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Robotic-Assisted Versus Open Transversus Abdominis Release (TAR) for Complex Ventral Hernia Repair: A Systematic Review and Meta-Analysis

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Abstract

Transversus abdominis release (TAR) is an effective posterior component separation technique for complex ventral hernia repair. While open TAR (oTAR) is the standard procedure, robotic-assisted TAR (rTAR) has emerged to mitigate the substantial wound morbidity associated with large abdominal incisions. This systematic review and meta-analysis aimed to evaluate the comparative effectiveness and safety of rTAR and oTAR. A systematic search of PubMed/MEDLINE, Embase, Cochrane Central Register of Controlled Trials (CENTRAL), Scopus, and Web of Science was conducted until August 2026. Studies comparing rTAR and oTAR in adults were included. The primary outcomes were overall complications, surgical site occurrences (SSOs), surgical site infections (SSIs), length of hospital stay (LOS), and hernia recurrence rates. Random-effects meta-analyses were performed, and the certainty of evidence was evaluated using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework. Twelve observational studies encompassing 1,651 patients (605 rTAR, 1,046 oTAR) met the inclusion criteria, with 10 studies providing data for quantitative synthesis (n=1,407). Compared with oTAR, rTAR was associated with a statistically significant reduction in overall postoperative complications (OR 0.48; 95% CI 0.34-0.68; p<0.001), SSOs (OR 0.43; 95% CI 0.25-0.75; p=0.003), and SSIs (OR 0.45; 95% CI 0.21-0.96; p=0.038). rTAR significantly reduced LOS (MD -3.76 days; 95% CI -4.68 to -2.84; p<0.001) and estimated blood loss (MD -107.44 mL; p<0.001), although it required significantly longer operative times (MD +53.62 min; p<0.001). In an exploratory subgroup analysis, the SSI reduction was observed with pure robotic techniques (OR 0.24) but not with hybrid approaches, which were represented by only two potentially overlapping studies. Data on long-term recurrence and patient-reported outcomes are sparse. Due to the observational nature of the included studies and inherent selection bias, the overall certainty of the evidence was rated as low to very low. rTAR is associated with perioperative advantages over oTAR, decreasing wound morbidity, overall complications, and LOS, albeit at the expense of longer operative times. Pure rTAR may offer greater wound benefit; however, high-quality randomized controlled trials are required to assess long-term hernia recurrence and cost-effectiveness.

Categories: General Surgery
Keywords: abdominal wall reconstruction, component separation, incisional hernia, meta-analysis, robotic surgical procedures, transversus abdominis release, ventral hernia

Introduction And Background

Ventral and incisional hernias represent significant and highly prevalent surgical challenges, with incisional hernias occurring in up to 20% of patients following laparotomy [1]. Repairing complex ventral hernias, characterized by large defect dimensions, altered tissue integrity, and loss of domain, is associated with high recurrence rates and substantial morbidity [2]. While the introduction of synthetic mesh improved durability compared to primary suture approximation, the management of complex and large defects exceeds the limits of standard retromuscular repair techniques [3].

To address the excessive tension associated with large fascial defects, component separation techniques have been developed. The traditional anterior component separation (ACS) necessitates extensive subcutaneous dissection, which carries a prohibitive risk of surgical site occurrences (SSOs) and wound morbidity, reported to be as high as 20-40% [2,3]. To circumvent these limitations, transversus abdominis release (TAR)

was introduced by Novitsky et al. in 2012 as a novel posterior component separation technique [4]. By dividing the transversus abdominis muscle, TAR facilitates massive medialization of the posterior rectus fascia, protects the neurovascular bundles, and creates a vast, well-vascularized extraperitoneal space for wide mesh reinforcement without the need for large fasciocutaneous flaps [2,4]. Open TAR (oTAR) has become the gold standard approach for complex abdominal wall reconstruction (AWR).

Despite its anatomical success and excellent long-term durability, oTAR still requires a large midline laparotomy, which is associated with postoperative pain, prolonged length of hospital stay (LOS), and notable risks of SSOs and surgical site infections (SSIs) [5,6]. The drive to mitigate these morbidities has led to the exploration of minimally invasive approaches. Although laparoscopic TAR is restricted by ergonomic and technical constraints in constrained workspaces, the advent of robotic surgical systems has expanded minimally invasive options in AWR [1,5]. Robotic-assisted TAR (rTAR) leverages three-dimensional visualization and articulating instruments to replicate the precise myofascial dissection and tension-free closure of oTAR while offering the established physiological benefits of minimally invasive surgery [6,7].

As the adoption of rTAR continues to expand, emerging literature suggests distinct advantages over the open approach, including reduced wound morbidity, diminished postoperative opioid consumption, and expedited functional recovery [6,8,9]. However, the evidence base for this remains fragmented. Previous studies and early meta-analyses have reported conflicting findings regarding operative times, severe perioperative complications, long-term recurrence rates, and overall healthcare costs [5,7]. Most recently, Cardoso et al. [6] pooled 10 observational studies (1,085 patients) with a search through February 2026. The present review extends the search to August 2026 and includes 12 studies (1,651 patients). It adds a pre-specified pure-versus-hybrid technique subgroup analysis, study-level Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) assessment, and outcome-level Grading of Recommendations Assessment, Development, and Evaluation (GRADE) ratings. Furthermore, as robotic learning curves plateau and utilization increases globally, a wealth of new observational data has emerged that necessitates an updated synthesis.

Therefore, this systematic review and meta-analysis aimed to evaluate the comparative effectiveness and safety of rTAR versus oTAR for complex ventral hernia repair. By quantitatively analyzing perioperative outcomes, postoperative complications, LOS, and patient-centered metrics, this study aims to provide an updated synthesis of the evidence to inform surgical decision-making and optimize patient selection for complex AWR.

Review

Methods

Protocol and Registration

This systematic review and meta-analysis was conducted in adherence to the updated Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [10]. The study protocol was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO; CRD420261344027) [11], ensuring methodological transparency and mitigating reporting biases.

Literature Search Strategy

A systematic literature search was performed across major electronic databases, including PubMed/MEDLINE, Embase, Cochrane Central Register of Controlled Trials (CENTRAL), Scopus, and Web of Science, from their inception to August 2026. To minimize publication bias, a grey literature search was conducted via ClinicalTrials.gov and the World Health Organization International Clinical Trials Registry Platform (WHO-ICTRP). The search syntax was constructed using a combination of Medical Subject Headings (MeSH), Emtree terms, and free-text keywords optimized with Boolean operators (AND, OR, NOT) and truncations. The search terms included "Transversus Abdominis Release", "TAR", "Robotic", "Robotic-assisted", "Open", "Ventral Hernia Repair", and "Abdominal Wall Reconstruction". Backward and forward citation searching ("snowballing") of all included articles and relevant reviews was manually performed to identify further eligible studies.

Eligibility Criteria

Study eligibility was strictly defined using the Population, Intervention, Comparator, Outcomes, and Study Design (PICOS) framework [12]. The population included adult patients (⩾18 years of age) undergoing complex ventral hernia repair (including incisional, recurrent, large, or loss-of-domain hernias). The intervention was rTAR, with or without mesh reinforcement, and the comparator was the oTAR.

The primary outcomes included overall complication rates, SSO, SSI, LOS, and hernia recurrence, while the secondary outcomes included operative time, readmission rates, reoperation rates, and systemic complications. We included randomized controlled trials (RCTs), prospective and retrospective cohort

studies, and case-control studies. Case reports, single-arm series lacking a comparator group, pediatric studies, cadaveric or animal investigations, and studies evaluating non-TAR component separation techniques were excluded.

Study Selection and Data Extraction

All retrieved records were imported into reference management software, where duplicates were automatically removed. Two investigators independently screened the titles and abstracts of the references, followed by a rigorous full-text evaluation of potentially eligible articles. Inter-rater reliability (IRR) during the selection process was quantified using Cohen's kappa coefficient (κ) to ensure robust agreement [13]. Discrepancies were resolved through arbitration by a third reviewer.

Data extraction was performed independently using a standardized, pre-piloted, electronic form. The extracted variables encompassed study characteristics (author, year, design), patient demographics (age, sex, BMI), hernia characteristics (defect size, recurrent status), and all primary and secondary perioperative and long-term outcomes. Outcomes were accepted as defined by each primary study. SSO was defined according to the Ventral Hernia Working Group criteria (SSI, seroma, hematoma, wound dehiscence, skin or soft tissue necrosis, cellulitis, non-healing wound, and enterocutaneous fistula), and SSI according to the Centers for Disease Control and Prevention (CDC) criteria. Perioperative outcomes were assessed within 30 days unless otherwise specified by the study. For studies reporting continuous data as medians with ranges or interquartile ranges, means and standard deviations were estimated using the mathematical methodologies described by Wan et al. [14].

Quality Assessment and Risk of Bias

The methodological quality and risk of bias of all included studies were independently evaluated by two reviewers using the ROBINS-I tool [15]. The overall certainty of the evidence for each primary outcome was evaluated and summarized using the GRADE framework [16].

Statistical Analysis

All statistical analyses and graphical visualizations were performed using R software version 4.6.1 (R Foundation for Statistical Computing, Vienna, Austria) utilizing the meta and metafor packages [17].

For dichotomous outcomes (e.g., SSOs, SSIs, complications, and readmissions), effect sizes were pooled and expressed as odds ratios (OR) with corresponding 95% confidence intervals (CIs). For continuous outcomes (e.g., operative time and LOS), effect sizes were calculated as mean differences (MD) or standardized mean differences (SMD) with 95% CIs. Recognizing the inherent clinical and methodological heterogeneity of surgical observational studies, a random-effects (RE) model utilizing the DerSimonian-Laird (DL) estimator was selected a priori as the primary pooling model [18].

Statistical heterogeneity across studies was quantified using the I^2 statistic and assessed via Cochran's Q test (where a p-value of <0.10 indicated significant heterogeneity). I^2 values of 25%, 50%, and 75% were interpreted as reflecting low, moderate, and substantial heterogeneity, respectively [19]. Leave-one-out sensitivity analyses were systematically conducted to explore the sources of heterogeneity and verify the robustness of the pooled estimates.

Publication bias and small-study effects were visually evaluated using a contour-enhanced funnel plot. For outcomes comprising 10 or more studies, funnel plot asymmetry was objectively quantified using Egger's regression test, with a p-value of <0.05 denoting significant publication bias [20].

Results

Literature Search and Study Selection

A systematic search of electronic databases and trial registries yielded 1,128 records. After the removal of 232 duplicates, 896 unique records underwent title and abstract screening. Of these, 31 reports were sought for full-text retrieval, and 27 were assessed for eligibility. Fifteen studies were excluded for the following reasons: wrong intervention (n=6), wrong population (n=5), lack of an oTAR comparator (n=2), insufficient TAR-specific outcomes (n=1), and non-isolatable hybrid procedures (n=1). Twelve observational studies met the inclusion criteria [21-32]. Ten of these studies provided arm-specific data for the quantitative meta-analysis. The study selection process is shown in the PRISMA flow diagram (Figure *1*).

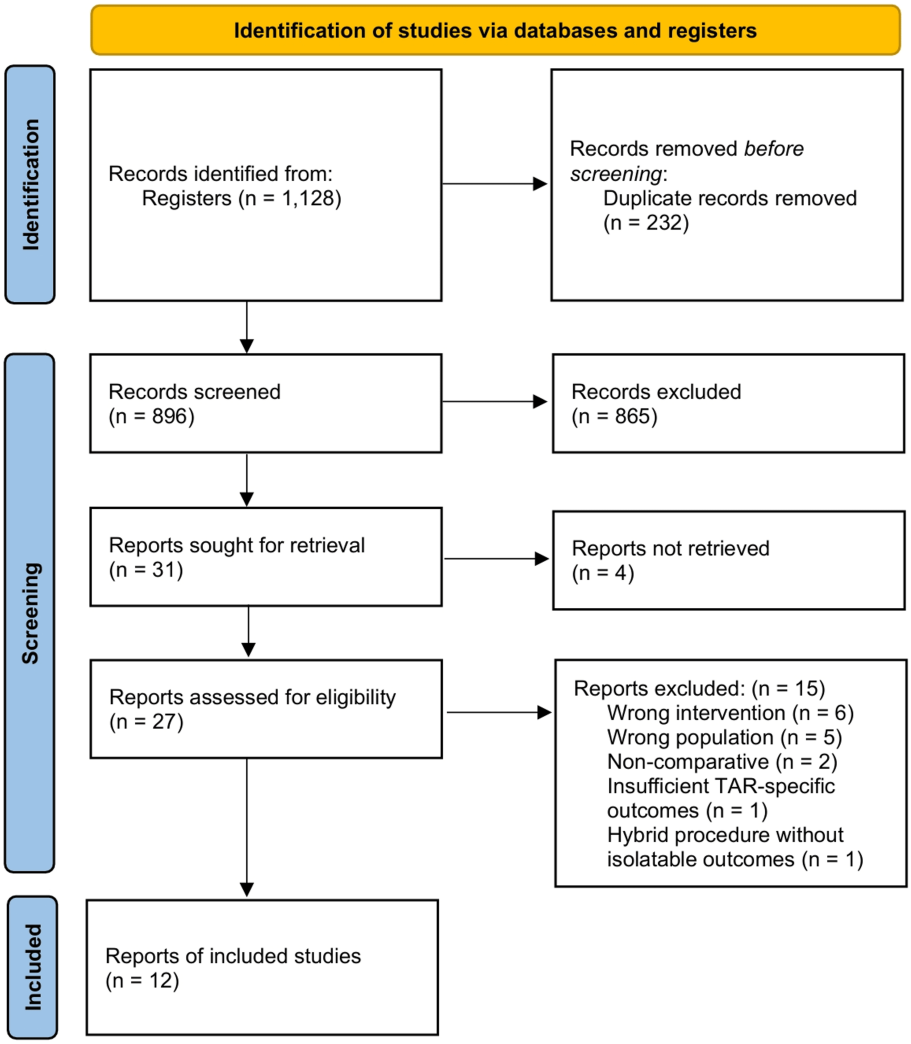


FIGURE 1: PRISMA 2020 flow diagram

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Study Characteristics and Patient Demographics

The 12 included studies comprised 1,651 patients, of whom 605 underwent rTAR and 1,046 underwent oTAR (Table *1*). The quantitative synthesis (k=10) included 1,407 patients. The studies included retrospective cohorts, case-matched cohorts, and propensity-matched analyses published between 2018 and 2025. Two studies utilized a hybrid robotic approach (robotic dissection with a midline incision for fascial closure) [23,25], while the remainder utilized a pure minimally invasive robotic technique. Age and BMI were broadly similar between arms (late 50s to 60s; mean BMI >30 kg/m^2), and mean defect widths ranged from 8.7 to 14.3 cm. Recurrent-hernia status was reported inconsistently, and adhesions, wound contamination class, and hernia-complexity grades were rarely reported per arm; therefore, comparability in hernia complexity could not be confirmed.

Study	Country	Design	Robotic technique	Laterality	Setting	n rTAR	n oTAR	FU rTAR (mo)	FU oTAR (mo)	Pooled
Bittner et al. 2018 [21]	USA	Retrospective cohort	Pure	Bilateral	Single center	26	76	3	3	Yes
Martin-del-Campo et al. 2018 [22]	USA	Case-matched cohort (1:2)	Pure	Bilateral	Two hernia centers	38	76	NR	NR	Yes
Halka et al. 2019 [23]	USA	Retrospective cohort	Hybrid	Bilateral	Single center (AHSQC)	49	134	1	1	Yes
Reeves et al. 2020 [24]	Australia	Case-control	Pure	Bilateral	Two tertiary hospitals	13	13	1	1	Yes
Abdu et al. 2021 [25]	USA	Propensity-matched (1:3)	Hybrid	Bilateral	Multicenter (AHSQC)	95	285	1	1	Yes
Dauser et al. 2021 [26]	Austria	Prospective database cohort	Pure	Mixed	Single center	16	10	NR	NR	Yes
Nguyen et al. 2021 [27]	USA	Retrospective cohort	Pure	Bilateral	Single center	27	16	1	1	Yes
Dewulf et al. 2022 [28]	NL/FI/BE	Two-center case-control	Pure	Bilateral	Two hernia centers	90	79	19	43	Yes
Kushner et al. 2022 [29]	USA	Retrospective cohort	Pure	Bilateral	Single quaternary center	88	212	1	1	Yes
Turcotte et al. 2024 [30]	USA	Retrospective cohort	Pure	Bilateral	Single surgeon	127	42	27.6	27.6	No
Van Hoef et al. 2025 [31]	Belgium	Retrospective cohort	Pure	Unilateral	Single center	10	54	1	1	Yes
Kushner et al. 2025 [32]	USA	Prospective cohort (PRO)	Pure	Bilateral	Single center	26	49	6	6	No

TABLE 1: Characteristics of the 12 included studies

rTAR: robotic-assisted transversus abdominis release; oTAR: open transversus abdominis release; FU: follow-up; mo: months; NR: not reported; AHSQC: Americas Hernia Society Quality Collaborative

Pure robotic technique denotes a wholly minimally invasive robotic TAR; hybrid denotes robotic TAR combined with a midline incision through the hernia sac for fascial closure. Pooled indicates whether the study contributed arm-specific data to at least one meta-analysis.

Risk of Bias and Certainty of Evidence

The methodological quality was assessed using the ROBINS-I tool (Figures 2-3). None of the included studies had a low overall risk of bias. Eight studies were judged to be at serious overall risk and four at moderate risk. The most prevalent domains driving the elevated risk were confounding (D1) and selection of participants (D2), reflecting the non-randomized nature of the surgical assignments which were influenced by surgeon preference, robotic availability, and chronological era. The GRADE certainty of evidence for all outcomes was rated as low or very low (Table 2).

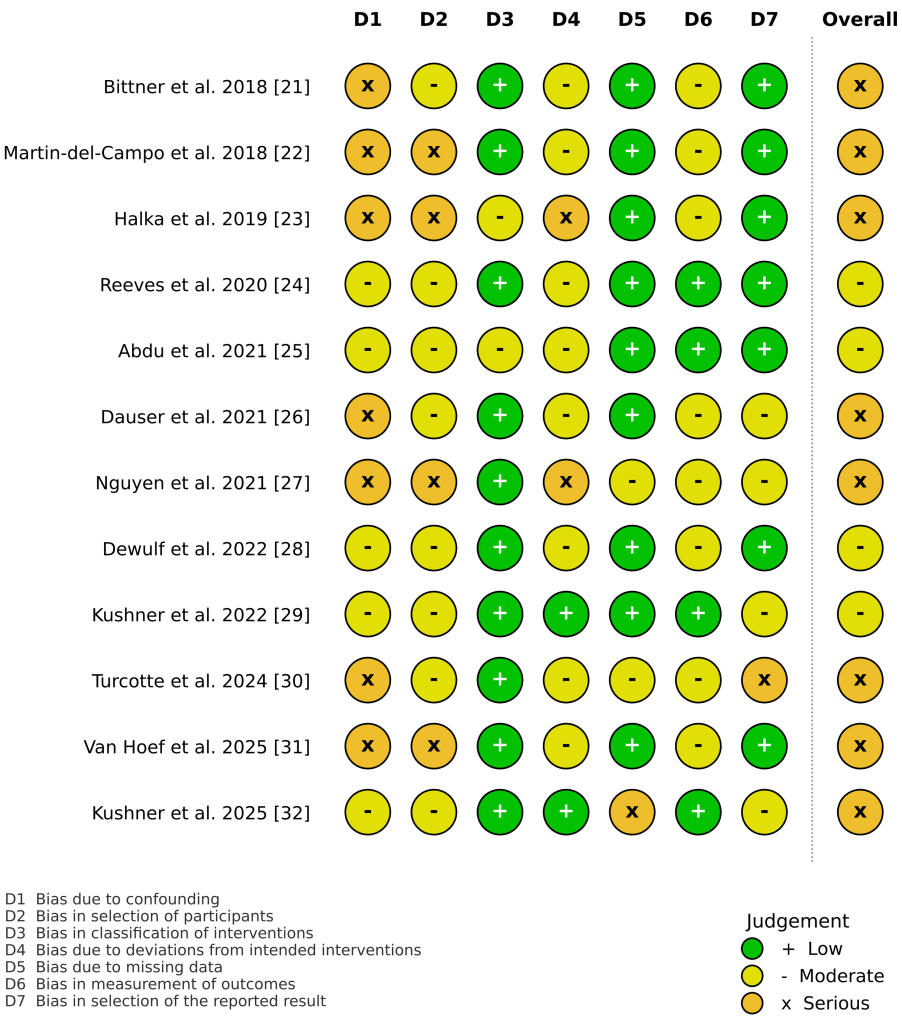


FIGURE 2: ROBINS-I traffic-light plot for all 12 included studies

ROBINS-I: Risk of Bias in Non-randomized Studies of Interventions

Domain-level and overall ROBINS-I judgements for each included study: Bittner et al. 2018 [21], Martin-del-Campo et al. 2018 [22], Halka et al. 2019 [23], Reeves et al. 2020 [24], Abdu et al. 2021 [25], Dauser et al. 2021 [26], Nguyen et al. 2021 [27], Dewulf et al. 2022 [28], Kushner et al. 2022 [29], Turcotte et al. 2024 [30], Van Hoef et al. 2025 [31], and Kushner et al. 2025 [32]. Green plus signs denote low risk, yellow minus signs moderate risk, and amber crosses serious risk. Every study carries at least one serious- or moderate-risk domain; eight of 12 are at serious risk overall, driven principally by confounding (D1) and participant selection (D2).

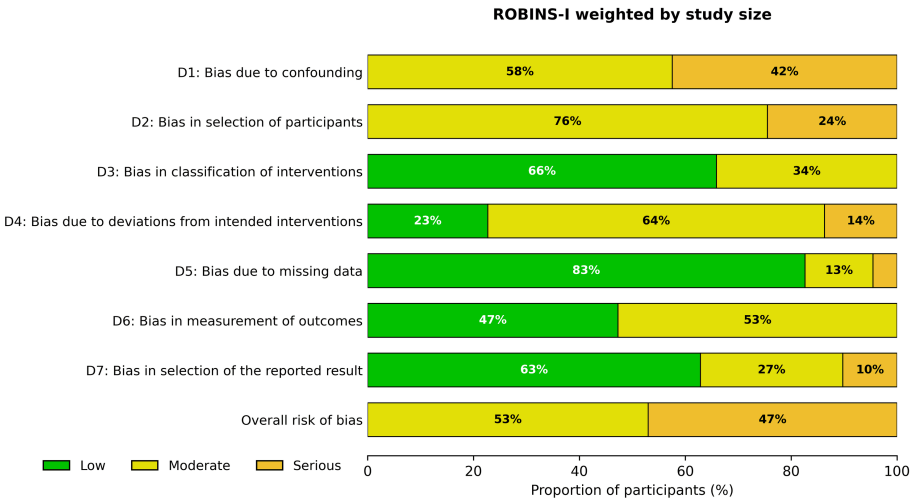


FIGURE 3: Distribution of ROBINS-I judgements weighted by study size

ROBINS-I: Risk of Bias in Non-randomized Studies of Interventions

Green plus signs denote low risk, yellow minus signs moderate risk, and amber crosses serious risk, with each study weighted by its total number of patients rather than counted equally. Weighting shifts the profile towards lower risk in several domains, confounding (serious risk falls from 83% of studies to 66% of patients), because the two largest contributions, Abdu et al. [25] (n=380) and Kushner et al. [29] (n=300), are the studies at moderate rather than serious overall risk. Even so, no domain approaches low risk, and 47% of the pooled patient population contributes evidence judged at serious overall risk of bias.

Outcome	k	n	Effect (95% CI)	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Upgrade	Certainty
Overall postoperative complications	7	870	OR 0.48 (0.34 to 0.68)	-1 serious	0 not serious	0	0	Not est.	+1 large effect?	LOW
Surgical site occurrence	6	1,091	OR 0.43 (0.25 to 0.75)	-1 serious	0 not serious	0	0	Not est.	0	LOW
Surgical site infection	9	1,381	OR 0.45 (0.21 to 0.96)	-1 serious	0 not serious	0	-1 sparse	Not est.	0	VERY LOW
Length of hospital stay	10	1,407	MD −3.76 d (−4.68 to −2.84)	-1 serious	-1 high I^2	0	0	Assessed	+1 large effect	LOW
Hernia recurrence	1	169	Peto OR 1.10 (0.29 to 4.22)	-2 v.serious	n/a	-1 short FU	-1 sparse	Not est.	0	VERY LOW
Operative time	8	727	MD +53.6 min (31.8 to 75.5)	-1 serious	-1 high I2	0	0	Not est.	0	LOW
Surgical site occurrence requiring procedural intervention	6	879	OR 0.49 (0.28 to 0.86)	-1 serious	0 not serious	0	-1 sparse	Not est.	0	VERY LOW
30-day readmission	7	888	OR 0.56 (0.31 to 1.00)	-1 serious	0 not serious	0	-1 sparse	Not est.	0	VERY LOW
Reoperation	3	596	OR 0.60 (0.27 to 1.37)	-1 serious	n/a	0	-1 sparse	Not est.	0	VERY LOW
Systemic/medical complications	4	384	OR 0.48 (0.20 to 1.12)	-1 serious	0 not serious	0	-1 sparse	Not est.	0	VERY LOW

TABLE 2: GRADE summary of findings

GRADE: Grading of Recommendations Assessment, Development, and Evaluation

All outcomes start at LOW certainty because the entire evidence base is non-randomized. "−1" and "−2" indicate the number of levels deducted in that domain; "0" indicates no deduction; and "+1" indicates an upgrade. Inconsistency was rated from the observed I^2 for each pooled outcome. Imprecision was rated down where the total event count was small or the confidence interval crossed a decision threshold. Publication bias was formally assessed only for length of stay (k=10) and could not be estimated elsewhere. Length of stay was upgraded for a large magnitude of effect; the upgrade shown against overall complications is marked provisional in the source assessment and was not applied to the final rating. Four outcomes rate LOW and six VERY LOW; no outcome reaches moderate or high certainty. n is the total number of patients contributing to that outcome.

Primary Outcomes

Overall postoperative complications: Data on overall postoperative complications were reported in seven studies (n=870 patients) [21,23,24,26,28,29,31]. The implementation of rTAR was associated with a statistically significant 52% reduction in the odds of overall complications compared with oTAR (OR 0.48; 95% CI 0.34-0.68; p<0.001). There was no statistical heterogeneity among the included studies (I^2=0.0%; p=0.737) (Figure *4*).

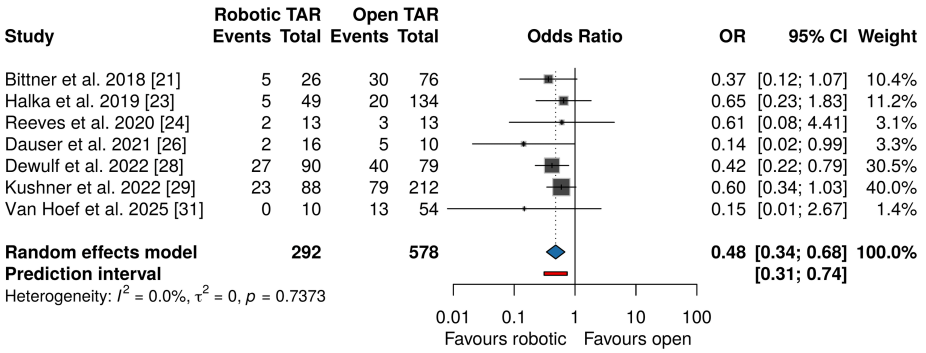


FIGURE 4: Forest plot: overall postoperative complications

TAR: transversus abdominis release

Random-effects meta-analysis of overall postoperative complications in seven studies: Bittner et al. 2018 [21], Halka et al. 2019 [23], Reeves et al. 2020 [24], Dauser et al. 2021 [26], Dewulf et al. 2022 [28], Kushner et al. 2022 [29], and Van Hoef et al. 2025 [31] (292 robotic and 578 open patients, 254 events). Squares represent individual study odds ratios with the square area proportional to study weight; horizontal lines are 95% confidence intervals; the diamond is the pooled random-effects estimate (OR 0.48; 95% CI 0.34-0.68) and the bar beneath it the 95% prediction interval. Odds ratios below 1 favor robotic TAR. Heterogeneity: I^2=0.0%; τ^2=0; P(Q)=0.737.

SSOs and SSIs: SSOs were reported in six studies [21,22,24,25,28,29], five of which had evaluable events contributing to the pooled effect estimate (Bittner et al. [21] reported zero events in both arms). The rTAR approach demonstrated a significant protective effect against SSOs, with a pooled OR of 0.43 (95% CI 0.25-0.75; p=0.003; I^2=24.1%) (Figure 5).

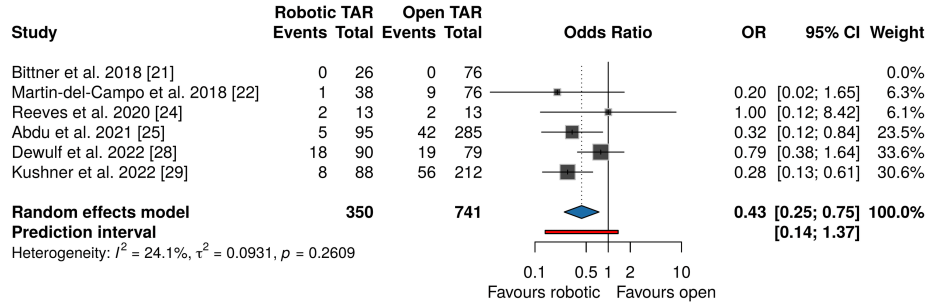


FIGURE 5: Forest plot: surgical site occurrence

TAR: transversus abdominis release

Random-effects meta-analysis of surgical site occurrences across evaluated studies: Bittner et al. 2018 [21], Martin-del-Campo et al. 2018 [22], Reeves et al. 2020 [24], Abdu et al. 2021 [25], Dewulf et al. 2022 [28], and Kushner et al. 2022 [29]. Bittner et al. [21] recorded no events in either arm and is displayed with zero weight. Pooled OR 0.43 (95% CI 0.25-0.75); p=0.003. Heterogeneity: I^2=24.1%; τ^2=0.093; P(Q)=0.261.

Similarly, across nine studies reporting SSIs, rTAR was associated with a statistically significant reduction in the odds of wound infection compared with oTAR (OR 0.45; 95% CI 0.21-0.96; p=0.038; I^2=28.1%) (Figure 6).

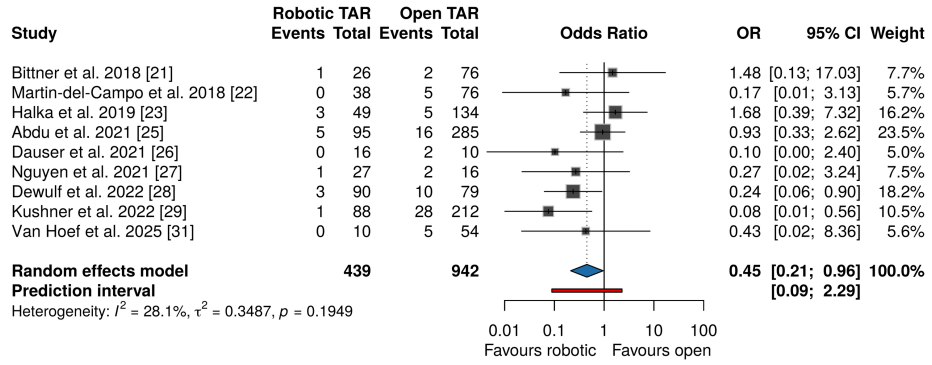


FIGURE 6: Forest plot: surgical site infection

TAR: transversus abdominis release

Random-effects meta-analysis of surgical site infection in nine studies: Bittner et al. 2018 [21], Martin-del-Campo et al. 2018 [22], Halka et al. 2019 [23], Abdu et al. 2021 [25], Dauser et al. 2021 [26], Nguyen et al. 2021 [27], Dewulf et al. 2022 [28], Kushner et al. 2022 [29], and Van Hoef et al. 2025 [31] (439 robotic and 942 open patients, 89 events). A continuity correction of 0.5 was applied to studies with a zero cell. Pooled OR 0.45 (95% CI 0.21-0.96); p=0.038. Heterogeneity: I²=28.1%; τ²=0.349; P(Q)=0.195. The wide prediction interval reflects the small number of events relative to the number of studies.

LOS: Ten studies contributed to the analysis of postoperative LOS (n=1,407). Patients undergoing rTAR experienced a significantly shorter hospital stay, with a pooled mean difference (MD) of -3.76 days (95% CI −4.68 to −2.84; p<0.001) (Figure 7). Substantial heterogeneity was noted (I^2=89.0%; p<0.001); however, all the included studies consistently favored the robotic approach.

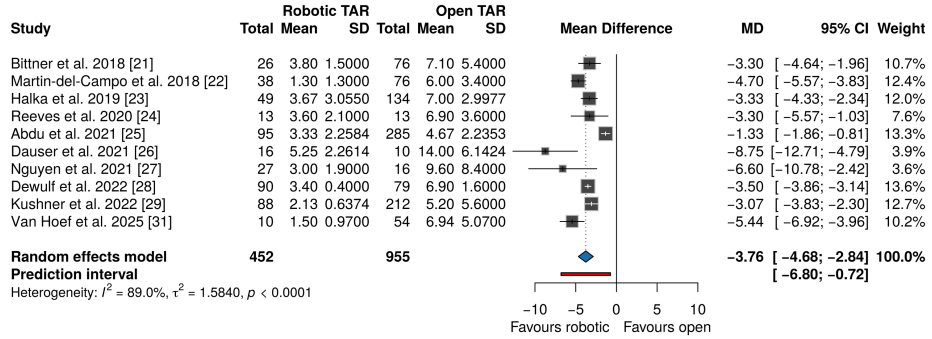


FIGURE 7: Forest plot: length of hospital stay

TAR: transversus abdominis release

Random-effects meta-analysis of postoperative length of hospital stay in 10 studies: Bittner et al. 2018 [21], Martin-del-Campo et al. 2018 [22], Halka et al. 2019 [23], Reeves et al. 2020 [24], Abdu et al. 2021 [25], Dauser et al. 2021 [26], Nguyen et al. 2021 [27], Dewulf et al. 2022 [28], Kushner et al. 2022 [29], and Van Hoef et al. 2025 [31] (452 robotic and 955 open patients). Pooled mean difference −3.76 days (95% CI −4.68 to −2.84) (p<0.001), favoring robotic TAR. Heterogeneity was substantial: I²=89.0%; τ²=1.584; P(Q)<0.0001. Study means and SDs are tabulated within the plot; several were reconstructed from medians.

Hernia recurrence: Data on long-term hernia recurrence are sparse and incompatible with meta-analytic pooling. Only Dewulf et al. [28] provided an estimable comparison, showing no significant difference between the arms (Peto OR 1.10; 95% CI 0.29-4.22); however, the follow-up times were markedly unbalanced (19 months for rTAR vs. 43 months for oTAR). Therefore, recurrence data were summarized narratively and rated as very-low-certainty evidence.

Secondary Outcomes

Operative time and estimated blood loss: Skin-to-skin operative time, reported in eight studies, was significantly longer in the rTAR group, requiring an additional 53.62 minutes on average (95% CI 31.79-75.45; p<0.001; I^2=61.2%) (Figure 8).

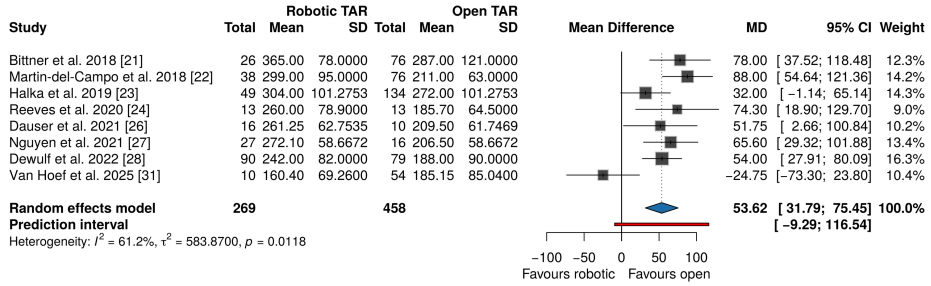


FIGURE 8: Forest plot: operative time

TAR: transversus abdominis release

Random-effects meta-analysis of skin-to-skin operative time in eight studies: Bittner et al. 2018 [21], Martin-del-Campo et al. 2018 [22], Halka et al. 2019 [23], Reeves et al. 2020 [24], Dauser et al. 2021 [26], Nguyen et al. 2021 [27], Dewulf et al. 2022 [28], and Van Hoef et al. 2025 [31] (269 robotic and 458 open patients). Pooled mean difference 53.62 minutes (95% CI 31.79-75.45) (p<0.001), indicating longer operations in the robotic arm. Heterogeneity: I²=61.2%; τ²=583.87; P(Q)=0.012. Van Hoef et al. [31], the only study of unilateral TAR, is the sole study favoring the robotic approach.

Estimated intraoperative blood loss (reported in three studies [22,27,29]) was significantly lower in the robotic cohort, with an MD of -107.44 mL (95% CI −118.82 to −96.06; p<0.001; I^2=0.0%) (Figure 9).

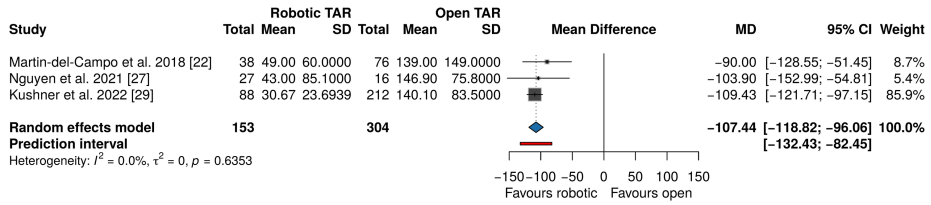


FIGURE 9: Forest plot: estimated blood loss

TAR: transversus abdominis release

Random-effects meta-analysis of estimated intraoperative blood loss in three studies: Martin-del-Campo et al. 2018 [22], Nguyen et al. 2021 [27], and Kushner et al. 2022 [29] (153 robotic and 304 open patients). Pooled mean difference −107.44 mL (95% CI −118.82 to −96.06) (p<0.001), favoring robotic TAR. Heterogeneity: I²=0.0%; τ²=0; P(Q)=0.635. Kushner et al. [29] contributes 85.9% of the weight.

Postoperative interventions and readmissions: The need for procedural intervention to address SSO (SSOPI) was significantly lower following rTAR across six reporting studies (OR 0.49; 95% CI 0.28-0.86; p=0.012; I^2=0.0%). Analysis of 30-day hospital readmissions (k=7) yielded a borderline result that did not reach conventional statistical significance (OR 0.56; 95% CI 0.31-1.00; p=0.051; I^2=0.0%). Furthermore, reoperation rates (k=3) showed no significant difference between the two surgical approaches (OR 0.60; 95% CI 0.27-1.37; p=0.224).

Systemic and intraoperative complications: There were no statistically significant differences between rTAR and oTAR in terms of the incidence of systemic/medical complications (OR 0.48; 95% CI 0.20-1.12; p=0.090), intraoperative complications (OR 0.50; 95% CI 0.21-1.18; p=0.114), or clinically apparent seroma formation (OR 0.57; 95% CI 0.27-1.20; p=0.142).

Patient-reported outcomes (PROs): PROs were reported in one study [32], but could not be pooled. The authors reported that HerQLes scores differed significantly at baseline (48.72 rTAR vs. 62.95 oTAR; p=0.001), preventing a like-for-like comparison of the percentage change. However, neither the HerQLes nor Carolinas Comfort Scale (CCS) percentage changes showed statistically significant differences between the arms at 180 days.

Subgroup, Sensitivity, and Publication Bias Analyses

A predefined subgroup analysis comparing pure and hybrid robotic techniques (Table 3) revealed a marked and statistically significant subgroup difference in SSI (p=0.009). The reduction in SSI was observed in pure rTAR (OR 0.24; 95% CI 0.10-0.54), whereas the hybrid technique exhibited no benefit over oTAR (OR 1.13;

95% CI 0.49-2.64). Because the hybrid subgroup comprised only two studies drawing on overlapping Americas Hernia Society Quality Collaborative (AHSQC) cohorts [23,25], this finding is hypothesis-generating.

Outcome	Metric	k pure	Pure rTAR (95% CI)	I² pure	k hybrid	Hybrid rTAR (95% CI)	I² hybrid	Q between	P-value
Overall complications	OR	6	0.46 (0.32 to 0.67)	0.0%	1	0.65 (0.23 to 1.83)	—	0.36	0.549
Surgical site occurrence	OR	4	0.47 (0.23 to 0.97)	36.5%	1	0.32 (0.12 to 0.84)	—	0.39	0.534
Surgical site infection	OR	7	0.24 (0.10 to 0.54)	0.0%	2	1.13 (0.49 to 2.64)	0.0%	6.82	0.009
SSOPI	OR	4	0.39 (0.17 to 0.91)	0.0%	2	0.59 (0.28 to 1.24)	0.0%	0.49	0.483
30-day readmission	OR	6	0.44 (0.21 to 0.93)	0.0%	1	0.81 (0.32 to 2.05)	—	0.99	0.321
Systemic complications	OR	3	0.24 (0.05 to 1.12)	0.0%	1	0.65 (0.23 to 1.83)	—	1.08	0.299
Seroma	OR	3	0.63 (0.29 to 1.40)	0.0%	1	0.29 (0.04 to 2.32)	—	0.47	0.493
Length of hospital stay	MD	8	−4.09 (−4.84 to −3.34)	69.2%	2	−2.29 (−4.24 to −0.33)	91.8%	2.83	0.092
Operative time	MD	7	57.12 (32.91 to 81.34)	62.1%	1	32.00 (−1.14 to 65.14)	—	1.44	0.230

TABLE 3: Subgroup analysis: pure versus hybrid rTAR

rTAR: robotic-assisted transversus abdominis release; SSOPI: need for procedural intervention to address surgical site occurrence; AHSQC: Americas Hernia Society Quality Collaborative

Subgroups are defined by robotic technique: pure (wholly minimally invasive) versus hybrid (robotic dissection with a midline incision for fascial closure). Q between and its p-value test for a difference between subgroups under the random-effects model. Only surgical site infection shows a statistically significant subgroup difference (p=0.009), with a marked benefit confined to pure rTAR (OR 0.24) and no effect for hybrid technique (OR 1.13). This finding rests on only two hybrid studies, Halka et al. [23] and Abdu et al. [25], which draw on overlapping AHSQC cohorts and should be interpreted as hypothesis-generating. Intraoperative complications, estimated blood loss, and reoperation were not subgrouped because all contributing studies used the same technique or the subgroup contained fewer than two studies.

The leave-one-out sensitivity analyses confirmed the robustness of the primary estimates. The effect direction and significance for overall complications, SSOs, SSOPI, LOS, and operative time remained stable regardless of which study was omitted. The SSI reduction became borderline non-significant only upon the exclusion of Dewulf et al. [28] (p=0.123). The meta-regression of publication year on LOS (I^2=0.00%; p=0.617) indicated that the observed heterogeneity in hospital stay reductions was not attributable to accumulating robotic experience or secular shifts in enhanced recovery practices over time (Table *4*).

Moderator	Estimate	SE	z	95% CI	P-value
Intercept	239.098	485.828	0.492	−713.108 to 1191.304	0.623
Publication year	−0.120	0.240	−0.500	−0.591 to 0.351	0.617

TABLE 4: Mixed-effects meta-regression of publication year on length of hospital stay

Model characteristics: k=10; τ² estimator DerSimonian-Laird; residual τ²=1.900 (SE 1.528); residual I²=90.23%; H²=10.23; R^2=0.00%. Test for residual heterogeneity: Q_e(df=8)=81.859; p<0.0001. Test of moderators: Q_m(df=1)=0.250; p=0.617. Publication year was examined as a proxy for accumulating robotic experience and for secular change in enhanced-recovery practice. It explains none of the between-study variance in length of stay (R^2=0.00%) and substantial residual heterogeneity persists, so the marked inconsistency in this outcome is not attributable to calendar time. No other moderator was modelled, since with 10 studies any further meta-regression would be severely overfitted.

Publication bias was assessed using Egger's regression test and contour-enhanced funnel plots for LOS, the only outcome meeting the threshold of 10 studies (Figure *10*). The test provided no statistical evidence of small-study effects or funnel plot asymmetry (p=0.249); however, due to substantial genuine heterogeneity,

the potential for publication bias cannot be entirely excluded.

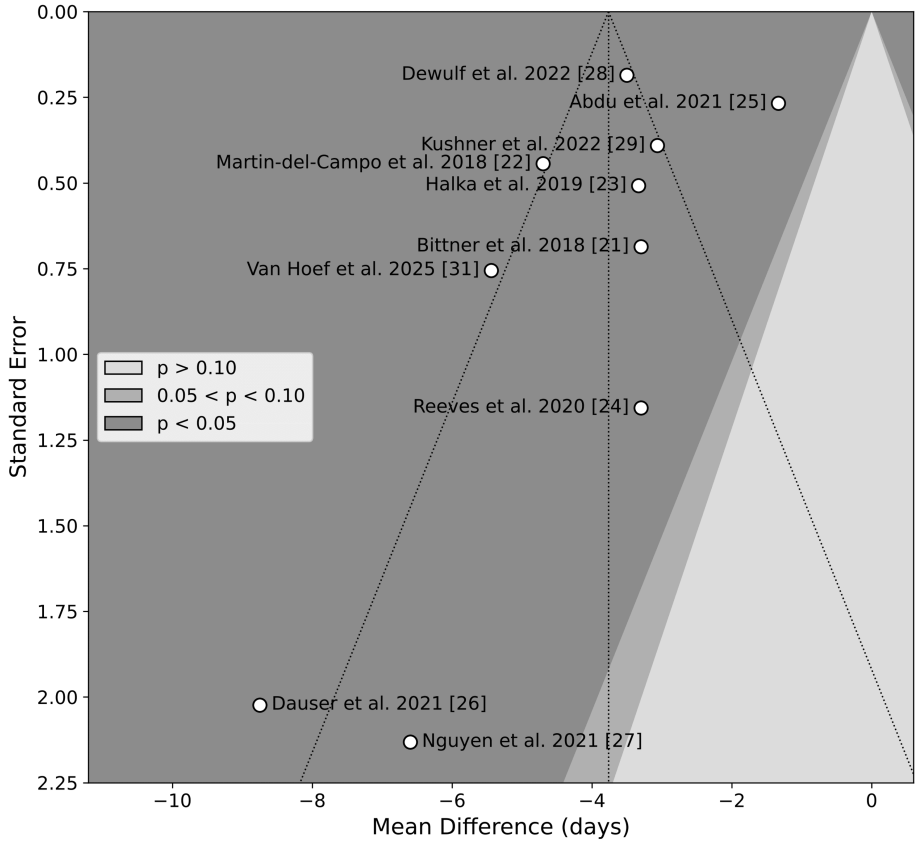


FIGURE 10: Contour-enhanced funnel plot: length of hospital stay

Funnel plot of the studies contributing to the length-of-stay analysis (Bittner et al. 2018 [21], Martin-del-Campo et al. 2018 [22], Halka et al. 2019 [23], Reeves et al. 2020 [24], Abdu et al. 2021 [25], Dauser et al. 2021 [26], Nguyen et al. 2021 [27], Dewulf et al. 2022 [28], Kushner et al. 2022 [29], and Van Hoef et al. 2025 [31]), with mean difference on the horizontal axis and standard error on the vertical axis. Shaded contours mark regions of statistical significance ($p>0.10$, $0.05<p\leq0.10$, $p\leq0.05$), so that studies falling in unshaded regions would indicate that asymmetry is unlikely to be driven by significance-chasing alone. Egger's regression test found no significant asymmetry ($t=-1.24$; $df=8$; $p=0.249$). Visual interpretation is limited by the small number of studies and by the substantial genuine heterogeneity in this outcome.

Discussion

The surgical management of complex ventral hernias requires a delicate balance between achieving durable, tension-free myofascial closure and minimizing perioperative morbidity. While oTAR has revolutionized AWR, its associated large incisions and subsequent wound complications remain critical clinical challenges [2,4]. This updated systematic review and meta-analysis of 12 observational studies comprising 1,651 patients demonstrated that rTAR offers a perioperative advantage over the traditional open approach. Specifically, rTAR was associated with a 52% reduction in the odds of overall postoperative complications, a 57% reduction in SSOs, and a clinically significant decrease in LOS by nearly four days.

The reduction in wound morbidity, as evidenced by significant decreases in SSOs, SSIs, and SSOPI, is the most compelling argument for the robotic platform in AWR. By circumventing the need for a large midline laparotomy and extensive subcutaneous flap creation, rTAR preserves the vascular supply to the anterior abdominal wall and limits dead space formation [3,21]. Our exploratory subgroup analysis suggested that the protective effect against SSIs may be limited to pure rTAR procedures (OR 0.24), whereas the hybrid technique, which combines robotic dissection with a midline incision for fascial closure, failed to demonstrate a significant SSI benefit over conventional oTAR (OR 1.13) [23,25]. This hypothesis-generating finding raises the possibility that avoiding the midline laparotomy incision contributes to improved wound outcomes in robotic AWR, emphasizing the importance of mastering pure intracorporeal fascial closure and mesh deployment. Our pooled SSI and readmission estimates (OR 0.45 and 0.56) are more conservative than those of Cardoso et al. (OR 0.27 and 0.39) [6]. However, our pure rTAR estimates (OR 0.24 and 0.44) closely match theirs, suggesting that the difference may reflect our inclusion and separate analysis of the hybrid cohorts [23,25].

In addition to superior wound outcomes, the rTAR cohort demonstrated markedly accelerated postoperative recovery, as reflected by a mean LOS reduction of 3.76 days. This is likely multifactorial, driven by reduced surgical trauma, lower estimated blood loss, decreased postoperative pain, and expedited return of bowel function [5,29]. While the 30-day readmission rate demonstrated a borderline reduction favoring rTAR (p=0.051), leave-one-out sensitivity analyses indicated that this finding was unstable. Furthermore, the odds of systemic complications and the necessity for reoperation did not differ significantly between the two modalities, indicating that while rTAR mitigates local wound issues, it does not eliminate the systemic risks of major AWR in often highly comorbid populations.

The primary trade-off for these minimally invasive benefits is a significantly prolonged operative time, with rTAR requiring an average of 53 additional minutes compared to conventional TAR. This increase is attributable to the necessary steps of robotic docking and undocking and the steep learning curve associated with complex intracorporeal suturing in a constrained extraperitoneal space [22,28]. However, as surgical teams surpass their learning curves and robotic technology evolves, operative times will likely progressively decrease. Our meta-regression analysis indicated that the publication year did not account for the variation in LOS, suggesting that institutional variations in enhanced recovery pathways and baseline patient complexity play more substantial roles than chronological technological maturation alone.

Despite these promising perioperative results, the evidence base has several critical limitations. First, all included studies were observational, and the overall ROBINS-I assessments indicated a moderate-to-serious risk of bias across the literature [15]. Selection bias and confounding by indication are pervasive; surgeons select operative approaches based on hernia size, loss of domain, and comorbidities. Although the extracted baseline defect widths were comparable between the arms (ranging from 8.7 cm to 14.3 cm), it is highly probable that the most hostile abdomens, widest defects, and cases with dense visceral adhesions were selectively channelled to the open cohort [28,31]. Because only two studies used matching [22,25] and adjusted estimates were not consistently reported, unadjusted estimates were pooled; the pooled effects therefore represent associations that remain susceptible to residual confounding. The GRADE certainty of evidence across all outcomes was rated as low or very low [16].

Second, the literature lacks long-term follow-up data. Hernia recurrence is the ultimate barometer of AWR success. In our review, recurrence data were too sparse and temporally unbalanced to allow for a reliable meta-analytic pooled estimate [28,31]. The durability of intracorporeal robotic fascial closure under physiological stress over a three- to five-year period remains to be proven compared to the robust heavy suture closure typically achieved in oTAR. Finally, the analysis of PROs and rigorous cost-effectiveness data was insufficient. While Dauser et al. [26] reported isolated cost metrics and Kushner et al. [32] reported on the HerQLes survey, the lack of standardized, uniformly reported data precluded quantitative data pooling. Given the high capital and consumable costs of robotic systems, evaluating whether the financial burden is adequately offset by shorter hospital stays and fewer SSO-related readmissions is an imperative next step for health economists [26].

Conclusions

rTAR is a promising option for complex ventral hernias that aims to combine the anatomical durability of posterior component separation with the physiological benefits of minimally invasive surgery. Low- to very-low-certainty observational evidence suggests that rTAR is associated with fewer overall postoperative complications, wound morbidity, and LOS compared to oTAR, albeit with an increased operative duration. Exploratory data suggest that the SSI benefit may be greater with a purely minimally invasive technique, although this requires confirmation. However, the literature is constrained by observational designs, selection bias, and a conspicuous absence of long-term recurrence data. High-quality multicenter RCTs with extended follow-up, standardized cost analyses, and patient-reported outcome measures are required to define the role of rTAR in complex AWR.

Additional Information

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All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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