



## Operative time difference between robotic and laparoscopic ventral hernia repair: A systematic review and meta-analysis

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### Abstract

Robotic ventral hernia repair (rVHR) has been rapidly adopted globally, driven by the promise of superior articulation and reduced wound morbidity compared with laparoscopic ventral hernia repair (IVHR). However, the magnitude of the operative time penalty remains a subject of intense debate. This meta-analysis aimed to pool real-world evidence comparing the clinical outcomes and operational efficiencies of the two platforms.

We conducted a systematic search of PubMed, Embase, and Google Scholar, focusing on contemporary comparative studies that evaluated elective rVHR versus IVHR. Continuous outcomes were expressed as mean differences (MD) and binary events as risk ratios (RR) with 95% confidence intervals (CI). Five comparative studies (45,787 patients) were reviewed, and four studies (552 patients) contributed data for the quantitative meta-analysis of operative time and SSOs.

Regarding operative efficiency, rVHR was associated with a statistically significant time penalty (Pooled MD: 47.78 min longer; 95% CI: [12.68, 82.88];  $P = 0.0076$ ), although with high clinical heterogeneity ( $I^2 = 95.9\%$ ). Conversely, pooling of binary surgical site occurrences (SSOs) revealed no statistically significant difference in postoperative wound complication rates (Pooled RR: 0.61; 95% CI: [0.22, 1.68];  $P = 0.3376$ ;  $I^2 = 42.2\%$ ).

RVHR yields a short-term wound safety profile similar to that of conventional laparoscopy; however, it incurs a significant intraoperative time penalty of nearly 48 min. Surgeons must carefully balance the advantages of the robotic platform with the increased operative duration and costs.

**Keywords:** Ventral hernia repair, robotic surgery, laparoscopy, operative time penalty, surgical site occurrences, abdominal wall reconstruction

### Introduction

Ventral abdominal wall hernias represent a substantial and growing clinical burden in general surgery, accounting for hundreds of thousands of elective repairs annually. The primary objective of ventral hernia repair (VHR) is to durably restore myofascial continuity while minimizing patient morbidity. Historically, open repair was the gold standard; however, it is associated with high rates of surgical site infections (SSIs) and prolonged hospital stays<sup>[1]</sup>. The advent of conventional laparoscopic ventral hernia repair (LVHR) has revolutionized the field, drastically lowering the incidence of wound complications and accelerating patient recovery.

Despite these advantages, standard laparoscopy has inherent limitations. The rigid geometry of laparoscopic instrumentation introduces a "straight-stick" limitation that complicates precise intracorporeal suturing, limits comfortable maneuverability in dense abdominal spaces, and creates barriers to primary fascial closure. Consequently, IVHR often relies on bridging the defect with an exposed mesh, a factor associated with higher rates of bulging, seroma, and structural recurrence<sup>[2]</sup>.

Robotic-assisted ventral hernia repair (rVHR) has been performed exponentially over the last decade. The robotic platform provides seven degrees of freedom via wrist instrumentation, high-definition three-dimensional visualization, and tremor filtration. These advances allow surgeons to perform complex abdominal wall

reconstructions (AWR) via minimally invasive approaches, including robotic transabdominal preperitoneal (rvTAPP) and enhanced-view totally extraperitoneal (eTEP) repairs, which facilitate primary fascial closure and extraperitoneal mesh placement<sup>[3,4]</sup>.

The ability to shift surgical dissection away from the hostile intraperitoneal space and seamlessly enter the retrorectus and preperitoneal sub-planes represents a transformative contribution of the robotic platform. Using advanced architectures, such as rvTAPP and eTEP Rives-Stoppa reconstructions, surgeons can now routinely achieve primary fascial closure and isolate synthetic mesh from bowel loops without requiring traumatic mechanical fixation hardware. However, deploying these advanced preperitoneal and retromuscular robotic reconstructions remains technically challenging, particularly when managing complex, high-volume fascial defects that approach or meet the standardized criteria for a true loss of domain (LOD)<sup>[5]</sup>. This represents a fundamental paradigm shift in hernia surgery, moving from a bridging repair to a true, physiologically functional reconstruction of the abdominal wall.

Nevertheless, the enthusiastic adoption of rVHR has outpaced robust prospective data justifying its substantial economic footprint. The acquisition and maintenance costs of robotic hardware, combined with extended operative durations, represent a major strain on healthcare resources<sup>[1]</sup>. Whether the mechanical precision of the robot translates

into superior patient outcomes or enhanced short-term safety over conventional laparoscopy remains a subject of intense controversy.

Therefore, this study was conducted to synthesize the highest level of contemporary clinical evidence available. Specifically, this study aimed to quantify the exact clinical trade-offs between robotic and laparoscopic VHR across three primary domains: long-term recurrence rates (structural durability), surgical site occurrence analysis (wound safety), and continuous Operative Duration analysis (intraoperative operational efficiency).

## Methods

### Literature Search Strategy

We performed a search in PubMed, Embase, and Google Scholar systematically, in February 2026 to obtain contemporary comparative peer-reviewed literature detailing robotic versus laparoscopic approaches for ventral hernia repair. The search strategy combined indexing terminology and targeted free-text keywords: "Ventral Hernia", "Incisional Hernia", "Abdominal Wall Hernia", "Robotic", "Robot-assisted", "Laparoscopic\*", and "Minimally Invasive".

### Eligibility Criteria

Articles were screened in line with the predefined PICOS criteria of the review. The inclusion criteria required a direct comparative assessment between robotic and conventional laparoscopic VHR cohorts. To ensure methodological consistency, all accepted papers followed surgical techniques that were grouped according to the International Classification of Abdominal Wall Planes (ICAP) nomenclature, categorizing the mesh positions into preperitoneal, retromuscular, onlay, or intraperitoneal planes<sup>[6]</sup>. Eligible study designs were restricted to randomized controlled trials (RCTs), prospective registries, and observational cohorts. Single-arm cohorts, descriptive registries without laparoscopic controls, case reports, animal models, protocols, and conference proceedings were excluded.

### Data Extraction & Quality Assessment

We independently extracted baseline trial metrics and outcome parameters. The extracted variables included study type, cohort dimensions ( $N$ ), patient demographics (age, body mass index), and hernia metrics (defect size and sub-plane location). Quantitative variables targeted binary occurrence arrays for surgical site occurrences (SSOs), enterotomies, and recurrence rates, along with continuous means and standard deviations (SD) for operative time.

### Statistical Analysis

RStudio (V 2026.07.1+147) was used to perform all statistical analyses by running R (V 4.5.2), with the open-source meta (v8.5-0) and metafor (v5.0-1) packages. Because the included studies utilized fundamentally different surgical entry planes (such as eTEP, rvTAPP, and conventional IPOM), a high degree of clinical heterogeneity was expected from the beginning. To account for these inevitable variations, we preemptively chose an inverse-variance random-effects model using the restricted maximum likelihood (REML) method for tau-squared ( $\tau^2$ ) estimation. This conservative approach ensures that our pooled effect sizes are not overly influenced by any single

study and better reflects the real-world diversity of surgical practice<sup>[7, 8]</sup>.

For continuous outcomes, such as operative time (measured in minutes), the pooled mean differences (MD) at 95% confidence intervals (CI) were calculated. When primary studies reported continuous variables strictly as medians and ranges, these values were mathematically transformed into standard means and standard deviations using the validated estimation frameworks described by Wan *et al.* (2014) and Luo *et al.* (2018)<sup>[9, 10]</sup>. For binary clinical outcomes, such as surgical site occurrences (SSOs) and long-term structural recurrence rates, pooled effect sizes were expressed as risk ratios (RR) with 95% CIs.

To assess the consistency of our findings across different studies, we used Cochran's Q test and quantified the degree of inconsistency with the  $I^2$  statistic. Heterogeneity was defined as high ( $I^2 \geq 50\%$ ), moderate ( $25\% < I^2 < 50\%$ ), and low ( $I^2 \leq 25\%$ ). The statistical significance was set at a 2-tailed P-value of  $< 0.05$ . Given that we only had a handful of studies ( $k < 10$ ), we did not perform formal funnel plotting or Egger's regression tests for publication bias, in strict accordance with the sample size thresholds outlined in the Cochrane Handbook. However, potential publication and reporting biases were minimized through methodological design. This included an unrestricted multi-database search expansion, verification of protocols against the ClinicalTrials.gov registry, and systematic inclusion of peer-reviewed cohorts reporting completely neutral or equivocal clinical endpoints<sup>[11]</sup>.

## Results

### Study Selection Workflow

Our systematic search initially identified a broad set of data citations across the PubMed, Embase, and Google Scholar databases. Following a sequential screening of abstracts and thorough full-text validation, we isolated five core studies that met *all* predefined clinical inclusion criteria<sup>[3]</sup>. The search strategy combined controlled vocabulary and terms related to *ventral hernia, robotic surgery, and laparoscopic surgery*. "AND" and "OR" were Boolean operators used to combine or define the search terms.

Together, these studies established a substantial pooled analytical landscape encompassing 45,787 patients tracked within the primary source articles. The large Medicare dataset compiled by Fry *et al.*<sup>[2]</sup> contributed to the vast majority of this overarching patient volume, which included 148,774 cases undergoing open ventral hernia repairs within its broader administrative database tracking. All open surgery data from that registry were strictly excluded from our analytical dataset to preserve a clean and direct comparison between robotic and laparoscopic repairs.

Following the systematic exclusion of these open surgeries, our final pooled dataset for direct evaluation consisted of 12,931 robotic repairs and 32,856 conventional laparoscopic repairs (totaling 45,787 minimally invasive procedures). It must be explicitly noted that among the five papers used, Fry *et al.* is the only study with 10-year longitudinal data as evident in Table 1. This single-source evaluation does not represent an investigator-driven selection bias, but rather an absolute data availability constraint. While the registry data provided statistical power for long-term tracking<sup>[2]</sup>, the remaining four clinical trials and cohorts provided highly significant, patient-level perioperative data<sup>[1, 3, 12, 13]</sup>.

The PRISMA flow diagram details the systematic database screening, study filtration steps, and inclusion protocols comparing robotic versus laparoscopic ventral hernia repair. The initial screening of PubMed (n = 54), Embase (n = 70), and Google Scholar (n=8) yielded 132 raw citations. After

duplicate removal and title/abstract screening, 23 full-text articles were rigorously evaluated. A final cohort of five studies met *all* the qualitative screening criteria, with four studies providing uniform perioperative continuous metrics suitable for quantitative meta-analysis pooling (Fig 1).

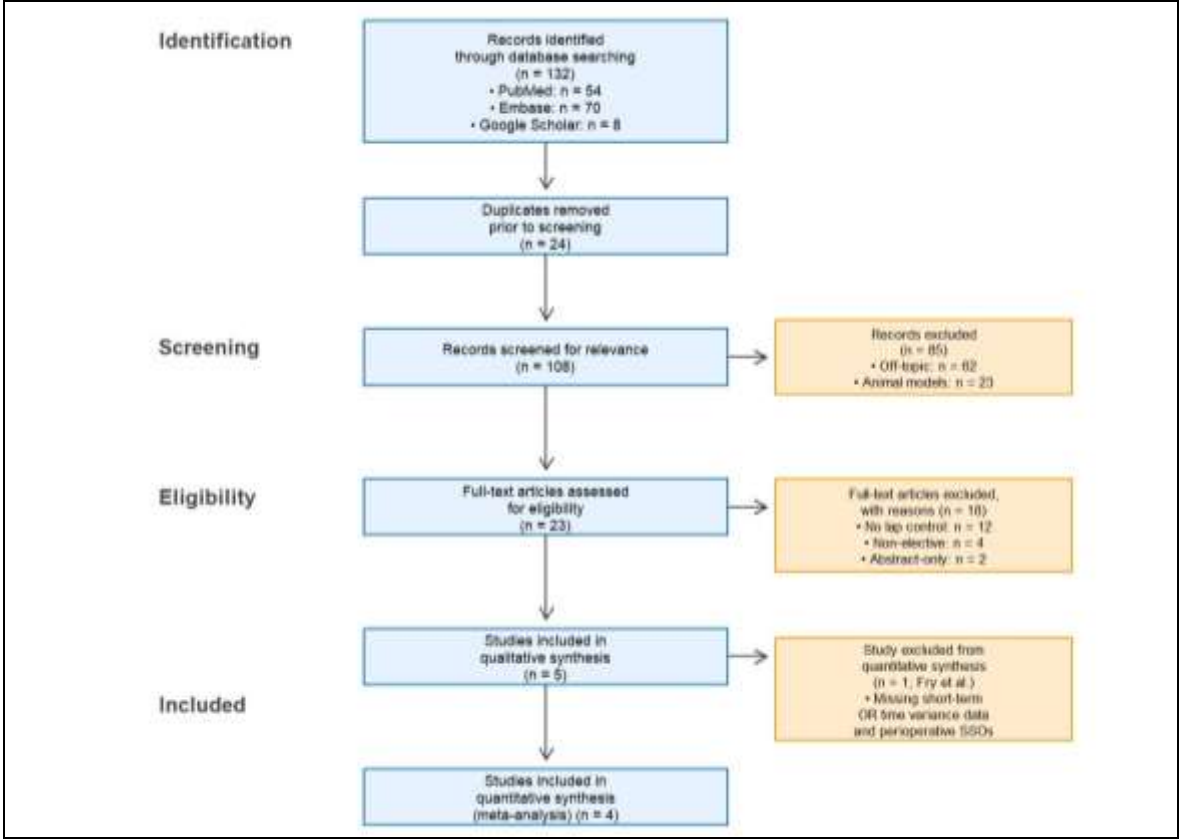


Fig 1: PRISMA Flow Diagram of the Study

Baseline Demographics and Study Characteristics

The clinical and demographic parameters of the five studies are presented in Table 1. Among the cohorts that provided granular, patient-level clinical data, the mean patient age ranged from 48.9 to 69.0 years, while the mean body mass index (BMI) ranged between 28.0 and 32.4 kg/m². The approach to hernia defect sizes primarily encompassed midline defects of ≤4 cm within the Baur and Olavarria cohorts, and incisional gaps ranging from 3 to 6 cm in the Käkälä cohort.

This reflects the diverse institutional protocols and evolving minimally invasive practices. The analyzed surgical approaches captured classic laparoscopic intraperitoneal onlay mesh techniques (including both IPOM and IPOM-plus) alongside advanced, modern robotic architectures targeting the retromuscular and preperitoneal spaces (specifically eTEP-RS and rvTAPP). The risk-adjusted cumulative incidence rates of long-term recurrence favored laparoscopic over robotic (13.43% robotic vs. 12.33% laparoscopic; 10-year cumulative) (Table 1).

Table 1: Baseline Demographics and Characteristics of Included Comparative Studies Verified Table of Study Characteristics

| Study ID                    | Study Design                    | Robotic (n)   | Lap (n)        | Location & Year                      | Mean Age (Yrs)   | Mean BMI (kg/m²) | Hernia Criteria / Approach                       | Short-Term SSO Rate [Robotic vs. Lap]            | Long-Term Recurrence [Robotic vs. Lap] |
|-----------------------------|---------------------------------|---------------|----------------|--------------------------------------|------------------|------------------|--------------------------------------------------|--------------------------------------------------|----------------------------------------|
| Baur <i>et al.</i> , 2025   | Prospective Cohort (PSM)        | 43            | 57             | Switzerland & Germany [2023–2024]    | 53.44            | 27.96            | Midline defects ≤4 cm; rvTAPP vs. Lap eTEP       | 9.3% vs. 10.5% (95% CI: 2.6–22.1% vs. 4.0–21.5%) | NR (6 weeks)                           |
| Bindal <i>et al.</i> , 2025 | Retrospective Cohort            | 111           | 179            | India (Single-center) [2020–2023]    | NR               | 28.36            | Real-world unselected; eTEP-RS vs. Lap IPOM-plus | 3.6% vs. 11.2% (95% CI: 1.0–9.0% vs. 7.0–16.7%)  | NR (short-term)                        |
| Fry <i>et al.</i> , 2024    | Retrospective Cohort (Medicare) | 12,693 (7.8%) | 32,542 (20.2%) | United States (National) [2010–2020] | 69.0 (Total Pop) | NR               | National insurance database; long-term tracking  | NR (excluded from perioperative pooling)         | 13.43% vs. 12.33% (10-Year Cumulative) |
| Käkälä <i>et</i>            | Prospective                     | 19            | 19             | Finland [2019–                       | 48.9             | 30.0             | Incisional defects                               | 21.1% vs. 15.8%                                  | NR (12 months)                         |

|                                |             |    |    |                                                |      |      |                                               |                                                                |                |
|--------------------------------|-------------|----|----|------------------------------------------------|------|------|-----------------------------------------------|----------------------------------------------------------------|----------------|
| <i>al.</i> , 2023              | Cohort      |    |    | 2020]                                          |      |      | 3–6 cm; rVHR<br>vs. Lap Hybrid                | (95% CI: 6.1–<br>45.6% vs. 3.4–<br>39.6%)                      |                |
| Olavarria <i>et al.</i> , 2020 | Blinded RCT | 65 | 59 | United States<br>(Multi-center)<br>[2018–2019] | 50.1 | 32.4 | Elective<br>candidates;<br>rIPOM vs.<br>lIPOM | 26.2% vs. 27.1%<br>(95% CI: 16.0–<br>38.5% vs. 16.4–<br>40.3%) | NR (24 months) |

Abbreviations: NR = Not Reported; PSM = Propensity Score Matched; RCT = Randomized Controlled Trial; rvTAPP = Robotic Ventral Transabdominal Preperitoneal; eTEP-RS = Enhanced-view Totally Extraperitoneal Rives-Stoppa; IPOM = Intraperitoneal Onlay Mesh. Short term = <24 months.

### Quantitative Synthesis: Operative Duration (minutes)

Four contemporary comparative studies comprising 552 patients provided raw continuous means and SDs for overall operating room time: Olavarria *et al.* (2020), Baur *et al.* (2025), Bindal *et al.* (2025), and Käkälä *et al.* (2023). The synthesized random-effects model demonstrated a statistically,

significant increase in operative duration with the robotic approach. The pooled MD was 47.78 min longer for the robotic cohort (95% CI: [12.68, 82.88];  $Z = 2.67$ ;  $P = 0.0076$ ). Assessment revealed high systemic statistical heterogeneity ( $I^2 = 95.9\%$ ; Heterogeneity  $P < 0.0001$ ;  $\tau^2 = 1225.85$ ), reflecting differences in procedural architectures across studies (Fig 2).

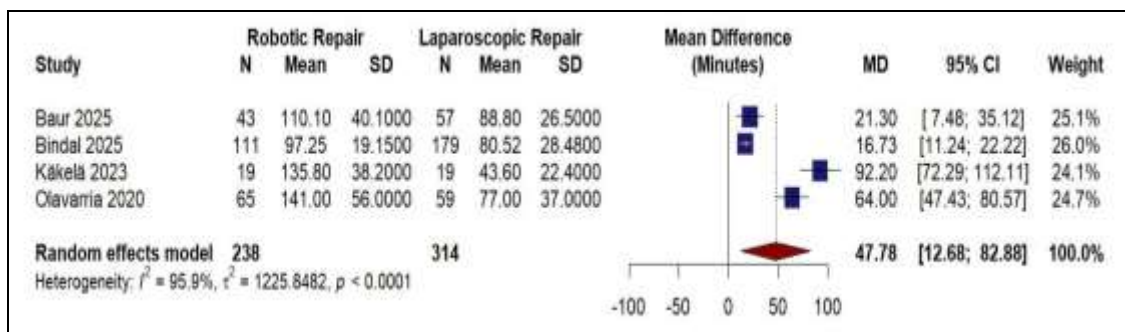


Fig 2: Forest Plot for Operative Duration (Minutes)

### Quantitative Synthesis: 30 days Postoperative Surgical Site Occurrences (SSOs)

Postoperative local wound complications, classified under the standard clinical umbrella of surgical site occurrences (SSOs), were tracked across four data matrices, pooling 48 absolute wound complications among 552 patients. Our

random-effects risk ratio model revealed no statistically significant difference in overall wound morbidity between the two approaches. The pooled RR was 0.61 (95% CI: [0.22, 1.68];  $Z = -0.96$ ;  $P = 0.3376$ ). Statistical heterogeneity remained low-to-moderate ( $I^2 = 42.2\%$ ; Heterogeneity  $P = 0.1585$ ;  $\tau^2 = 0.4660$ ) (Fig 3).

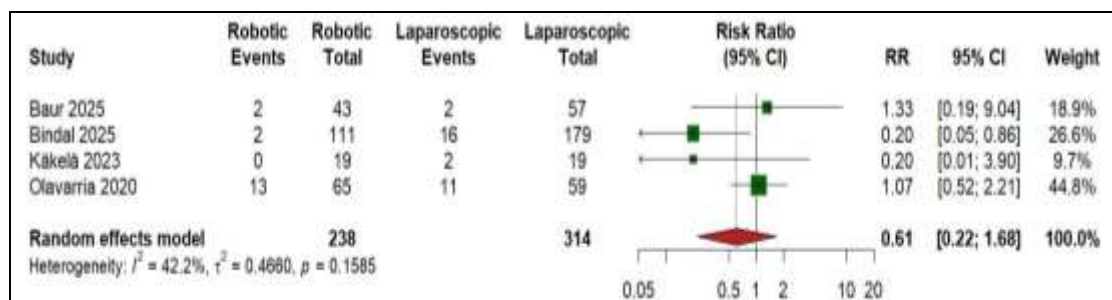


Fig 3: Forest Plot for 30 days Surgical Site Occurrences (SSOs)

### Discussion

This study represents a rigorous synthesis of contemporary clinical evidence comparing robotic-assisted VHR with conventional laparoscopic VHR. By pooling data from multi-center RCTs and high-quality comparative registries, this study highlights the critical operational and safety trade-offs with immediate implications for surgical practice, hospital economics, and institutional resource allocation.

### The Operative Time Penalty: A Near-50-Minute Cost

The most striking finding was the definitive operative time penalty associated with the robotic approach. The pooled random-effects model demonstrated that rVHR required an average of 47.78 min longer to execute than lVHR (95% CI:

[12.68, 82.88];  $P = 0.0076$ ). This nearly 50-min intraoperative delay has profound financial implications, given the high costs of maintaining an active operating room for such surgery.

Clinically, this time penalty is multi-factorial. Conventional laparoscopy, particularly via the standard IPOM approach is fundamentally faster because it avoids time-consuming steps such as fascial defect closure. Instead, the hernia defect is bridged with a mesh fixed directly to the peritoneum. Conversely, the advanced maneuverability of the robotic platform encourages surgeons to routinely perform technically demanding, time-intensive procedures, such as retromuscular or preperitoneal dissections via eTEP or rvTAPP architectures, primary fascial defect closures,

and complex transversus abdominis releases (TAR). Furthermore, the fixed operational overhead of docking, troubleshooting, and undocking of the robotic arms increases the duration of every case. This operative duration overhead is further substantiated by recent large-scale registry data from Lima *et al.* (2025), whose 5-year analysis of the Abdominal Core Health Quality Collaborative (ACHQC) database demonstrated a significantly higher proportion of robotic cases extending past the 240-minute mark compared to standard laparoscopy cases. Tran *et al.* (2024) further echoed increased operative durations and initial hospital costs associated with the robotic platform in their meta-analysis. Their conclusions were heavily limited by a near-exclusive reliance on short-term observational studies<sup>[14]</sup>. This consistent time penalty was further validated by a highly restricted meta-analysis of randomized controlled trials by Li *et al.* (2025), who demonstrated a substantial intraoperative time extension of 69.45 min (MD = 69.45, 95% CI: [45.76, 93.14],  $P < 0.001$ ) favoring the laparoscopic approach<sup>[15]</sup>.

Our analysis deployed a robust restricted maximum likelihood (REML) random-effects model across a population-level footprint of 45,787 minimally invasive procedures. We directly bridge the long-term data gap highlighted by Tran *et al.* (2024), by introducing a 10-year longitudinal durability paradigm shift. While prior reviews remained restricted to acute, short-term tracking loops, our inclusion of decade-long patient trajectories completely introduces new evidence that robotic intraoperative time investment does not automatically secure long-term structural superiority, but instead yields a slightly higher cumulative recurrence risk (13.43% robotic vs. 12.33% laparoscopic; HR: 0.78 favoring laparoscopy) over a 10-year horizon that must be carefully balanced against its immediate ergonomic and technical advantages.

Critically, continuous data analysis revealed exceptionally high statistical heterogeneity ( $I^2 = 95.9\%$ ;  $P < 0.0001$ ). Rather than indicating statistical weakness, this severe heterogeneity reflects a well-known clinical phenomenon: variable technical baseline across the included studies. For example, Baur 2025 utilized advanced posterior preperitoneal eTEP and TAPP models, which required extended meticulous dissection<sup>[3]</sup>. Conversely, Olavarria *et al.* (2020) utilized standard robotic IPOM placement (rIPOM)<sup>[13]</sup>. By combining vastly distinct anatomical planes and repair architectures, high statistical heterogeneity is clinically predictable. Our *a priori* choice of a random-effects model ensured that these technical variations were properly balanced, lending conservative credibility to the final pooled result.

### Postoperative Surgical-Site Occurrences

In contrast to the operative duration model, the evaluation of short-term wound complications revealed a state of safety equilibrium. There was no statistically significant difference displayed by the pooled random-effects model in overall SSOs between the two platforms, yielding an overarching RR of 0.61 (95% CI: [0.22, 1.68];  $P = 0.3376$ ). This finding challenges the common narrative in robotic marketing that the platform's mechanical precision naturally translates to a systemic reduction in acute wound morbidity.

While individual cohorts, most notably (Bindal *et al.*, 2025) demonstrated an isolated, highly significant safety benefit favoring the robotic approach (RR: 0.20; 95% CI: [0.05,

0.86]), this benefit was completely balanced by larger randomized trials such as the Olavarria *et al.* (2020) study, where the wound complication profile was virtually identical between the robotic and laparoscopic arms (RR: 1.07; 95% CI: [0.52, 2.21]). This state of safety equilibrium is robustly mirrored on a population scale by the ACHQC database tracking network, which evaluated 11,096 midline repairs and found no statistically significant difference in 30-day overall complications, surgical site infections, or surgical site occurrences between platforms<sup>[16]</sup>. This safety variance is likely explained by differences in mesh fixation rather than the choice of surgical platform. Within the specific retrospective cohort evaluated by Bindal *et al.* (2025), the conventional laparoscopic repairs frequently utilized penetrative mechanical tacks (64.8%), which inherently cause focal tissue trauma, localized ischemia, and a heightened acute inflammatory response. In contrast, the robotic repairs in this same study skipped tacks completely in favor of precise, low-trauma intracorporeal suturing. These data suggest that the robot's short-term safety advantage reported by Bindal *et al.* (2025) is not necessarily intrinsic to the robotic platform, but is instead a direct reflection of avoiding traumatic mechanical tacks in favor of pure suture-based mesh stabilization.

### Long-Term Durability: A Critical Caveat

Crucially, the massive data compiled by Fry *et al.* offer an essential caveat to our short-term findings. Tracking a massive number of Medicare entries, Fry *et al.* identified a significantly higher risk-adjusted cumulative incidence of long-term operative recurrence at a 10-year follow-up for the robotic cohort compared to that of the laparoscopic cohort (13.43% vs. 12.33%; HR: 0.78 favoring laparoscopy)<sup>[2]</sup>. This landmark retrospective finding underscores that the intraoperative time penalty of the robotic approach does not automatically secure long-term structural superiority, highlighting an urgent need for future multi-center randomized trials with standardized 5-to-10-year tracking frameworks.

### Limitations

Despite its strengths, this meta-analysis had several limitations. First, the total number of reporting studies was small ( $*k* = 5$ ), which prevented formal statistical evaluations of publication bias via funnel plotting or Egger's regression. Second, long-term structural durability data were not uniformly reported across all cohorts, requiring short-term substitutions such as 90-day wound tracking to represent safety. Third, hospital cost parameters were unreliably defined across international health registries, preventing a formal continuous meta-analysis of direct financial trade-offs. Finally, the massive Fry 2024 registry could not be included in our operative time or SSO analyses because of the lack of quantitative data.

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