complications			
Bowel Lesion	2 (3.7%)	0	0.156
Ureteral Injury	1 (1.9%)	0	0.210

[a]*As stated by Muysoms et al. [1].*
[b]*According to the Center for Disease Control and Prevention (CDC) classification.*
Values marked in bold are statistically significant.

TABLE 3 | Outcome characteristics.

	Open TAR	Robot TAR	*p*-value
N	54	10	
Operation Time (in minutes)	185.15 ± 85.04	160.40 ± 69.26	0.389
Hospital stay	6.94 ± 5.07	1.50 ± 0.97	**0.001**
In hospital complications			
None	41 (75.9%)	10 (100.0%)	0.082
Hemorrage	0	0	
SSI	2 (3.7%)	0	0.536
Prolonged Ileus	6 (11.1%)	0	0.268
Medical Complications	10 (18.5%)	1 (10.0%)	0.512
In hospital Clavien Dindo			
<II	46 (85.1%)	10 (100.0%)	0.621
II	7 (13.0%)	0	
IIIa	0	0	
IIIb	1 (1.9%)	0	
30 Days Clinical Seroma Rate	5 (9.3%)	0	0.316
30 days SSI	5 (9.3%)	0	0.316
Mesh removal	None	None	
30 days Recurrence	None	None	

Values marked in bold are statistically significant.

of laparoscopic hernia repair [11], and our series, together with others [6–8, 12], shows a similar effect of the robotic approach, even in more complex lateral hernia cases. We were unable to detect any differences in SSI- or complication-rate between both groups, and this despite the higher ASA-score in the open group and despite the significant difference in used mesh size. Several other groups have stated a similar trend [6, 8], where a large recent systematic review by Bracale et al. confirmed this finding [13]. However, it should be noted that in their analysis, this effect might be due to inclusion of hybrid procedures. Our SSI-rate in the open group is similar to that reported by the large systematic review by Vasavada et al. [14], and this despite the high rate of immunosuppressant-use in this group. As these procedures were all performed in a liver-transplantation center, we are faced with a high number of incisional hernias after liver transplantation. However, it seems that immunosuppressant-use did not significantly impact our SSI-rate [15].

In contrast to other similar studies [6, 8, 9, 13], our operation time did not significantly differ between the open and robotic group. This might be in part by the fact that all procedures were performed by dedicated (robotic) hernia surgeons, bypassing any learning curve. However, another explanation might be that in the open procedure, the hernia surface area was higher and placed mesh was larger, resulting in a larger and more laborious dissection during these procedures. With only a follow-up of 30 days, no statement can be made about technique superiority regarding recurrence rate.

As our series shows, a robotic approach is safe and feasible when faced with incisional hernias with a lateral component. It provides a shorter LOS, with no difference in short-term peri- and post-operative outcomes. As our SSI-rate does not differ between both group, one can argue, that this lower LOS can be attributed to less post-operative pain, and earlier mobilization, similar to what Carbonell et al proposed during robotic retromuscular ventral hernia repair [16]. However, open hernia repair often involves additional wound drainage, which might be reflected in the larger mesh used, involving larger dissection planes, and therefore this could impede early discharge. A larger prospective study with longer follow-up is needed, to confirm these findings and to be able to compare recurrence rates.

We do acknowledge that our study has several limitations. As this series is a retrospective study, it suffers from the limitations thereof. Furthermore, according to our surgical experience with open and robotic TAR, patient selection bias might be present, which we attribute to an early robotic experience. Furthermore, we suffer from a relative small sample size and unevenly distributed groups. Therefore the true effect on LOS might be overestimated as well as it makes proper cohort matching, as well as sub-analysis of different parameters impossible.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The study was approved by UZ Gent Ethics committee under number BN-09636. Informed consent was obtained from all patients.

AUTHOR CONTRIBUTIONS

Data review and analysis was performed by SV and MA. Manuscript draft by SV. Review and corrections by MA, FB, and HE. All authors contributed to the article and approved the submitted version.

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CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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REVIEW
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Laparoscopic Versus Robotic Ventral Hernia Repair With Intraperitoneal Mesh: A Systematic Review and Meta-Analysis Comparing the Perioperative Outcomes Randomised Controlled Trials

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Objective: The objective of this meta-analysis is to compare the perioperative surgical outcomes and cost-effectiveness of robotic ventral hernia repair (RVHR) versus laparoscopic ventral hernia repair (LVHR) with intraperitoneal mesh.

Methods: Randomised control trials (RCTs) reporting perioperative outcomes and costs in patients undergoing RVHR versus LVHR were selected from medical electronic databases and meta-analysis was conducted in accordance with the guidelines of the Cochrane Collaboration using statistical software RevMan version 5.

Results: Four RCTs on 337 patients reporting perioperative outcomes and cost comparison were included. In the random effect model analysis, the duration of operation was shorter, and cost was lower in the LVHR group but with significant statistical heterogeneity [standardized mean difference (SMD) −48.07, 95%, CI (−78.06, −18.07), Z = 3.14, P = 0.002], [SMD 0.82, 95%, CI (−1.48, −0.16), Z = 2.45, P = 0.01]. However, the variables of hernia recurrence and surgical site complications were statistically similar in both groups without any statistical heterogeneity among the included studies [Risk Ratio (RR) 1.05, 95%, CI (0.22, 4.99), Z = 0.06, P = 0.95], [RR 0.85, 95%, CI (0.48, 1.50), Z = 0.55, P = 0.58].

Conclusion: This systematic review demonstrates that RVHR does not offer any superiority among the compared perioperative variables (Duration of operation, hernia recurrence and surgical site complications) and it is not cost-effective when compared to LVHR. Due to the paucity of the RCTs and significant heterogeneity among the compared variables, a major multi-centre RCT is needed to validate these findings.

Keywords: laparoscopic ventral hernia repair, robotic ventral hernia repair, perioperative outcomes, cost comparison, IPOM

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INTRODUCTION

A ventral hernia is one of the most common presentations among the patients encountered by the surgeons and the general practitioner [1]. In the UK alone around 100,000 abdominal wall hernia surgeries are repaired annually [2] which includes a significant proportion of ventral hernias (VH). The operative management of VH can be challenging due to the diversity of surgical approaches (open repair, laparoscopic repair, robotic repair), techniques of mesh fixation, size of the defect and implantation of a wide variety of biological or synthetic meshes necessary to achieve desired outcomes of minimum hernia recurrence risk and other post-operative complications such as surgical site infection, haemorrhage and enterocutaneous fistula [3]. Prior to the 1990s, VH repairs were primarily done through an open approach [4]. With the advent of the laparoscopic approach, surgeons utilised this approach to reduce the risk of hernia recurrence and postoperative surgical site infections with better health-related quality of life. Nonetheless, the laparoscopic approach is associated with a few drawbacks, primarily poor views due to intra-abdominal adhesions and reduced manoeuvrability of laparoscopic instruments [5].

The first documented use of the robotic approach for surgical procedures was reported in the year 2000 [6]. The use of a robotic approach for the surgical resections of urological malignancies and gynaecological malignancies has been a common practice in the last two decades with variable and diverse outcomes [7, 8]. Published studies have reported favourable outcomes for robotic ventral hernia repair (RVHR) compared to the relatively conventional approach of laparoscopic ventral hernia repair (LVHR) There are several studies reported in the literature demonstrating the superiority of the robotic approach for ventral hernia repair over the laparoscopic approach [7–9]. Due to the extra cost involved in performing the robotic procedures, there has always existed a debate among hernia surgeons about the effectiveness of the robotic approach. Primary variables such as duration of operation, blood loss, bowel injury, length of hospital stay, hernia recurrence, post-operative wound-related and systemic complications may well be similar in RVHR versus LVHR but secondary or tertiary variables like extra cost of the procedure and similar postoperative health-related quality of life seem to be a limiting factor in the use of robotic approach in the management of VH. The objective of this meta-analysis is to compare the perioperative surgical outcomes and cost-effectiveness of RVHR versus LVHR and report.

METHODS

Data Sources and Literature Search Technique

This meta-analysis has been registered with the research registry reviewregistry1726. Electronic databases PubMed, EMBASE, MEDLINE and the Cochrane Library were reviewed and carefully searched. Relevant articles were identified with the use of MeSH terms (Robotic hernia repair, Laparoscopic hernia repair, Ventral hernia repair) and Boolean operators (AND, OR) and PICO approach was used to systematically refine and narrow down the search results. The references were further searched to identify the relevant articles for a detailed analysis.

Trial Selection

The inclusion criteria for the systematic review was the randomised control trials (RCTs) comparing RVHR against LVHR, reporting perioperative outcomes and cost analysis. All trials regardless of their language of publication and number of recruited patients were deemed suitable for inclusion.

Data Collection and Management

The published data was searched and collected by authors independently on a pre-planned standard data extraction sheet. The collected data was scrutinized involving all authors to detect any discrepancy and a mutual agreement was reached about accuracy. The main variables for data collection included were the list of published authors, the country where the RCT was conducted, year of publication, demographic details of the study population, hernia recurrence numbers, duration of operation, surgical site infections, wound seroma, wound break down, delayed wound healing, cost of the laparoscopic procedure and the cost of the robotic procedure.

TABLE 1 | Quality of the included randomised control trials.

Study	Randomization technique	Concealment	Blinding	Intention to treat analysis	Ethical approval	Registration number	Power calculation
Costa 2022 [19]	Computer generated	Sealed envelopes	Single blinded	NR	Approved	NCT03283982	NR
Dhanani 2023 [20]	Computer generated	Sealed envelopes	Single blinded	NR	Approved	NCT03490266	Reported
Olavarria 2020 [21]	Computer generated	Sealed envelopes	Multi-blinded	Reported	Approved	NCT03490266	Reported
Petro 2020 [22]	Block randomisation	Concealed	Single blinded	Reported	Approved	NCT03283982	Reported

NR, Not reported.

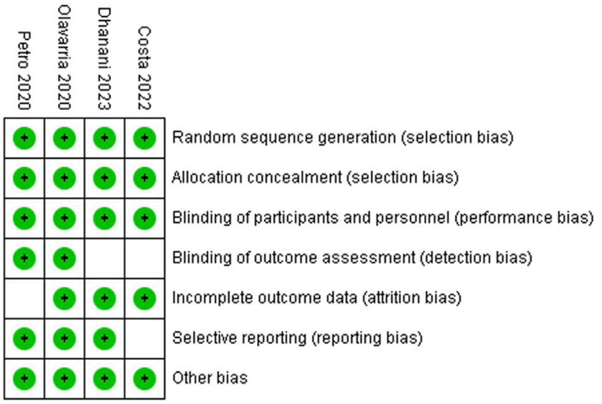

FIGURE 1 | Risk of bias summary: review authors' judgements about each risk of bias item in included trials.

Evidence Synthesis Using RevMan Statistical Software

RevMan version 5.4 (Review Manager 5.4, The Nordic Cochrane Centre, Copenhagen, Denmark) was used for the statistical analysis [10] of the data. In order to present the summated outcome of continuous variables such as cost of the procedure and duration of operation; the standardised mean difference (SMD) was used, and the risk ratio was used to present the summated outcomes of dichotomous data (Wound complication and hernia recurrence). The SMD and RR were calculated and presented with a 95% confidence interval (CI) under the random-effects model analysis [11, 12]. A forest plot was used for the graphical presentation of the results. The statistical heterogeneity was calculated by computing the chi^2 test, with significance set at $P < 0.05$ whereas the quantification of the heterogeneity was tested using the I^2 test with a maximum value of 30 per cent identifying low heterogeneity [13]. For the calculation of the SMD, the inverse-variance method was used and for the calculation of the risk ratio, the Mantel- Haenszel method was used under the random effect model analysis [14, 15]. If standard deviation was not reported in the published article on RCT, it was estimated either from the range or p-value or 0.5 was added in the cell frequency assuming the same variance in both the groups which might not be true in all the cases. The estimate of the difference between both techniques was pooled, depending upon the effect weights in results determined by each trial estimate variance.

Quality of Analysis

The quality of the included RCTs was assessed by using various reported tools including the tool provided by the Cochrane Collaboration [16–18]. The quality of included studies is given in **Table 1** and depicted in **Figures 1**, **2**.

Selected Endpoints for Analysis

The recurrence of VH at the end of the follow-up period was considered the primary endpoint for this systematic review. The criteria to diagnose the VH recurrence included the symptomatic presentation of the patient with a recurrent lump at the site of previous surgery, clinical assessment by a senior surgeon and the reporting of the radiological diagnostic investigation to confirm it. The secondary endpoints were the surgical site complications, duration of operation, length of hospital stay and the cost of LVHR as well as the cost of RVHR.

RESULTS

The primary search of the standard medical databases yielded 22 potential includable studies in this systematic review. After going through the various stages of screening, 18 trials were excluded due to the reasons given in the PRISMA flowchart (**Figure 3**).

Methodological Quality of Included Studies

The reported quality variables in the included RCTs used to assess their strength of published evidence is summarized in **Table 1**.

Author(s): Anurag Singh, Wei H Toh, Muhammad S Sajid
Question: Robotic repair compared to Laparoscopic repair for incisional/ventral hernia
Setting:
Bibliography:

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Robotic repair	Laparoscopic repair	Relative (95% CI)	Absolute (95% CI)		
Wound complications												
4	randomised trials	not serious	not serious	not serious	not serious	publication bias strongly suspected all plausible residual confounding would reduce the demonstrated effect	18/161 (11.2%)	23/176 (13.1%)	**OR 0.83** (0.42 to 1.62)	**20 fewer per 1,000** (from 71 fewer to 65 more)	⊕⊕⊕⊕ High	
Recurrence												
3	randomised trials	not serious	serious	serious	not serious	all plausible residual confounding would reduce the demonstrated effect	9/125 (7.2%)	4/137 (2.9%)	**OR 2.56** (0.73 to 8.95)	**42 more per 1,000** (from 8 fewer to 183 more)	⊕⊕⊕◯ Moderate	
Cost comparison												
2	randomised trials	not serious	serious	serious	not serious	all plausible residual confounding would reduce the demonstrated effect	78	83	-	SMD **0.82 lower** (1.48 lower to 0.16 lower)	⊕⊕⊕◯ Moderate	
Operative time												
3	randomised trials	not serious	not serious	not serious	not serious	all plausible residual confounding would reduce the demonstrated effect	114	122	-	MD **58.86 lower** (68.98 lower to 48.74 lower)	⊕⊕⊕⊕ High	

CI: confidence interval; **MD:** mean difference; **OR:** odds ratio; **SMD:** standardised mean difference

FIGURE 2 | Evidence and summary of findings in accordance with the GRADEpro.

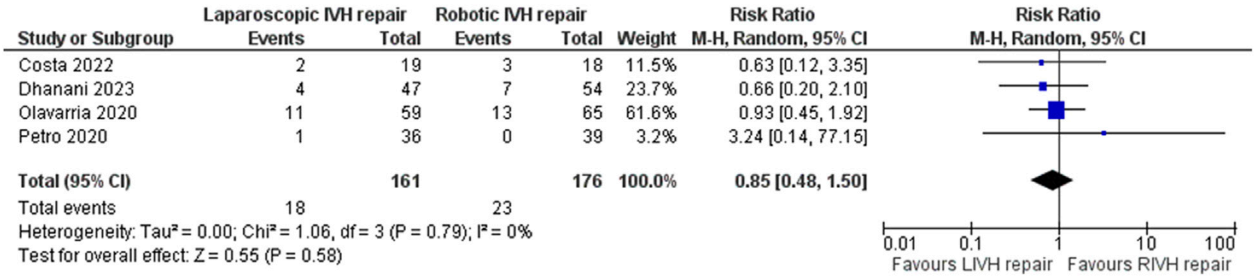

FIGURE 3 | PRISMA flowchart showing literature search outcomes.

TABLE 2 | Demographics of the included studies.

Study	Country	Type	Age (mean ± SD) (Years)		Gender (female %)		Follow up duration
			Laparoscopic	Robotic	Laparoscopic	Robotic	
Costa 2022 [19]	Brazil	RCT	59.7 ± 12.7	65.2 ± 10.8	61.2	68.4	2 years
Dhanani 2023 [20]	United States	RCT	48 ± 13	50 ± 13	63	74	2 years
Olavarria 2020 [21]	United States	RCT	48 ± 12.9	50.1 ± 13.3	63	74	5 years
Petro 2020 [22]	United States	RCT	55 ± 8.18	56 ± 14.84	58	41	30 days

RCT, Randomised control trial; SD, Standard deviation.

TABLE 3 | Treatment protocol among the included studies.

Study	Laparoscopic ventral hernia repair	Robotic ventral hernia repair
Costa 2022 [19]	• Hernia type - incisional hernia following laparotomy for abdominal malignancy • Mesh securing technique - intraperitoneally with 5 cm overlap • Type of mesh - Macroporous mesh • Hernia defect width - (mean ± SD) 8.9 ± 5.6 cm	• Hernia type - incisional hernia following laparotomy for abdominal malignancy • Mesh securing technique - intraperitoneally with a 5 cm overlap • Type of mesh - Macroporous mesh • Hernia defect width - (mean ± SD) 12.1 ± 5.3 cm
Dhanani 2023 [20]	• Hernia type – Primary, recurrent and incisional • Mesh securing technique - intraperitoneally with trans-fascial sutures and circumferential single/double permanent tacks • Types of mesh - mid-density coated polypropylene • Hernia defect width - median (IQR): 3 (1–4.5) (cm)	• Hernia type - Primary, recurrent and incisional • Mesh securing technique - intraperitoneally with running 2-0 barbed PDS circumferentially • Types of mesh - mid-density coated polypropylene • Hernia defect width - median (IQR): 3 (2,5) (cm)
Olavarria 2020 [21]	• Hernia type - Primary, recurrent and incisional • Mesh securing technique - intraperitoneally with trans-fascial sutures and a circumferential double crown of permanent tacks, defect closed with 0 polydioxanone sutures • Types of mesh - mid-density hydrogel adhesion barrier-coated polypropylene • Hernia defect width - Median (IQR): 3 (1–4.5) (cm)	• Hernia type - Primary, recurrent and incisional • Types of mesh - mid-density hydrogel adhesion barrier-coated polypropylene • Mesh securing technique - intraperitoneally with 2-0 PDS, defect closed with locking barbed 0 polydioxanone sutures • Hernia defect width - Median (IQR): 3 (2–5) (cm)
Petro 2020 [22]	• Hernia type - Primary, recurrent and incisional • Mesh securing technique - circumferentially with 4 permanent trans-fascial sutures followed by a double crown of permanent tacks, the defect was closed with the figure of 8 stitches using 0 monofilament permanent suture • Types of mesh - Barrier-coated monofilament polypropylene Hernia defect width - Median (IQR): 4 (2–5) (cm)	• Hernia type - Primary, recurrent and incisional • Mesh securing technique - circumferentially with 3/0 monofilament absorbable self-locking sutures, the defect was closed using 0 monofilament permanent suture • Mesh was secured Types of mesh - Barrier-coated monofilament polypropylene • Hernia defect width - Median (IQR): 3 (2.5–5) (cm)

SD, Standard deviation; PDS, Polydioxanone suture; IQR, Inter-quartile range.

The randomization technique used in the included RCTs was computer generated in all RCTs [19–22]; the concealment was done using sealed envelopes in three included RCTs [19–21]; single blinding was reported in three RCTs [19, 20, 22] and multi-blinding [21] was reported in one included RCT. All included studies reported ethical approval and were registered before the conduction of the trial. Power calculation was done and reported in three studies [20–22].

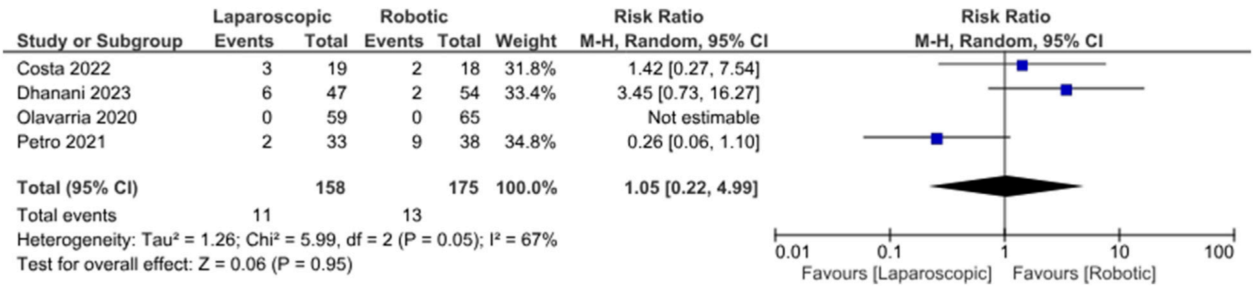

FIGURE 4 | Forest plot showing the risk of recurrence in LVHR versus RVHR group. The outcome is presented as a risk ratio with a 95% confidence interval.

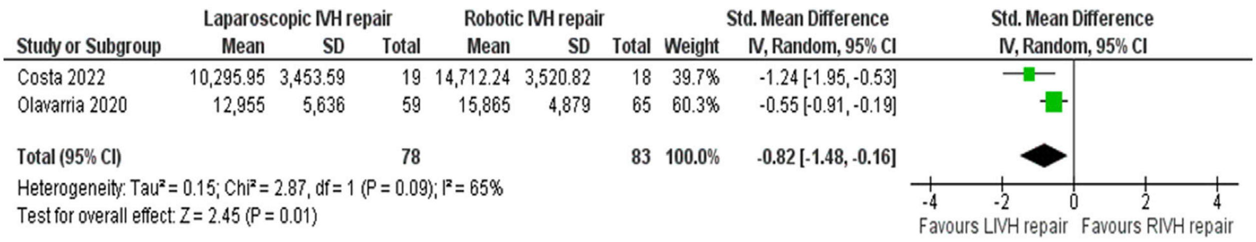

FIGURE 5 | Forest plot showing the risk of surgical site complications in LVHR versus RVHR group. The outcome is presented as a risk ratio with a 95% confidence interval.

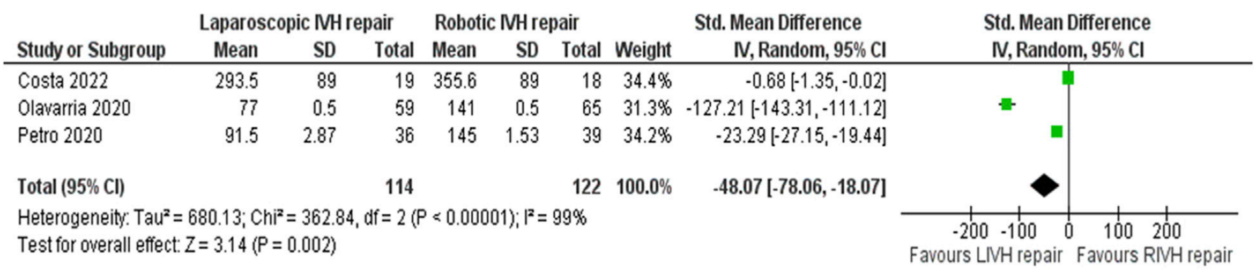

FIGURE 6 | Forest plot showing the duration of operation in LVHR and RVHR cohorts. The outcome is presented as a standardised mean difference with a 95% confidence interval.

Characteristics and Demographics of Included Studies

Four RCTs [19–22] on 337 patients were included to study for perioperative outcomes and cost comparison. A one year-follow up of Petro, et, al; was used to study the recurrence rate as well [23]. One included RCT was reported from Brazil [19] and three reported RCTs were from the USA [20–22]. The characteristics of the included RCTs are presented in **Table 2** and the treatment protocols used in the included studies are presented in **Table 3**.

Primary Outcome Analysis

In the random effects model analysis, the incidence of VH recurrence was statistically similar between groups of laparoscopic versus robotic groups [RR 1.05, 95%, CI (0.22, 4.99), Z = 0.06, P = 0.95; **Figure 4**]. There was moderate heterogeneity among included RCTs (Tau^2 = 1.26; Chi^2 = 5.99, df = 2; (p = 0.05; I^2 = 67%).

Secondary Outcomes Analysis

In the random effects model analysis, the risk of surgical site complications (surgical site infection, seroma formation, wound break down, slow wound healing, failed wound healing) was statistically similar between LVHR group and RVHR group and there was no heterogeneity [RR, 0.85, 95%, CI (0.48, 1.50), Z = 0.55, p = 0.58; **Figure 5**], (Tau^2 = 0.00; Chi^2 = 1.06, df = 3; (p = 0.79; I^2 = 0%). The duration of operation was shorter in patient undergoing LVHR compared to RVHR indicating superiority of laparoscopic approach over robotic approach [SMD -48.07, 95%, CI (−78.06, −18.07), z = 3.14, p = 0.002; **Figure 6**]. However, there was statistically significant heterogeneity among included studies on the calculation of this variable (Tau^2 = 680.13; Chi^2 = 362.84, df = 2;

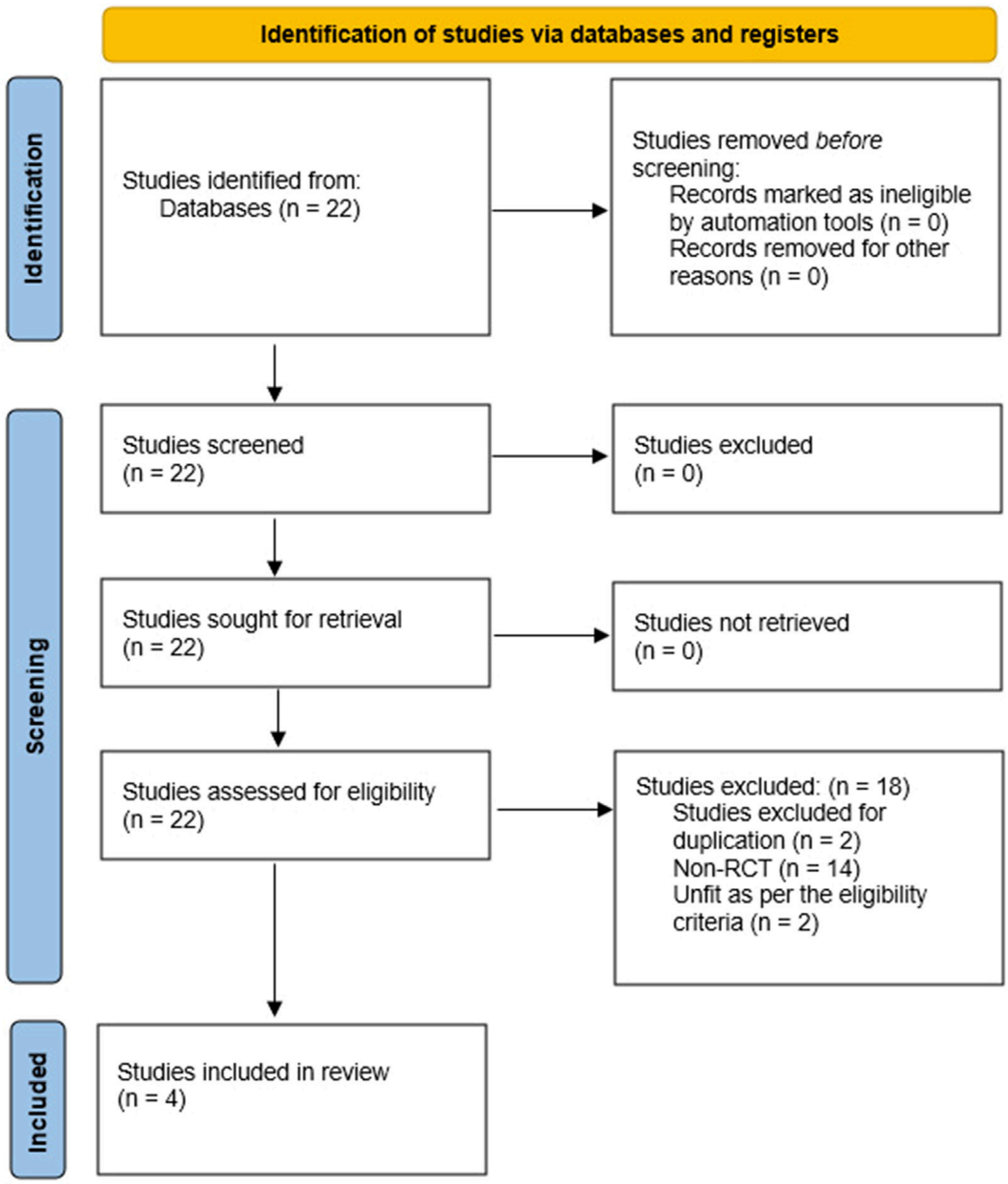

FIGURE 7 | Forest plot showing the operative cost in LVHR and RVHR cohorts. The outcome is presented as a standardised mean difference with a 95% confidence interval.

(p = 0.00001; I^2 = 99%). In addition, LVHR was associated with reduced cost compared to RIVR in the random effects model analysis [SMD 0.82, 95%, CI (−1.48, −0.16), z = 2.45, p = 0.01; **Figure 7**]. However, there was statistically significant heterogeneity among included RCTs (Tau^2 = 0.15; Chi^2 = 2.87, df = 1; (p = 0.09; I^2 = 65%).

DISCUSSION

Based upon the findings of this systematic review, LVHR seems to have the advantage over RVHR in terms of shorter duration of operation, lower cost of the procedure and equivalent efficacy for surgical site complications and hernia recurrence. RVHR failed to prove any clinical advantage over LVHR. Although these are very conclusive findings, however, this conclusion should be taken cautiously because of the paucity of RCTs with fewer patients undergoing VH repair.

Comparison With Existing Literature

A previously published systematic review in 2023 [24] compared LVHR against RVHR and reported patient-related outcome measures. It was concluded that the available data on laparoscopic and robotic primary ventral hernia repair was scarce, and it was highly heterogeneous, thus making it difficult to assess the superiority of either approach in the management of VH. The current study provided evidence generated from the summated outcome of four RCTs and concludes that RVHR does not seem to have any proven clinical advantage over LVHR. Another published systematic review in 2020 [25] reported perioperative outcomes in a group of patients undergoing LVHR versus RVHR. The results of this review suggested that RVHR maintained some of the advantages of laparoscopic surgery and might provide an additional advantage of reduced hernia recurrence risk. This may well be explained by the ability to perform a more complex hernia repair with robotic assistance secondary to the ease of closure of the fascial defect. Whereas the current study analysed RCTs only and failed to demonstrate the previously reported advantage of the robotic approach. Several comparative trials have been reported with diverse outcomes [26, 27] and without any conclusive recommendations.

Limitations

There was significant methodological and clinical diversity among included trials indicating heterogeneity. This study is based upon the findings of four RCTs on 337 patients and due to this reason, these findings cannot be generalised. The inclusion criteria were also different and patients with incisional hernia and primary ventral were jointly recruited in both limbs of trials which can potentially contribute to the biased outcome. The size of the hernia defect was reported in all studies, but it was of different size. The duration of follow-up in included RCTs varied from 1 year to 5 years which seems to be insufficient for the accurate estimation of the recurrence rate of hernia. Power calculations and intention to treat analysis were also not reported in the two included RCTs.

Future Implications

A major multicentre RCT is mandatory to validate the findings of the current study before drawing a stronger conclusion about the advantages of the robotic approach in the management of VH. Trials on primacy ventral hernia and incisional hernia should be conducted separately to assess which group of hernia can benefit more from either approach. The patient recruitment criteria should be strict in terms of hernia defect size, type of mesh used, and technique of mesh fixation used to reduce methodological diversity in the RCTs. Trials should be conducted using a gold standard radiological diagnostic tool to detect clinical and subclinical recurrence for accurate measurement of primary outcome.

AUTHOR CONTRIBUTIONS

(I) Conception and design: AS, MS, and WT; (II) Administrative support: AS, WT, GK, and MB; (III) Provision of study materials or patients: MS, GK, and NE; (IV) Collection and assembly of data: AS, GK, and WT; (V) Data analysis and interpretation: AS, MS, WT, and MB; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors. All authors contributed to the article and approved the submitted version.

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CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

PUBLISHER'S NOTE

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Robot-Assisted Extraperitoneal Ventral Hernia Repair—Experience From the First 160 Consecutive Operations With Lateral eTEP and eTAR Techniques

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Introduction: There is a growing consensus on the benefits of retro-muscular (RM) mesh positioning, highlighted by its recommendation in the latest edition of EHS guidelines. The eTEP method has facilitated minimally invasive hernia repairs with retro-muscular mesh placement. With the increasing availability of robotic systems, there has been a corresponding increase in robotic adaptations of minimally invasive techniques involving retro-muscular mesh placement.

Materials and Methods: All patients who underwent robotic ventral hernia repair using the lateral extraperitoneal eTEP technique at Kempten Hospital between September 2019 and December 2023 were includes in the study. Preoperative characteristics, perioperative parameters, postoperative parameters, and hernia-specific parameters, were retrospectively analyzed using the hospital information system.

Results: 160 patients were operated using a lateral approach eTEP technique during the observation period, 111 (69.38%) for incisional hernia repair and 49 (30.63%) for primary hernia repair. 43 cases required TAR (30 unilateral TAR and 13 bilateral TAR). 139 patients had a medial (86.98%), seven patients (4.14%) a lateral and 14 patients (8.88%) a combined hernia defect. The median operative time was 143 min (range: 53 min–495 min). The median length of hospital stay was 3 days (range: 2–16). There was one intraoperative complication. The postoperative complication rate was 6.25% (10 patients), with 1.72% (2 patients) requiring reoperation. Sonographic follow-up examinations revealed seromas in 5 patients, with 4 located in the retromuscular mesh space and 1 in the former hernia sac. None of these seromas required surgical intervention.

Conclusion: The "lateral approach" of robotic eTEP provides a safe surgical method for treating ventral hernias using minimally invasive techniques and mesh augmentation in the retro-muscular space. Further studies are necessary to compare extraperitoneal with transperitoneal methods.

Keywords: eTEP, robotic abdominal wall repair, eTAR, retromuscular mesh repair, extraperitoneal mesh placement

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INTRODUCTION

There is increasing consensus regarding the advantages of retro-muscular (RM) mesh positioning, to the point that it has been recommended in the latest edition of guidelines (EHS Guidelines 2023) [1]. In recent years, the conventional approach to minimally invasive hernia repair has been predominated by procedures involving intraperitoneal mesh placement. However, the latest registry analyses conducted across several European nations reveal a relevant decline in the adoption of this method [2, 3]. Concurrently, there has been a notable increase in the development of innovative minimally invasive methods for retro-muscular mesh implantation. This shift is largely driven by the demonstrated benefits of positioning mesh within the retro-muscular space, as outlined in numerous meta-analyses [4–6].

Belyansky et al. [7] first introduced the enhanced-view totally extraperitoneal (eTEP) method as a technique for minimally invasive hernia repair, which includes the placement of mesh in the retro-muscular space. Similarly, the endoscopic mini or less open sublay hybrid technique, published by Schwarz et al. [8] and the laparoscopic transperitoneal sublay mesh repair published by Schroeder [9], have emerged as elegant and promising approaches combining the benefits of minimally invasive surgery with the proven efficacy of retro-muscular mesh positioning.

Unfortunately, these surgical procedures turned out to be technically demanding when performed in a traditional endoscopic or laparoscopic setting. Particularly at the start of the learning curve, they have proven to be very time-consuming, which has led to limited adoption. As a result, these techniques have been primarily performed in select specialized centers.

Alongside the increasing availability of robotic systems, there has been a rise in robotic adaptations of minimally invasive techniques invloving retromuscular mesh placement. These robotic approaches have helped overcome the technical challenges, such as reduced dexterity and precision, often encountered with conventional "straight-stick" laparoscopy. Notable among these adaptations is the transabdominal retromuscular umbilical prosthetic hernia repair (TARUP) technique, introduced by Muysoms et al. [10], and the totally extraperitoneal robotic eTEP (r-eTEP) method outlined by Belyansky et al [11].

Since 2019, our hospital has been applying a robotic system in the treatment of hernias [12]. Robotic operative techniques quickly became our standard approach for ventral hernia repair when mesh implantation was indicated. Within 2 years, the proportion of minimally invasive hernia repairs had risen to 87.5%, with nearly 95% of these procedures achieving extraperitoneal mesh placement.

During the initial phases of the learning curve, transperitoneal procedures such as ventral TAPP and TARUP were used. However, already within the first year, the extraperitoneal eTEP approach for retrorectus repair has become the predominant method for treating ventral hernias. This technique has since become the standard procedure for retromuscular mesh placement, even for more complex cases requiring bilateral TAR.

This study aims to demonstrate the safety and feasability of the extraperitoneal eTEP technique with lateral trocar placement in ventral hernia repair through a retrospective analysis of perioperative outcomes.

MATERIALS AND METHODS

All patients who underwent a robot-assisted eTEP procedure between September 2019 and December 2023 at Kempten Hospital were retrospectively analyzed using data retrieved from the hospital's information system.

During this period, with a few exceptions, nearly all patients indicated for retromuscular or retrorectus mesh placement underwent surgery via the eTEP technique. Exceptions where open surgery was required included emergency cases, hernias with a defect diameter of more than 15 cm, and cases involving a loss of domain. Patients undergoing simultaneous abdominal wall reconstruction were also treated using the open technique. The reasons for opting for a transperitoneal approach during robotic retromuscular repair were either simultaneous intraperitoneal procedures or a recurrence situation where a retromuscular mesh obstructed access to the retrorectus space. Patients with a rectus muscle diameter of less than 5 cm were operated on using the eTEP technique with caudal trocar positioning, as the retrorectus space was too narrow for lateral trocar placement. The IPOM technique was only applied in rare cases, usually in older, multimorbid patients.

All procedures were performed by two surgeons who had prior experience with endoscopic eTEP repair before the introduction of robotic surgery. Both surgeons had exclusive access to the robot for hernia surgery, therefore their learning curves were included in the study.

The following parameters were retrospectively examined: preoperative characteristics (gender, age, ASA status, height, weight, body mass index [BMI]), perioperative parameters (operative time, mesh size, number of meshes, intraoperative complications), postoperative parameters (complication rate, reoperation rate, length of hospital stay), and hernia-specific parameters (type of hernia, hernia size, hernia location). Perioperatively, all patients received antibiotic prophylaxis and postoperatively received thrombosis prophylaxis. Hernia findings were classified according to the European Hernia Society (EHS) classification [13]. Mesh position was designated based on Parker's classification [14]. The complexity of the procedures was categorized according to the criteria outlined in the publication by Slater et al. [15]. Written consent to participate in the Herniamed quality assurance study was obtained from all patients [16].

Operative Technique

All procedures were performed using the DaVinci-X system (Intuitive Surgical, Sunnyvale, CA, United States). The "lateral approach" is described as follows: patients are positioned in a slightly extended supine posture. The side of access is determined based on the width of the rectus sheath, presence of scars, and any additional hernia findings (e.g., inguinal or lateral hernias). The

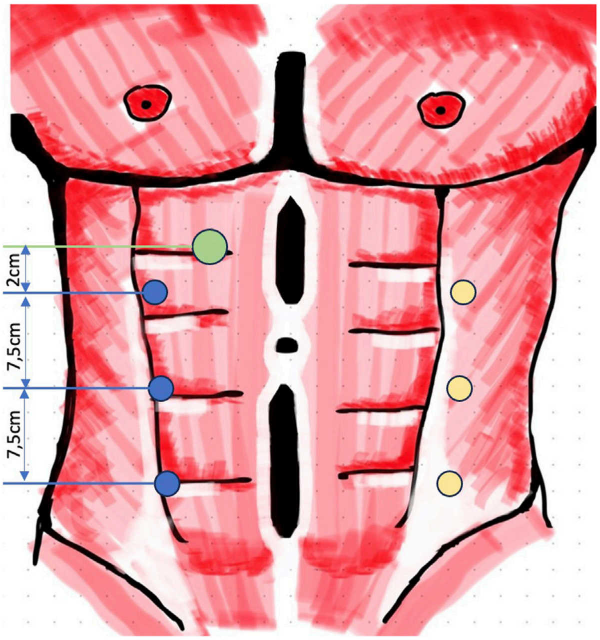

FIGURE 1 | Trocar positioning lateral r-eTEP (green, 12 mm access port; blue, 8 mm robotic ports; yellow, second portline for bilateral TAR with double docking).

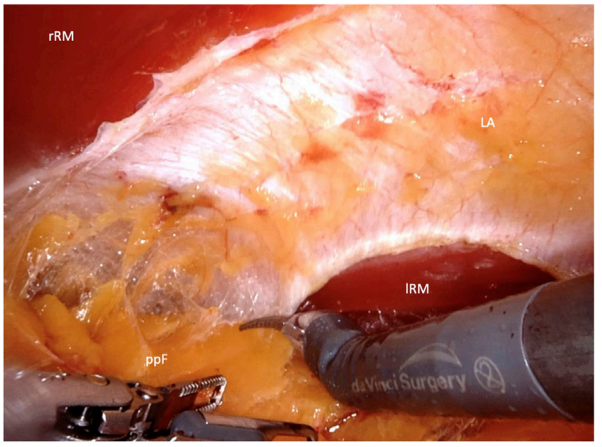

FIGURE 2 | Crossover through the midline in the upper abdomen (rRM, right rectus muscle; lRM, left rectus muscle; LA, linea alba; ppF, preperitoneal fatty tissue).

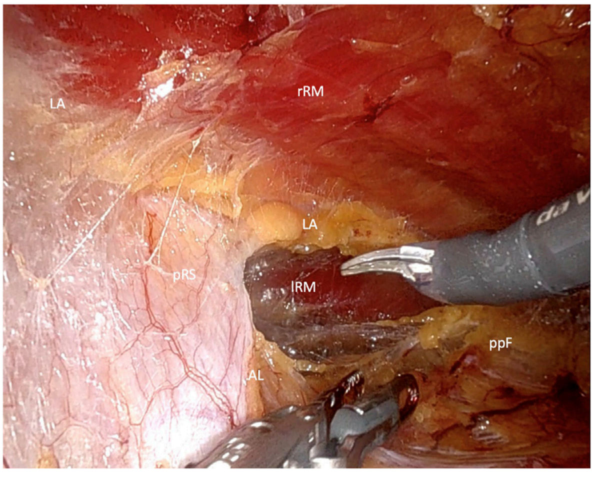

FIGURE 3 | Crossover through the midline in the lower Abdomen (rRM, right rectus muscle; lRM, left rectus muscle; pRS, posterior rectus sheath; LA, linea alba; AL, arquate line; ppF, preperitoneal fatty tissue).

robotic patient cart is placed on the opposite side of the selected access. If double docking is not required, the patient's arm on the robot-facing side is extended, while the other arm remains aligned with the body. Double docking was only necessary in cases of bilateral transversus abdominis release (TAR) or simultaneous bilateral inguinal hernia repairs. Preoperatively, anatomical landmarks, such as the rib cage, pelvic bones, rectus sheath boundaries, and hernia or scar locations, are marked. In the upper abdomen, a 12-mm optical port is used to access the retrorectus space (**Figure 1**), with the robotic 8-mm camera already in use for this entry. No additional laparoscopic system is necessary. Balloon dissection can be avoided, as blunt dissection with the camera suffices to create space for the placement of the first 8-mm DaVinci port in the mid-abdomen, medial to the lateral border of the rectus sheath.

After placement of the first 8-mm DaVinci port, endoscopic dissection of the ipsilateral retrorectus space is continued. Two additional 8-mm DaVinci ports are then inserted along the same line in the upper and lower abdomen. The DaVinci X system is subsequently docked from the opposite side of the patient. The crossover maneuver into the contralateral retrorectus space can be initiated either in the upper abdomen (**Figure 2**) or the lower abdomen (**Figure 3**).

In the upper abdomen, a longitudinal incision is made in the posterior rectus sheath, slightly lateral to its transition into the linea alba. This exposes the preperitoneal fat of the falciform ligament, which is carefully dissected from the linea alba. Dissection is carried out to the opposite side, creating a space between the linea alba and preperitoneal adipose tissue unil the contralateral rectus muscle is visualized through the posterior rectus sheath. A similar longitudinal incision is then made on the contralateral side, lateral to the linea alba.

In the lower abdomen, below the arcuate line, where the posterior rectus sheath is absent, the crossover maneuver is completed by dividing the connective tissue of the linea alba that separates the retrorectus spaces on both sides. During this midline dissection, the hernia is mobilized and repositioned. The dissection of the contralateral retrorectus space continues up to the lateral border of the rectus sheath, while preserving neurovascular bundles under direct visualization. If required, a unilateral single docking or bilateral double docking transversus abdominis release (TAR) may be performed (**Figure 4**).

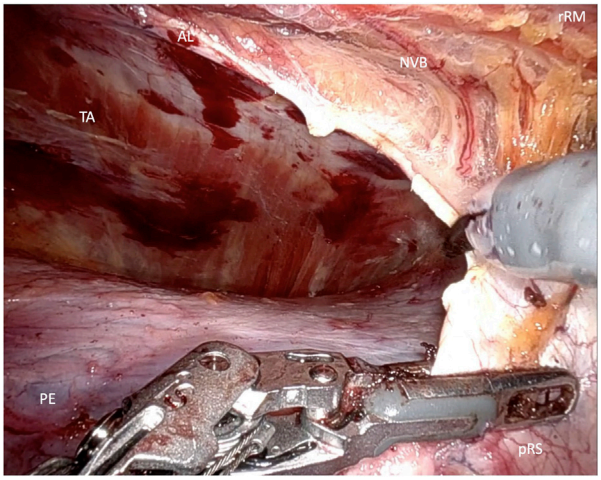

FIGURE 4 | Transversus abdominis release (rRM, right rectus muscle; pRS posterior rectus sheath; AL, arquate line; NVB, neuovascular bundle).

Any peritoneal perforations are meticulously closed to prevent contact between mesh and the intestine. The anterior rectus sheath is reconstructed with absorbable barbed sutures, and rectus diastasis correction, if necessary, is done concurrently. The dissected space is then measured, and a large, uncoated synthetic mesh is introduced through the optical trocar, ensuring it overlaps all trocar sites. A drainage tube is placed in the retrorectus space, and an abdominal binder is applied to the patient at the conclusion of the procedure.

Preoperative Diagnostics and Preparations

All patients with incisional hernias underwent a preoperative CT scan. In cases where a W3 defect was present, preconditioning with botulinum toxin was performed 4 weeks prior to surgery. The indication for a TAR procedure was determined preoperatively based on the Carbonell Index, which considers the ratio of the rectus muscle diameter to the hernia defect diameter. For primary hernias, an ultrasound examination of the abdominal wall was conducted.

Postoperative Follow-Up

All patients who underwent robotic surgery were scheduled for a follow-up appointment in our outpatient clinic approximately 6 weeks postoperatively. During this visit, patients received a comprehensive assessment of their general wellbeing, as well as a physical and an ultrasound examination. Special attention was paid to retro-muscular seromas and hematomas, as well as local wound complications.

RESULTS

A total of 160 patients underwent ventral hernia repair using the lateral approach eTEP technique. The median age was 62 years (range: 26–87), with 97 male patients (60.63%) and 63 female patients (39.37%). The median ASA score was 2 (range: 1–3). Patients had a median height of 1.73 m (range: 1.52 m–2.06 m) and a median weight of 89.5 kg (range: 50 kg–145 kg), resulting in a median BMI of 30 (range: 22–45) (see **Table 1**).

The median operative time was 143 min (range: 53 min–495 min). The median length of hospital stay was 3 days (range: 2–16). Among the cases, 111 (69.38%) were incisional hernias and 49 (30.63%) were primary ventral hernias. The median mesh size was 540 cm^2 (range: 225–1,350), with a median hernia defect size of 25 cm^2 (range: 2.25–375). This results in a median defect-to-mesh ratio (MDR) of 21 (range: 2.33–150). 9 simultaneous inguinal hernias were treated with additional mesh during the operation. In 5 cases it was a unilateral inguinal hernia, in 2 cases it was a bilateral finding. 139 patients presented with a medial hernia defect (86.98%), seven patients (4.14%) presented with lateral hernias, and 14 (8.88%) presented with combined hernias. A total 43 cases required TAR for complete fascial closure (30 unilateral TAR and 13 bilateral TAR) out of which 22 patients suffered a medial hernia defect. All 21 patients with lateral or combined hernias needed TAR to close the defect and ensure a sufficient mesh overlap. Complete fascial closure was obtained in all cases (see **Table 2**). All TAR procedures were preoperatively indicated based on the ratio of rectus muscle diameter to hernia defect diameter. An unplanned intraoperative extension of the procedure to include a TAR was not necessary.

There was one intraoperative complication involving a patient with a previous skin transplantation after open abdomen, where multiple serosal tears occurred during complex adhesiolysis. This necessitated a segmental resection of the small intestine with subsequent anastomosis. Despite the complexity of the case, the patient's postoperative course was without further complications.

In two additional cases, both involving large L4 hernias after partial nephrectomy, an intraoperative conversion to open preperitoneal repair was required after completion of the robotic transversus abdominis release (TAR). The conversion was necessary due to extensive scarring caused by the use of a hemostyptic cellulose agent during the previous operation in the retroperitoneum. The postoperative course of both patients was uneventful (see **Table 3**).

The postoperative complication rate was 6.25% (10 patients), with 1.72% (2 patients) requiring reoperation. In five patients, a seroma was identified during sonographic follow-up, occurring four times in the retromuscular mesh space and once in the former hernia sac; none of these cases required surgical intervention. A superficial wound healing disorder around a trocar incision was treated conservatively.

Additionally, one patient experienced an acute episode of chronic pancreatitis during hospitalization, while another developed postoperative pneumonia. One patient developed a hematoma, which was evacuated via laparoscopy Another patient experienced temporary neuropraxia of the femoral nerve due to a positioning injury, which consequently led to an ankle fracture requiring surgical stabilization.

DISCUSSION

"No disease of the human body, belonging to the province of the surgeon, requires in its treatment, a better combination of

TABLE 1 | General patient characteristics.

		all	n = 160	eTEP	n = 117	eTAR	n = 43
Age (years)	Median/Range	62.00	(23–87)	63.00	(26–87)	60.00	(23–85)
Male	Number/Percentage	97	60.63%	75	64.10%	22	51.16%
Female	Number/Percentage	63	39.38%	42	35.90%	21	48.84%
ASA	Median/Range	2	(1–3)	2	(1–3)	2	(1–3)
Height (m)	Median/Range	1.73	(1.52–2.06)	1.73	(1.52–2.06)	1.72	(1.54–1.87)
Weight (kg)	Median/Range	89.5	(50–145)	90	(50–145)	82	(53–128)
BMI (kg/m2)	Median/Range	30	(20–45)	30	(20–45)	29	(20–42)

TABLE 2 | Intra- and postoperative parameters.

		all	n = 160	eTEP	n = 117	eTAR	n = 43
Operating Time (min)	Median/Range	143	(53–495)	125	(68–351)	238	(53–495)
Length of Stay (days)	Median/Range	3	(2–16)	3	(2–9)	4	(2–16)
Incisional Hernias	Number/Percentage	111	69.38%	69	58.97%	42	97.67%
Primary Hernias	Number/Percentage	49	30.63%	48	41.03%	1	2.33%
Mesh Size (ventral hernia)	Median/Range	540	(225–1,350)	510	(260–880)	750.00	(225–1,350)
Mesh Size (all hernias)	Median/Range	560	(225–1,392)	510	(260–984)	756.00	(225–1,392)
Defect Size	Median/Range	25	(2.25–375)	16	(2.25–200)	120	(4.5–375)
MDR	Median/Range	21	(2.33–150)	30	(3.06–150)	5.92	(2.33–80)
Medial Hernia	Number/Percentage	139	86.98%	117	100.00%	22	51.16%
Lateral Hernia	Number/Percentage	7	4.14%	0	0.00%	7	16.28%
Combined Hernia	Number/Percentage	14	8.88%	0	0.00%	14	32.56%
Complete Defect Closure	Number/Percentage	160	100.00%	117	100.00%	43	100.00%

TABLE 3 | Intra- and postoperative complications including conversion rates.

		all	n = 160	eTEP	n = 117	eTAR	n = 43
Complications	Number/Percentage	11	6.88%	7	5.98%	4	9.30%
Intraoperative	Number/Percentage	1	0.63%	0	0%	1	2.32%
Postoperative	Number/Percentage	10	6.25%	7	5.98%	3	6.98%
Conversions	Number/Percentage	2	1.25%	0	0.00%	2	4.65%
Clavien Dindo 1	Number/Percentage	6	3.75%	5	4.27%	1	2.33%
Clavien Dindo 2	Number/Percentage	2	1.25%	1	0.85%	1	2.33%
Clavien Dindo 3a	Number/Percentage	0	0.00%	0	0.00%	0	0.00%
Clavien Dindo 3b	Number/Percentage	2	1.25%	1	0.85%	1	2.33%
Clavien Dindo 4	Number/Percentage	0	0.00%	0	0.00%	0	0.00%
Clavien Dindo 5	Number/Percentage	0	0.00%	0	0.00%	0	0.00%

accurate, anatomical knowledge with surgical skill than hernia in all its varieties" – Sir Aston Pestley Cooper [17].

Though bold and perhaps applicable across all surgical disciplines, this quote by renowned surgeon and anatomist Sir Astley Paston Cooper from 1804 underscores the enduring challenge and anatomical complexity of hernia surgery, which probably remained unchanged to this day.

The integration of robotics into hernia surgery has introduced new possibilities for the implementation of minimally invasive techniques with extraperitoneal mesh placement, while also allowing for new anatomical considerations. Enhanced visualization and precision offered by robotic systems have enabled surgeons to explore novel approaches to accessing and repairing hernias.

In 2021, Baur et al [18] investigated two of these robotic adaptations involving transperitoneal access in a large group of 118 patients with ventral and incisional hernias in Switzerland: rv-TAPP ("robotic ventral transabdominal preperitoneal plasty") with preperitoneal mesh implantation and r-TARUP with retrorectus mesh implantation (r-Rives). This study demonstrated that robotic surgery combines the advantages of minimally invasive procedures (low complication rate) with the advantages of open procedures (morphological reconstruction) and enables consistent extraperitoneal mesh placement.

In 2018, Belyansky first described a robotic adaptation of the eTEP technique. As previously mentioned, unlike transabdominal procedures, this approach opts for a total extraperitoneal access route, initially dissecting the non-preoperated layers of the abdominal wall, far from the hernia site. In a feasibility study involving 37 patients with ventral, incisional, lateral, or parastomal hernias, Belyansky demonstrated the safety and feasibility of robot-assisted hernia surgery utilizing an extraperitoneal approach [11].

Given the absence of a control group for this study, we have compared our results with the available data in the literature in order to contextualize our results.

In 2020, Morrell et al. [19] reported on technical standardisation and their anatomical considerations in robot-assisted eTEP repair of ventral hernias and described 10 key steps for safe and reproducible repair. In 2021, Kudsi and Gokcal [20] reported on the short-term results after using a lateral eTEP approach with and without transversus abdominis release (TAR) in 52 patients. Quezada et al. released postoperative data from a case series involving 66 patients in 2022 [21].

In the study conducted by Morell et al., no intraoperative complications were observed among the 22 patients included. However, one postoperative seroma was reported, resulting in a surgical complication rate of 4.5%. Reoperation was not required in any of the three studies analyzed. In another case series by Belyansky et al., the authors documented no intraoperative complications, but two postoperative seromas necessitating interventional drainage. This corresponds to a surgical complication rate of 5.4% among the 37 patients included in this study. Kudsi and Gokcal reported a series of 52 patients. Similarly, their results showed no intraoperative complications or conversions. Nonetheless, two seromas and one hematoma following a fall were identified, resulting in a postoperative complication rate of 5.8%. Quezada et. al reported one recurrence (1.5%) and 10 surgical site occurrences (15%) including 6 seromas, 2 hematomas and 2 surgical site infections. Four patients out of their series required reinterventions (6%).

Over a span of more than 4 years, we encountered similar results and complication rates. Regarding the reoperations in our series, one involved an open reduction and internal fixation for an ankle fracture caused by a fall, which resulted from neuropraxia of the femoral nerve due to positioning-related overextension. Notably, in our series, there were no cases of suture rupture of the posterior rectus sheath or peritoneum, which can lead to intraparenchymal hernias and is considered one of the primary risks associated with new minimally invasive procedures involving extraperitoneal mesh placement. Additionally, four patients in our cohort developed significant retromuscular seromas postoperatively, none of which required intervention.

One possible reason for this low number of seroma complications is the consistent postoperative application of an abdominal binder in combination with retromuscular drain as recommended by Mazzola Poli de Figueiredo et al. [22] in their review article published in 2023. Furthermore, in a systematic review published in 2023 by Marcolin et al. [23], there appears to be evidence of a significant reduction in postoperative seromas through drain placement. In accordance to this finding a drain was placed above the mesh at the end of every operation regardless of intraoperative fluid accumulation. In comparison, the complication rate of 6.25% is consistent with the data published in current literature.

Moreover, the robotic systems offer an excellent modality for a totally extraperitoneal adaptation and safe implementation of a posterior component separation as described by Novitsky [24].

Although there are currently no specific publications highlighting the benefits of the extraperitoneal approach in hernia surgery, we have observed significant advantages in the fact that the robotic system can be introduced into a space where no prior surgeries have been performed, thereby avoiding adhesions. This is particularly valuable in cases of incisional hernia surgery, where intraperitoneal adhesions are ought to be expected.

Given the fact, that a large portion of ventral hernia operations involve incisional hernias, the choice of access and trocar placement is paramount for the success of the operation. In this context and in contrast to transperitoneal techniques, there appears to be a particular advantage, in that the robot, can be docked in the retrorectus space without requiring major adhesiolysis.

Unlike transperitoneal techniques, intraperitoneal adhesiolysis is rarely required and typically limited to a small area after opening the hernial sac. However, based on our experience, the use of robotic systems offers a distinct advantage in performing adhesiolysis. This benefit has been reflected in recent literature, where robotic surgery appears to be associated with a lower rate of bowel injuries compared to laparoscopic control groups [25, 26].

On the other hand, the possibility of unnoticed transperitoneal damage to the intestine poses a significant risk during surgery. Prakhar [27] et al. reported two cases of occult bowel injuries that required surgical revision on the second postoperative day. A possible cause for such injuries could be the uncontrolled use of monopolar energy, potentially leading to damage from leakage currents in areas of thinned peritoneum, as commonly found in scar tissue.

Additionally, by minimizing intraperitoneal adhesiolysis, there could be potential for a further reduction in the rate of bowel injuries, similar to the outcomes observed in minimally invasive inguinal hernia surgery. In a study reported by Felix et al. in 1995 [28], the authors compared large numbers of cases involving TEP and TAPP surgeries. Their results showed a significantly lower number of bowel injuries in patients treated with the TEP technique. The same result was found in the study by Tamme [29] in 2003, where none of the over 5000 TEP patients experienced a bowel injury.

During the initial stages of our robotic surgery program, transperitoneal procedures were preferred, in accordance with the recommended training pathway of the European Hernia Society (EHS), due to the complexity of extraperitoneal techniques. Currently, the extraperitoneal eTEP technique has become the standard approach in our hospital, even for complex hernias. It is also routinely used for large W3 hernias requiring bilateral TAR, as intraperitoneal adhesions are often present in this situation and access problems are to be expected.

To minimize suture tension, our hospital utilizes a technique similar to the MILOS (Mini/Less Open Sublay) method, in which the posterior rectus sheath is left open, and only the peritoneum is repaired to preserve the integrity of the abdominal wall.

Furthermore, trocar positioning offers a distinct advantage compared to transperitoneal techniques, where trocars are typically placed more laterally along the anterior axillary line during lateral docking. In extraperitoneal procedures, trocars are positioned along the midclavicular line, providing more space between the ribcage and iliac crest. This allows for greater distance between the individual incisions, resulting in greater range of motion of the individual robotic arms, thereby reducing the risk of collisions with the patient or the operating table. Additionally, this approach eliminates the need for placing the patient in an overextended position, as often required in bottom-up or top-down techniques.

In contrast to transperitoneal procedures (TARUP) trocar insertion sites are extraperitoneal and covered by mesh, herein reducing the risk of subsequent trocar hernias.

We encountered a limitation related to the width of the rectus muscle, which ideally should measure at least 5-6 cm. This requirement arises from the fact that the distance from the remote center of the robotic trocars, positioned at the fascial entry point, to the instrument tip measures 6 cm. This technical constraint, inherent to the robotic system in use, must be acknowledged as it directly influences the maneuverability and effectiveness of the instruments within the confined retrorectus space.

For the dissection of the retrorectus space at the beginning of the operation, a section of native tissue is required at the lateral edge of the rectus sheath on one side of the body. Extensive scarring or pararectus access routes that extend far laterally thus pose limitations to the method. This constraint is similarly applicable in cases of reoperations where previously implanted meshes occupy the entire retrorectus space, as these meshes may obstruct access and hinder effective dissection.

In case of early accidental pneumoperitoneum, the procedure may potentially increase in complexity. With sufficient experience in robotic or endoscopic extraperitoneal surgeries, this typically does not pose a significant issue. At the beginning of the learning curve however, it may necessitate a conversion to a transperitoneal or even open approach. Therefore, robotic eTEP should not be considered a "beginner's operation" or a training procedure [30] for robotic surgery but rather be trained gradually through hands-on courses and proctoring in order to shorten the learning curve, similarly to its endoscopic counterpart as demonstrated by Korneffel et al [31].

CONCLUSION

The "lateral approach" of robotic eTEP offers a safe surgical method for treating ventral hernias with minimal invasive techniques and mesh augmentation in the retro-muscular space. Given appropriate expertise even in complex cases of large W3 hernias or lateral hernias, a complete fascial closure can be achieved by performing TAR. The major limitations of the method are confined to cases that have been previously operated on in the retro-muscular space or present scars in the access areas. Compared to transperitoneal procedures, there appear to be specific advantages with regard to reduced need for adhesiolysis and improved trocar positioning in extraperitoneal approaches. However, further comparative studies are necessary to better understand the relative benefits and outcomes of these approaches. This would provide a more comprehensive assessment of their clinical advantages, particularly in terms of patient safety, recovery, and long-term efficacy.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

ETHICS STATEMENT

The evaluation of the data was carried out exclusively on the basis of retrospective data, which were anonymized at the source. Therefore ethics approval or specific consent procedures were not required for this study.

AUTHOR CONTRIBUTIONS

RV and BM contributed equally to this work; RV and BM analyzed data; RV and BM drafted the manuscript; RV, FH, PB, and BM are responsible for the interpretation of results and the critical revision of the manuscript. All authors contributed to the article and approved the submitted version.

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CONFLICT OF INTEREST

BM has received payments for proctoring by Intuitive Surgical, Klinikum Kempten is a case observation center of Intuitive Surgical.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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MINI REVIEW
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Artificial Intelligence—What to Expect From Machine Learning and Deep Learning in Hernia Surgery

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This mini-review explores the integration of Artificial Intelligence (AI) within hernia surgery, highlighting the role of Machine Learning (ML) and Deep Learning (DL). The term AI incorporates various technologies including ML, Neural Networks (NN), and DL. Classical ML algorithms depend on structured, labeled data for predictions, requiring significant human oversight. In contrast, DL, a subset of ML, generally leverages unlabeled, raw data such as images and videos to autonomously identify patterns and make intricate deductions. This process is enabled by neural networks used in DL, where hidden layers between the input and output capture complex data patterns. These layers' configuration and weighting are pivotal in developing effective models for various applications, such as image and speech recognition, natural language processing, and more specifically, surgical procedures and outcomes in hernia surgery. Significant advancements have been achieved with DL models in surgical settings, particularly in predicting the complexity of abdominal wall reconstruction (AWR) and other postoperative outcomes, which are elaborated in detail within the context of this mini-review. The review method involved analyzing relevant literature from databases such as PubMed and Google Scholar, focusing on studies related to preoperative planning, intraoperative techniques, and postoperative management within hernia surgery. Only recent, peer-reviewed publications in English that directly relate to the topic were included, highlighting the latest advancements in the field to depict potential benefits and current limitations of AI technologies in hernia surgery, advocating for further research and application in this evolving field.

Keywords: AI, machine learning, deep learning, hernia surgery, neural network

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INTRODUCTION

"A computer would deserve to be called intelligent if it could deceive a human into believing that it was human" [1] a phrase once coined by Alan Mathison Turing, who is widely regarded as a pioneer in computer science and artificial intelligence. Turing's early substantial contributions to AI in the mid-20th century, notably his role in deciphering the Enigma code during World War II, laid the foundation for the field [2].

Adopting Turing's quote to contemporary times, one could identify any device capable of producing realistic videos, photos, and conversations as intelligent since artificial Intelligence (AI) has reached a level of sophistication where it can convincingly mimic human behavior. As a result, the term AI is now used ubiquitously as it is entangled within a vast area in modern computer

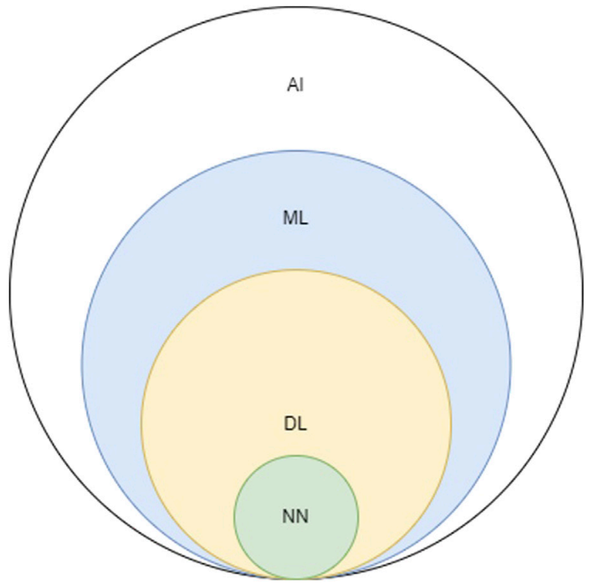

FIGURE 1 | Schematic depicting the relationship between AI, artificial intelligence; ML, machine learning; DL, deep learning; NN, neural networks.

science. Consequently, related terms are often incorrectly used interchangeably [3]. For simplicity reasons, AI can be considered an umbrella term that includes concepts such as machine learning (ML), neural networks (NN), and deep learning (DL) (**Figure 1**).

Many of these technologies have naturally also found applications in medicine, including hernia surgery. Machine learning algorithms (MLA) for example can, in simple terms, learn from existing data, generalize them, and extrapolate future, yet unknown data, allowing them to perform tasks without explicit instructions [4]. For instance, Hassan et al [5] trained an MLA on preoperative clinical data to accurately predict complications in abdominal wall reconstruction (AWR) surgery.

Classical machine learning algorithms typically rely on structured, labeled data (i.e., data organized according to a set hierarchy) to make predictions, making them generally more dependent on human intervention for learning. In contrast, deep learning (DL), being a subset of machine learning, does not necessarily require labeled datasets. Deep Learning algorithms can be regarded both as a refined as well as mathematically complex evolution of machine learning algorithms. To put it illustratively, just as a human brain uses its neural pathways to process information and reach decisions, deep learning employs artificial neural networks that simulate this process. These networks are capable of learning from data in an incremental manner, which enables them to make complex deductions as more information becomes available. It can utilize raw data, such as text, images, and videos, to identify features and distinguish explicit patterns, thus discovering data groupings without human interference [6–8].

The distinction between ML and DL is defined by the number of layers in a neural network also known as hidden layers (**Figure 2**) [9]. If more than three of these layers are present, the algorithm is considered a DL model. In summary, hidden layers act as intermediary stages between the input and output of a neural network. They play a crucial role in capturing complex patterns in data, which makes neural networks highly effective for diverse applications such as image and speech recognition and natural language processing. The configuration and weighting of these hidden layers are essential for creating effective neural network models. In particular, DLMs (deep learning models) involved in computer-aided diagnosis have been successfully applied in cranial [10, 11] trauma [12, 13] and oncologic [14–16] computed tomography (CT) analysis. In this context, Elhage et al. [17] have demonstrated that an 8-layered convolutional neural network (CNN), a type of DL architecture, can effectively predict surgical complexity in AWR procedures, competing with a panel of expert surgeons. Furthermore, DLMs have proven to be effective in predicting surgical outcomes and post-operative complications [18–20].

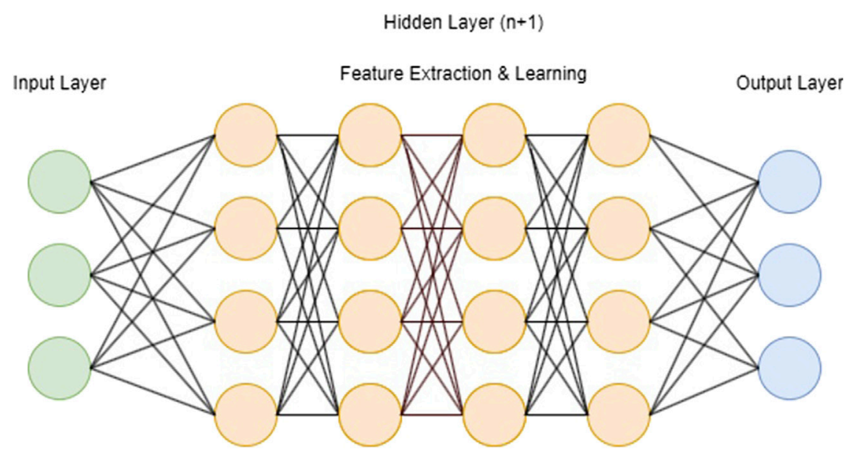

FIGURE 2 | Schematic visualization of a deep learning model with input layer, n + 1 hidden layers and output layer).

The aim of this mini-review is to explore the advancements and applications of AI, particularly ML and DL, as well as other notable advancements in computing science in the field of hernia surgery, highlighting their potential benefits and current limitations.

METHODOLOGY

In conducting this mini review, we utilized literature from several databases including, PubMed and Google Scholar. The key terms used in our search were: "hernia," "artificial intelligence, "deep learning," "machine learning," "abdominal wall reconstruction," "hernia surgery," and "augmented reality."

Inclusion criteria for this review involved publications directly relevant to the study topic. Specifically, we included studies that focused on preoperative planning, intraoperative imaging and techniques, as well as postoperative management and follow-up in the context of abdominal wall reconstruction. We considered articles published in peer-reviewed journals, studies published in English, and publications from the last 10 years to ensure the inclusion of the most recent advancements.

Publications were excluded if they were not related to hernia surgery, studies not involving AI, ML, DL, or augmented reality in a surgical context, and non-peer-reviewed articles such as opinion pieces, editorials, or non-scientific reports. We also excluded articles focusing on animals or *in vitro* models rather than human subjects, and duplicate studies or publications with overlapping data sets.

DISCUSSION

The potential impact of computing sciences on medicine was already being anticipated in the 1970s. W B Schwartz [21] predicted that "computing science would likely have significant effects by enhancing and possibly even replacing certain intellectual functions traditionally performed by physicians." The author noted that the integration of computers in medical practice could profoundly influence physician manpower and the quality of healthcare. Schwartz's foresight highlighted the transformative potential of computing science in medicine. 52 years later in 2022, a protocol was developed by Saeidi et al. [22] that enables a robot to autonomously perform a small bowel anastomosis with minimal human interference.

The rapid advancements in AI hence raise the question of not whether AI will shape our surgical future, but rather how it will do so.

In a quality improvement study conducted by Elhage et al. [17], the researchers aimed to assess the potential of image-based deep learning in predicting the complexity of AWR surgeries, specifically the need for component separation, as well as predicting pulmonary and wound complications. To achieve this, they developed an 8-layer CNN capable of analysing image characteristics.

The study design involved a comparison of the CNN-based surgical complexity model with a validation set of CT-images. The validation set was evaluated by a panel of 6 expert AWR surgeons, who were blinded to the surgical complexity DLM. The dataset utilised for analysis comprised 369 patients and 9303 CT images.

In summary, Elhage et al. found that the CNN-based DLM was more accurate than expert surgeon judgment in predicting the surgical complexity of AWR procedures [81.3% compared to the surgeons' accuracy of 65.0% ($p < 0.001$)]. Furthermore, they observed that an additional DLM accurately predicted the occurrence of surgical site infections [AUC 0.898 ($p < 0.001$)]. These findings highlight the potential of image-based DLMs as valuable tools in forecasting surgical outcomes and improving decision-making in AWR surgery.

In another article published by Hassan et al. [5], the authors displayed the effectiveness of machine learning models (MLMs) in predicting hernia recurrence (HR), surgical site occurrences (SSOs), and 30-day readmission. Their study reported that MLMs achieved mean accuracy rates of 85% (95% CI 80%–90%) for HR prediction, 72% (95% CI 64%–80%) for SSOs, and 84% (95% CI 77%–90%) for 30-day readmission. These ML algorithms, trained on readily available preoperative clinical data, proved to be highly accurate in forecasting complications associated with AWR-surgery. The authors concluded to support the integration of MLMs into the preoperative evaluation process for patients undergoing AWR.

To facilitate the advancements of AI in hernia surgery, it is in our view crucial to expand patient databases on an international scale. Increasing the diversity and size of these databases will provide a broader range of data for training AI models and allow for more comprehensive and accurate predictions.

Since the effectiveness of AI predictions relies heavily on both the accuracy and the thoroughness of the input data, access to diverse patient populations will help address potential biases and ensure the reliability of AI algorithms across different demographics [23]. Expanding patient databases internationally can also help identify patterns and trends that may not be apparent in smaller or more localised datasets.

Moreover, the collection and analysis of video data in surgical procedures hold great potential for advancing the field of hernia surgery. By capturing surgical procedures through video recordings, it becomes possible to create detailed anatomical maps and explore the integration of AR with robotics in surgical interventions [24]. By integrating DLMs on video data, it appears to be possible to extract relevant information, such as anatomical landmarks, tissue characteristics, and procedural phase recognition, which can contribute to the development of more precise surgical interventions [25]. Additionally, the combination of video data with augmented reality has the potential to enhance surgical visualisation and navigation as well as robotic surgery training-simulators. By possibly overlaying real-time anatomical information and guidance onto the surgeon's view, AR could provide valuable assistance during complex hernia surgeries. Surgeons can benefit from visual cues, real-time feedback, and enhanced precision, ultimately leading to improved surgical outcomes. For example, Cui et al. [26] used a CNN model comprised out of surgical videos from 35 patients in laparoscopic hernia repair in order to detect the vas deferens and their results suggested that the CNN promptly identifies and visualises vas deferens images.

Another promising approach combines wide-field, planar, near-infrared fluorescence imaging with AI for automated real-time guidance during surgery as highlighted by Gioux et al. [27]. This technology could help identify and avoid hidden tissues, such as nerves or blood vessels covered by fatty or connective tissue, by highlighting their location within the surgical field. Like following a breadcrumb trail, the AI system could guide surgeons in the direction of dissection, enhancing precision and hence reducing the risk of complications.

An essential pillar of AI is characterized through the concept of phase recognition. This involves the utilization of MLAs and computer vision techniques to automatically discern and categorize distinct phases or stages within a process.

Phase recognition AI utilizes algorithms, frequently rooted in DL, to scrutinize patterns, features, and temporal sequences within video data. This capability allows the system to differentiate between diverse stages of the surgical process [28, 29].

In a recently published study by Takeuchi et al. [30], the primary objective was to develop a DL-based automated phase-recognition system for identifying surgical phases in Transabdominal Preperitoneal (TAPP) procedures (i.e. preparation, peritoneal flap incision, peritoneal flap dissection, hernia dissection, mesh deployment, mesh fixation, peritoneal flap closure, and additional closure). A secondary aim was to explore the correlation between surgical skills and the duration of each phase. An AI model (AIM) was trained to automatically recognize surgical phases from videos, and the study assessed the relationship between phase duration and surgical skills. A fourfold cross-validation was used to evaluate the AIMs performance, achieving accuracies of 88.81% and 85.82% for unilateral and bilateral cases, respectively.

Ortenzi et al. [31] reported on an AI-based computer vision algorithm designed to automatically recognize surgical steps in videos of totally extraperitoneal (TEP) inguinal hernia repair. The algorithm achieved an overall accuracy of 88.8% in recognizing the complete procedure. The per-step accuracy was highest for the hernia sac reduction step at 94.3% and lowest for the preperitoneal dissection step at 72.2%. The authors concluded that this novel AIM could provide fully automated video analysis with a high level of accuracy. High-accuracy AIMs that enable automation of surgical video analysis allow for the identification and evaluation of surgical performance.

However, the integration of video data and DLMs in hernia surgery research and practice requires the accumulation of diverse and high-quality video datasets. It seems obvious, that these datasets should encompass various surgical techniques, patient characteristics, and procedural variations to ensure the robustness and generalisability of AIMs [32]. To optimize this process, Hashimoto et al. [33] propose extensive collaborations among surgeons as well as data scientists. These efforts are crucial to facilitate the sharing and pooling of video data, which will accelerate the development and refinement of AI-driven approaches in hernia surgery.

In a scoping review published by Taha et al. [34], the authors provided a comprehensive summary of the current objectives related to the integration of AI in the field of hernia surgery. They highlighted the potential applications and benefits of AI in areas such as medical imaging and surgical training. However, the authors also acknowledged the limited number of publications available on this specific topic, indicating a gap in the existing literature.

Based on this observation, Taha et al. emphasised the need for further research and the publication of original articles to explore and investigate the ways in which AI can effectively assist in medical imaging and support the training of surgeons in the context of hernia surgery.

Furthermore, ever since AI has emerged, ethical considerations have played a significant role in discussions surrounding the technology. While the potential benefits are undeniable, questions arise regarding accountability if complications occur. O'Sullivan et al. [35] categorise responsibility into accountability, liability, and culpability. Drawing a parallel to self-driving cars, they compare the surgeon overseeing the hypothetical autonomous robot to the driver of a car, making the surgeon ultimately responsible for the robot's actions. Undeniably, a robust legal framework is paramount prior to implementing semi-autonomous programs or machines into any medical field.

In conclusion, further research on the applications of AI is undoubtedly of crucial importance. Moreover, we believe that promoting international collaboration in expanding patient and video databases are indispensable in facilitating this process.

AUTHOR CONTRIBUTIONS

RV and BM contributed equally to this work; RV and BM drafted the manuscript; RV and BM are responsible for the interpretation of results and the critical revision of the manuscript. All authors contributed to the article and approved the submitted version.

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CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The eTEP/eTEP-TAR Repair of Ventral Hernias a Study From One Center/ One Surgeon—The First Five Years of Experience

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Objective: The objective of this study is analyze the outcomes of retro-muscular repair techniques for ventral hernias performed by a single surgeon in a renowned hernia surgery center.

Method: This study involved 197 patients who underwent surgery between May 2016 and December 2021 under the care of a single surgeon (VR). Respecting the indication/ contraindications of the eTEP procedure, 197 of 212 patients with ventral hernias underwent eTEP/eTEP-TAR surgery during this period. The cohort consisted of diverse hernia types, including median, lateral, and multiple-site defects. The safety of this approach was evaluated based on postoperative occurrences, where the number of complications accounted for 5% of the cases.

Results of the study indicated that there was a significant improvement in the quality of life of patients following the procedure. The assessment, which measured postoperative pain, normal activity, and aesthetics on a 0–10 scale, showed improvement at 2 weeks and 3 months after surgery compared to the preoperative level. However, after a mean of 51.11 months, only one case of recurrence was reported. This recurrence occurred on top of the mesh, 18 months after the initial operation. The follow-up period lasted between 24 and 90 months. Patient monitoring was conducted either in person or over the phone, focusing on quality of life, postoperative pain, and the occurrence of recurrence. In conclusion, the laparo-endoscopic retro-muscular repair of ventral hernias, whether primary or incisional, has shown to yield excellent results in medium and long-term follow-up. The eTEP technique combines the benefits of the Rives-Stoppa technique (considered the gold standard in open ventral hernia repair) with the advantages of minimally invasive surgery.

Keywords: ventral hernia, laparo-endoscopic retro-muscular repair, eTEP technique, Rives-Stoppa technique, minimally invasive surgery

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INTRODUCTION

The Rives-Stoppa procedure is widely recognized as the gold standard for open ventral hernia repair [1]. It involves restoring the linea alba and placing a mesh underneath the rectus muscles. In our center, the cases were resolved using the eTEP-RIVES-STOPPA procedure, which combines the enhanced view provided by laparoscopy (e.g., enhanced view totally extraperitoneal), with the principles of Rives-Stoppa. This approach offers a minimally invasive option with improved outcomes compared to traditional open approaches. In cases involving large hernia defects, lateral hernias, sub-xiphoidal hernias, suprapubic hernias, or complex hernias with multiple defect sites, as well as patients who have undergone previous anterior component separation, a posterior component separation technique may be necessary. This technique involves releasing the transversus abdominis muscle (TAR) alongside other surgical maneuvers to achieve optimal hernia repair and abdominal wall reconstruction [2]. Certainly, in both the eTEP Rives-Stoppa and eTEP-TAR procedures, a polypropylene mesh is placed in the retro-muscular space to provide additional support and augmentation [3].

The goal of the procedure is to restore the linea alba, which is the central tendon of the abdomen, and strengthen the abdominal wall. This is achieved by covering the entire dissected area with a polypropylene mesh [4]. In this study, hernia defects were closed using non-resorbable barbed sutures for restoring the linea alba, and resorbable barbed sutures were used for closing the posterior layer such as the posterior rectus sheaths or peritoneum. Macroporous polypropylene meshes were then placed in the retro-muscular space for augmentation.

PATIENTS AND METHOD

We reviewed the medical records of patients who underwent laparo-endoscopic retro-muscular repair (specifically, the Rives-Stoppa procedure and abdominal wall reconstruction TAR) for ventral hernias (both primary and incisional). These procedures were performed using a laparo-endoscopic approach (eTEP and eTEP-TAR) between May 2016 and December 2021. The surgeries were conducted by the same surgeon and surgical team at Life Memorial Hospital in Bucharest, Romania. During this period, 212 patients with ventral hernias underwent surgery. However, out of that total, only 197 patients were operated on using the eTEP/eTEP-TAR approach. The remaining 15 patients were not operated on via this access due to contraindications, such as loss of domain (3 cases), poor condition of the overlying skin, infection or pubo-xifoidian scar (8 cases), recurrent hernia after Rives-Stoppa or TAR (4 cases); some cases presented different combination of these conditions.

All the hernias are classified according to EHS criteria [5].

The primary parameter evaluated in terms of postoperative progression has been hernia recurrence. This is routinely assessed during clinical follow-up appointments or through a set of four questions asked during phone follow-up: 1. Do you feel that your hernia is back?, 2. Has any physician told you that your hernia is back?, 3. Do you have a bulge/lump where your hernia used to be?, 4. Do you have any painful area on your abdominal wall? [6]. Other parameters that are measured include the length of hospital stay, occurrence of surgical site issues such as seroma, hematoma, and infection, 30-day readmission following the surgery, and any additional medical or surgical complications that may arise during the follow-up period.

The quality of life was assessed using the VAS. We monitored the level of pain before and after the operation by asking patients about their pain levels while at rest, any restrictions in daily activities (such as walking and climbing stairs), and any cosmetic concerns related to the abdomen and hernia site. Patients provided numerical responses on a scale of 0–10. Chronic pain was defined as pain persisting for more than 3 months after surgery and affecting daily activities. **Table 2** and **Table 5** respectively depict the pre- and post-operative pain levels.

Demographic Data of the Patients

This study involved 197 consecutive patients (92 males and 105 females) who were operated on by a single surgeon between May 2016 and December 2021. The mean age of the patients wea 53 years old (median 54 years old).

Comorbidities of the Patients

Approximately half of the patients were obese (44.7%, n = 88), with a mean BMI of 28.93 and a median BMI of 29.17 (standard deviation 5.5360; range 17.1–45.4). Additionally, 34 patients (17.3%) had diabetes mellitus. When considering cardiovascular and other systemic diseases, the total number of patients with comorbidities was 101 (51.3%, n = 101). Taking in consideration these comorbidities, we calculated the ASA score and obtained the following results: ASA I (a normal healthy patient) 88 patients (44.7%), ASA II (a patient with mild systemic disease) 103 patients (52.3%), ASA III (a patient with severe systemic disease) 6 patients (3%).

Hernia Characteristics

The most common type of hernia observed was incisional hernia (62%, n = 122), with the median site of the abdomen being the

TABLE 1 | Hernia characteristics.

	n (%)
Hernia type	
Primary	75 (38%)
Incisional	122 (62%)
Hernia site	
Median	192 (90.6%)
Lateral	5 (2.4%)
Multiple sites	15 (7.1%)
Hernia complexity	
Simple	169 (85.8%)
Complex	28 (14.2%)
Recurrent hernia	
R0	174 (88.3%)
R_n	23 (11.7%)

TABLE 2 | Preoperative level of the pain using VAS.

VAS	n	Percent
0	149	75.6
1	19	9.6
2	16	8.1
3	7	3.6
4	4	2.0
5	2	1.0
Total	197	100.0

most frequent location (80.18%) (**Figure 1**). Out of all the cases, 41 (19.3%) were considered complex incisional hernias, defined as hernias larger than 10 cm in width, with multiple recurrences or multiple site defects [7]. The specific characteristics of the hernias can be found in **Table 1**.

The diagnosis of hernias is generally made based on clinical evaluation. In cases of complex incisional hernias or recurrent hernias, imaging diagnostics, such as CT scans, can provide additional information regarding the hernia site, size, abdominal wall structure, and the presence of any previous mesh. In this study, the diagnosis was made using clinical evaluation alone in 140 cases (71.1%). In 55 cases (27.9%), clinical evaluation was supplemented with CT scans, and in 2 cases (1%), ultrasonography was used in addition to clinical evaluation. The length and width of all of the hernias were measured also intraoperatively, as a common step of the procedure,

We assessed the preoperative level of pain during the clinical examination using the 0–10 numerical scale (Visual Analogue Scale—VAS). The majority of patients (74.5%) reported no pain or discomfort (see **Table 2**).

The median defect area is 122 cm^2, ranging from 6 cm^2 to 625 cm^2.

It is well-known that the hernia defect width is the most critical characteristic in closing the defect and reconstructing the abdominal wall, this dimension being one of the characteristics of parietal defects in the EHS classification.

In the patient cohort operated via the eTEP approach, the defect width ranged from 2.5–17 cm in midline incisional hernia, with an average of 6.5 cm, from 7–11 cm in lateral incisional hernia with an average of 7.66 cm, and from 2–7 cm with an average of 3.77 cm in primary ventral hernia (**Table 3**).

When it comes to multiple site hernias, these are unique cases that involve at least two distinct hernia sites. In our study, we encountered 12 such cases. The most common scenario for multiple site hernias was a combination of median and lateral (flank) hernias, as well as parastomal hernias with a median component hernia simultaneously. Due to the complexity of these situations, accurately assessing the defect area and determining suitable technical solutions often require the use of two meshes. Therefore, these cases were not included in our analysis table for defect/mesh size.

In 40 cases (20.3%), diastasis recti were found to be associated with ventral hernias. This condition is crucial in determining the size of the mesh to be used. Therefore, regardless of the case, the linea alba is repaired by suturing the anterior sheaths and reinforcing the suture line with an appropriately-sized mesh placed in the retro-rectus space.

In our analysis, the size of the weakness is defined as the actual "diastasis defect" rather than just the hernia defect. For example, if a patient has a small umbilical hernia measuring 2 cm by 2 cm, along with a diastasis recti measuring 5 cm in width and 20 cm in length, we would consider the area of the defect to be 100 cm^2. In this case, the mesh should be at least 30 cm in length, with the width of the mesh shaped to fit into the retro-rectus space between the two semilunaris lines. In cases involving diastasis, the average length of the defect was 18 cm (minimum 10 cm to maximum 25 cm), and the average length of the mesh used was 28 cm (minimum 10 cm to maximum 30 cm). As for the width of the diastasis, it measured an average of 5 cm (minimum 3 cm to maximum 9 cm), and the mesh was on average 17 cm wide (minimum 10 cm to maximum 25 cm) in order to adequately cover the entire dissected area.

Procedures

The patient selection process (exclusion criteria) was based on contraindications for the procedure, which included LOD, poor skin condition, recurrence after previous retro-muscular repair, and mesh infection. Out of the total of 212 patients, only 15 underwent open surgery due to contraindications for the eTEP procedure.

Four patients required conversion to an open approach. These conversions were necessary for various reasons: two cases experienced respiratory difficulties during the procedure, one case encountered dense fibrosis within the retro-rectus space, and another case had bowel adhesions to a previous mesh.

The procedures carried out included eTEP Rives-Stoppa (61.9%), eTEP-TAR (36%), and in the converted cases, Rives-Stoppa (1.5%, n = 3) and open TAR (1 case).

TABLE 3 | Location and size of the defect; Mesh/defect ratio.

	n	Width (cm) mean (min-max)	Defect area (cm^2) mean (min-max)	Mesh area (cm^2) mean (min-max)	Mesh/Defect ratio mean (min-max)
Incisional hernia–midline	105	5.51 (2.5–17)	107 (6–405)	688.25 (195–2025)	10.01 (2.2–66.7)
Ventral hernia–midline	38	3.77 (2–7)	17.74 (4–63)	292.47 (100–600)	28.16 (1.8–99)
Ventral/incisional hernia and diastasis recti - midline	39		82.18 (36–200)	475.9 (200–750)	6.3 (2.8–12.8)
Incisional hernia - lateral	3	7.66 (7–11)	43.25 (18–99)	375 (160–600)	9.06 (6.1–14.2)
Multiple sites defects	12		NA (not applicable)	NA	NA

TABLE 4 | Mesh fixation.

Mesh fixation	n	%
No fixation	146	74.1
Glue	44	22.3
Resorbable tack	2	1.0
Suture	1	0.5
Mixt (Glue + Tack/Suture)	4	2.0
TOTAL	197	100.0

Using these procedures, I was able to achieve the main goal of restoring the linea alba, which is the central tendon of the abdomen. For all of the cases, the defect was closed using non-resorbable barbed sutures.

The abdominal wall was reinforced by placing a macroporous, monofilament, medium-weight polypropylene prosthesis in the retro-muscular space. The size of the mesh used in all cases followed the guidelines, with an overlap of the defect of more than 5 cm in each direction (**Table 3**).

Mesh fixation was common during the early stages of the eTEP procedure. In a total of cases, the mesh was fixed using glue, tackers, or other methods in 25.9% (n = 51) of cases (**Table 4**).

I want to highlight that, during the initial 2 years of my experience, I used to fix the mesh. However, my current belief is that overlapping the defect is a safe and effective approach for preventing recurrence. Please refer to **Figure 2** for a visualization of the mesh fixation in the eTEP approach.

RESULTS

Throughout my surgeries, I experienced a total of three intraoperative safety events, which accounts for 1.5% of cases. In two instances, I unexpectedly discovered inguinal

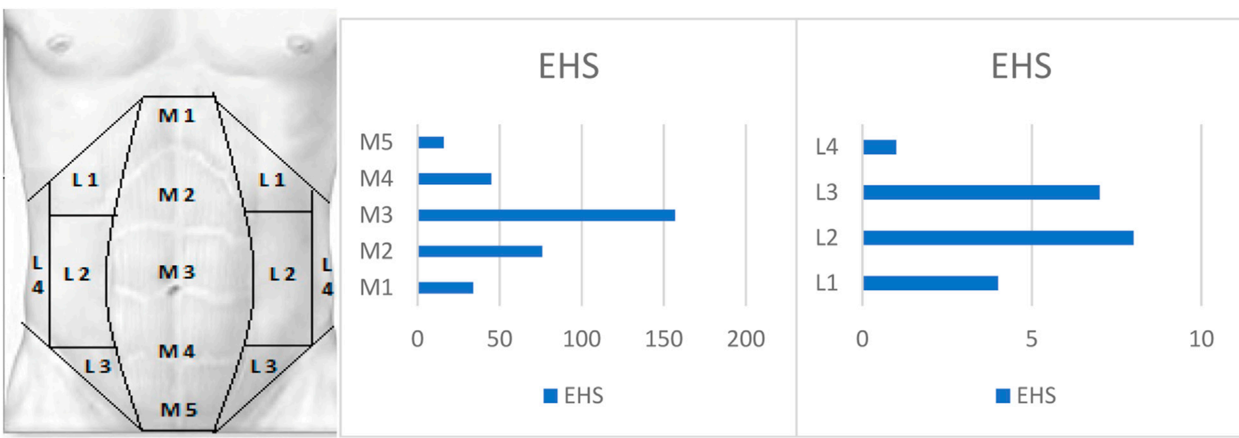

FIGURE 1 | Hernia locations according to the EHS classification are as follows.

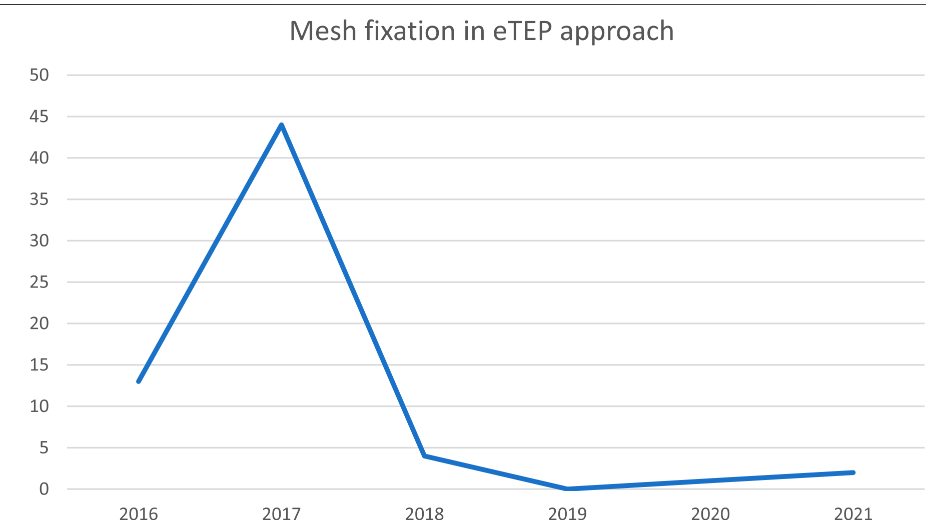

FIGURE 2 | Mesh fixation in eTEP approach.

TABLE 5 | Postoperative pain VAS score related.

VAS (level of pain)	Frequency	Percent
0	183	92.9
1	6	3.0
2	4	2.0
3	3	1.5
Total	196	99.5
Missing System	1	.5
Total	197	100.0

hernias that were not diagnosed prior to the operation due to the lack of clinical evidence. Additionally, there was one case where a small bowel injury occurred. However, I was able to successfully address and repair all of these issues during the same procedure.

The duration of the operating room (OR) time varied based on the complexity of the hernias (whether they were primary or incisional) and the specific procedure, such as with or without TAR. On average, the OR time was approximately 3 hours (176.37 min).

In the case of primary ventral hernia repair using the eTEP Rives-Stoppa procedure, the average operating room time was 2 hours (121.80 min), while it was 210 min for incisional hernia repair. The mean OR time in eTEP-TAR procedure was 250.54 min (median 240.00 min).

The majority of patients were discharged on the day following their surgery. In order to measure the length of hospitalization (LOS), I recorded the number of hours from the end of the surgery to the time of discharge. The median LOS in this study was found to be 20 h.

The shorter hospital stay can be attributed to the patients experiencing a low level of pain. On average, patients reported taking a median of 2.0 doses (min 0 - max 19) of regular painkillers such as ibuprofen or paracetamol, and no morphine-like medication was required.

Postoperatively, there were a few instances of complications observed. These included 1 case of small bowel obstruction caused by an intraparietal hernia through a ruptured sutured posterior rectus sheath (after eTEP Rives-Stoppa), 1 case of ischemia of the umbilical skin (after eTEP Rives-Stoppa), and 5 cases of retro-muscular hematoma (after eTEP-TAR), with 3 of them requiring re-operation. Additionally, there were 2 cases of suture rupture, one after eTEP Rives-Stoppa and the other after eTEP-TAR, both of which were re-operated on the following day. The postoperative course of the remaining 187 cases (94.9%) was without complications.

I have clinically monitored all of the patients or followed up with them via phone calls for a average period of 51 months (median 52.50 months). The key parameters we have monitored include recurrence (with one patient experiencing recurrence 18 months after surgery, above the mesh) and pain.

To measure the level of discomfort or pain, we utilized the visual analog scale (VAS). The results have been very positive, particularly during the first 3 months after the operation (**Table 5**).

DISCUSSION AND CONCLUSION

Results of the study indicated that there was a significant improvement in the quality of life of patients following the MIS retro-muscular procedure. The assessment, which measured postoperative pain, normal activity, and aesthetics on a 0–10 scale, showed improvement at 2 weeks and 3 months after surgery compared to the preoperative level. These results build upon the initial findings published by the same author after the first year of experience, on a cohort of 60 patients. The pain level has consistently been low from the start, with less than 3 doses of analgesics needed per day [8].

However, after a mean of 51.11 months, only one case of recurrence was reported. This recurrence occurred on top of the mesh, 18 months after the initial operation.

Regarding the surgical technique, retro-muscular repair continues to be the preferred method for open ventral hernia repair and is also deemed as the most effective approach in laparoscopic procedures. This technique is associated with fewer surgical site occurrences (SSO) and recurrences, as supported by existing literature [8]. Additionally, patients experience less pain and faster recovery time.

Placing the mesh in the retro-muscular space ensures excellent results in terms of mesh integration with the scar tissue and effective abdominal wall reinforcement. The ideal characteristics of the mesh include polypropylene monofilament, macroporous structure, and medium weight.

Although the eTEP Rives-Stoppa and eTEP-TAR techniques are advanced and require expertise, they combine the principles of the gold standard technique in open ventral hernia repair (Rives-Stoppa) with the benefits of minimally invasive surgery. Consequently, these techniques may yield the best outcomes for hernia treatment.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because the restrictions are related to GDPR: we did not use any personal data of the patients that could lead to the identification of patients (e.g., name, photos, etc.). Requests to access the datasets should be directed to VR, victoradu@gmail.com.

ETHICS STATEMENT

The protocol was approved by the ethics committee of the institution (Life Memorial Hospital—Medlife). All the patients gave the informed consent for procedure and scientific data use as standard in our hospital.

AUTHOR CONTRIBUTIONS

VR, the surgeon who performed the procedures, monitored the patients collected data, and edited the text DS put all the collected data in SPSS and edited the tables. All authors contributed to the article and approved the submitted version.

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CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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