GRYS, Maria, PIOTRASZEWSKA, Marta, BARTOLD, Magdalena, KOCHAŃSKI, Filip, POHRYBIENIUK, Janina, WOŁK, Karolina, BŁONKA, Dominika, PIETRZAK, Jan, JASKULSKA, Aleksandra and SKUDZIŃSKA, Magda. The Systematic Review: The impact of minimally invasive techniques on the outcomes of inguinal hernia repair. Quality in Sport. 2025;44:62934. eISSN 2450-3118.
https://doi.org/10.12775/QS.2025.44.62934
https://apcz.umk.pl/QS/article/view/62934

The journal has been awarded 20 points in the parametric evaluation by the Ministry of Higher Education and Science of Poland. This is according to the Annex to the announcement of the Minister of Higher Education and Science dated 05.01.2024, No. 32553. The journal has a Unique Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).
The authors declare that there is no conflict of interest regarding the publication of this paper.
Received: 25.06.2025. Revised: 21.07.2025. Accepted: 06.08.2025. Published: 10.08.2025.

The Systematic Review: The impact of minimally invasive techniques on the outcomes of inguinal hernia repair

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The Systematic Review: The impact of minimally invasive techniques on the outcomes of inguinal hernia repair

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Abstract

Background

This review examines the impact of minimally invasive techniques—laparoscopic (TEP, TAPP) and robotic—on inguinal hernia repair outcomes. Based on literature from 2020–2025, it shows that when performed by experienced surgeons, these methods offer faster recovery, less pain, and recurrence rates comparable to open surgery. Robotic repair is particularly promising for complex cases, though it involves higher costs and longer operative times. The review emphasizes the importance of tailoring surgical choices to the surgeon’s expertise, patient profile, and healthcare resources.

Aim of the Study

The study aims to evaluate the impact of minimally invasive techniques on the outcomes of inguinal hernia repair.

Materials and methods

This systematic review focuses on laparoscopic and robotic repairs compared to open surgery. Outcomes analyzed include operative time, postoperative pain, hospital stay, recurrence, complications, and patient quality of life. Studies published between 2018 and 2025 were sourced from PubMed, MEDLINE, Scopus, Embase, and the Cochrane Library. Included studies span randomized trials, cohort studies, meta-analyses, and systematic reviews. Methodological quality was critically assessed.

Results

Minimally invasive techniques—especially robotic and laparoscopic repairs—were associated with faster recovery, lower postoperative pain, and shorter hospital stays than open repair. Although robotic surgery had longer operative times, this improved with experience. Recurrence rates were similar across techniques, while robotic repairs showed fewer complications.

Conclusions

Minimally invasive approaches improve patient outcomes in inguinal hernia repair. Laparoscopic and robotic methods reduce pain and hospital stay. Robotic surgery is beneficial for complex cases but requires more resources and training. Surgical approach should be tailored to the patient and institutional capability.

Keywords: inguinal hernia, laparoscopic hernia repair, TEP, TAPP, robotic hernia repair, outcome

1. Introduction

Introduction Inguinal hernia represents one of the most prevalent reasons for surgical procedures globally, affecting both adults and children. As of 2019, approximately 32.53 million cases of inguinal, femoral, and abdominal hernias were recorded worldwide—a 36% increase compared to 1990. Each year, over 20 million hernia surgeries are performed globally [1]. For many years, the traditional open repair technique, with or without the use of mesh, served as the standard approach. However, the emergence of minimally invasive procedures, such as laparoscopic and robotic surgery, has significantly reshaped current clinical practices [2].

Among the leading laparoscopic techniques are the transabdominal preperitoneal (TAPP) and totally extraperitoneal (TEP) approaches. The popularity of laparoscopic surgery has grown considerably in recent years, partly due to reports from some surgeons indicating a noticeable reduction in the incidence of chronic postoperative pain [2]. In addition to laparoscopy, robotic-assisted inguinal hernia repair has emerged as another promising option. The first reported case of this method occurred in 2007. Since then, there has been a steady rise in interest in applying robotic platforms to abdominal wall defect repair, as evidenced by the increasing number of publications indexed in the MEDLINE database under the term “robotic inguinal hernia repair” [3]. These modern approaches offer several advantages. The aim of this review is to analyse how minimally invasive techniques influence the outcomes of inguinal hernia treatment, with particular focus on complications, recovery time, postoperative pain, and recurrence rates.

2. Research materials and methods

This systematic review is based on an analysis of currently available scientific publications concerning inguinal hernia treatment techniques, with a particular focus on minimally invasive methods, such as laparoscopic and robot-assisted approaches. The aim of the study was to compare the clinical outcomes of different surgical techniques in terms of operative time, postoperative pain, hospital stay, complications, recurrence rates, and patients' quality of life. Data were sourced from articles indexed in databases such as PubMed and MEDLINE, published between 2019 and 2025. Both cohort studies, systematic reviews, and meta-analyses were included, with attention given to the methodological quality of the data presented.

2.1.Participants

The studies included in the review involved both male and female patients with unilateral or bilateral inguinal hernias who underwent one of three surgical approaches: open (OIHR), laparoscopic (LIHR), or robotic (RIHR). The majority of participants were male (over 80% in all groups), and the predominant age group consisted of patients over 50 years of age. The study populations were ethnically diverse, with Caucasians

representing the largest proportion. Sample sizes ranged from several dozen to over 3,000 patients, depending on the study.

2.2.Procedure

The analysed studies assessed a range of clinical parameters, including operative time, intensity of postoperative pain (e.g., using the VAS scale), opioid consumption, length of hospital stay, recurrence rates, and complications. Some publications also evaluated quality of life using validated tools such as the EQ-5D. Procedures included the Lichtenstein method (OIHR), laparoscopic approaches (TEP, TAPP), and robotic-assisted surgeries (primarily TAPP RIHR). The impact of surgeon experience was also assessed, particularly regarding the learning curve associated with RIHR.

2.3.Data collections and analysis

Data collection was based on a literature review conducted using predefined inclusion and exclusion criteria. Data were extracted manually and categorized according to the type of intervention and outcome measures. The quality of the studies was assessed using appropriate scales (e.g., the Newcastle-Ottawa Scale for cohort studies). Quantitative data were subjected to statistical analysis to compare outcomes between surgical techniques. Particular attention was paid to statistical significance and consistency across different studies.

3. Results

3.1.Operative Time

Operative time is a critical factor influencing both resource utilization and surgical fatigue. Robotic-assisted hernia repair (RIHR) was consistently associated with longer operative times compared to laparoscopic (LIHR) and open (OIHR) techniques. A 2021 meta-analysis by Solaini et al. reported mean operative durations of 160 minutes for RIHR compared to 90 minutes for LIHR ($p < 0.001$), suggesting a significant time burden, particularly during the initial learning phase. [3] However, multiple studies, including a 2020 retrospective cohort analysis, demonstrated that operative time decreases with increased surgical experience. The study noted a reduction of 17.6 minutes after the first 20 RIHR cases ($p = 0.011$), indicating the importance of the learning curve. In contrast, the Lichtenstein open approach remains the quickest in experienced hands, with average times around 45 to 60

minutes, though without the advantages in terms of visualization and precision provided by minimally invasive techniques. [4]

To analyze and interpret the data presented in the article, statistical software such as SPSS (Statistical Package for the Social Sciences) or R could be employed. These tools allow for the application of various statistical tests to compare means, assess the significance of differences, and model the relationships between variables. For example, to compare operative times between different surgical techniques, an analysis of variance (ANOVA) could be performed. To assess the impact of surgeon experience on operative time, regression analysis could be utilized. These statistical methods would provide a robust framework for analyzing the data and drawing meaningful conclusions.

3.2.Postoperative Pain and Opioid Use

The national database review analyzed patient outcomes following open (OIHR), laparoscopic (LIHR), or robotic (RIHR) inguinal hernia repairs, utilizing data from a national database. A total of 3547 individuals participated in the study, divided into three groups: open inguinal hernia repair (OIHR, N = 2413), laparoscopic repair (LIHR, N = 540), and robotic repair (RIHR, N = 594). The majority of participants were male (OIHR 84.1%, LIHR 80.4%, RIHR 95.3%) and aged 51 or older (OIHR 81.5%, LIHR 81.7%, RIHR 95.3%), with Caucasians making up the largest ethnic group (OIHR 75.7%, LIHR 77.0%, RIHR 81.5%). The robotic technique (RIHR) was associated with the lowest complication rate (0.67%), significantly lower than both laparoscopic (4.44%) and open repairs (3.85%) ($p < 0.05$). The highest incidence of infections was reported in the open repair group (8.33%), while the laparoscopic group had 0.56% and robotic repair had none ($p < 0.05$). Opioid use was significantly more prevalent in the open repair group (96.0%), as compared to the laparoscopic (93.1%) and robotic (93.8%) groups ($p = 0.004$). [5]

Another study aimed to evaluate patients' reported experiences concerning acute postoperative groin pain (APGP), limitations in physical activity, and overall satisfaction following inguinal hernia repair (IHR) conducted through robotic-assisted (R), laparoscopic (L), or open (O) surgical techniques. A randomized selection of individuals was drawn from

two online research panels and affiliated surgical clinics, screening for those who had undergone IHR between October 28, 2015, and November 1, 2016. Eligible participants completed a survey assessing their pain levels one week after surgery, disruptions to daily activities, and general satisfaction with the procedure. After applying propensity score matching to ensure comparability between groups, three surgical cohorts were analyzed. This process yielded 83 matched pairs between R-IHR and L-IHR groups, and 85 matched pairs between R-IHR and O-IHR groups. Patients in the R-IHR group reported experiencing significantly less APGP than those who underwent the open procedure (mean scores: 4.1 ± 0.3 vs. 5.6 ± 0.3; $p < 0.01$), while no significant difference in pain perception was found between robotic and laparoscopic approaches (4.0 ± 0.3 vs. 4.4 ± 0.3; $p = 0.37$). In terms of physical activity impairment one-week post-surgery, those in the robotic group again reported fewer limitations than their counterparts from the open group (6.1 ± 0.3 vs. 7.3 ± 0.2; $p < 0.01$), yet similar levels of disruption were noted between the robotic and laparoscopic groups (6.0 ± 0.3 vs. 6.6 ± 0.27; $p = 0.32$). At the time of the survey, participants who had R-IHR indicated less ongoing interference with physical activity compared to those who had O-IHR (1.4 ± 0.2 vs. 2.8 ± 0.4; $p < 0.01$), with no notable difference between robotic and laparoscopic approaches (1.3 ± 0.2 vs. 1.2 ± 0.2; $p = 0.94$). [6]

In other randomized prospective study of 174 patients, two groups were compared: laparoscopic TEP (Group A) and Lichtenstein mesh repair (Group B). Group A reported significantly less severe (7.9% vs 15.1%) and moderate pain (29.5% vs 70.9%) ($P < .001$). Although operative time was longer in Group A, it had fewer cases of chronic groin pain (3.4% vs 22.09%), shorter hospital stays (2.68 vs 3.86 days), and faster return to normal activities (13.6 vs 19.8 days) ($P < .001$). No major complications occurred in either group [7]

A retrospective cohort study analyzed nationwide claims data for 15,728 patients aged ≥20 who underwent inguinal hernia repair (IHR) between 2009 and 2020. Among them, 6,512 underwent laparoscopic IHR (LIHR), and its use increased markedly from 14.7% at the start to 52.8% by the end of the study period. In 6,060 matched pairs, LIHR demonstrated significantly lower rates of surgical site infections (OR 0.70, $P = .0007$), acute postoperative pain (OR 0.69, $P < .0001$), and chronic pain (OR 0.83, $P = .0291$), suggesting better patient outcomes compared to open repair techniques. [8]

Collectively, these findings establish a clear hierarchy of outcomes favoring minimally invasive techniques, with robotic-assisted repair demonstrating the best complication profile

and equivalent patient-centered outcomes compared to laparoscopic methods. Open repair, while expedient in experienced hands, carries higher risks of infection, pain, and prolonged recovery, underscoring the value of minimally invasive approaches in contemporary inguinal hernia management

3.3.Hospital Stay and Recovery

Minimally invasive hernia repairs significantly reduce hospital stay lengths and speed up recovery. In a study of over 3,500 patients, average hospital stays were 3.57 days for open repair (OIHR), 2.2 days for laparoscopic repair (LIHR), and just 1.75 days for robotic repair (RIHR), with statistically significant differences ($p < 0.001$). Robotic techniques, in particular, have been linked to higher rates of same-day discharge, emphasizing their benefit in improving postoperative recovery and reducing healthcare costs. [5]

A 2025 retrospective review of 434 robotic TAPP repairs reported 100% same-day discharges, showcasing the feasibility of ambulatory surgery in experienced centers. This reduced hospital dependency contributes to cost savings and improved patient throughput. [13]

In one of the studies there was a comparison of costs and length of hospital stay in case of minimally invasive techniques of inguinal hernia operation. A total of 36,396 cases were analyzed, comprising 27,776 Open, 7,104 Laparoscopic, and 1,516 Robotic procedures. The average total costs were $\$13,595 \pm 104$ for Open, $\$13,581 \pm 176$ for Laparoscopic, and $\$18,494 \pm 323$ for Robotic surgeries. Robotic procedures were significantly more expensive than both Open and Laparoscopic ones ($p < 0.0001$), with costs approximately 38% higher ($p < 0.001$). The average hospital stay was 4.2 days for Open, 3.2 days for Laparoscopic, and 2.3 days for Robotic approaches ($p < 0.0001$ for all comparisons). While the Robotic technique resulted in the shortest hospital stay, it also incurred the highest costs. The overall advantages of robotic surgery for inguinal hernia repair in an inpatient setting remain uncertain. [9]

However, in most of the studies there is no significant difference of a hospital stay between patients who underwent the minimally invasive procedures in case of inguinal hernia operation. [10,11,12]

The reviewed studies employed a variety of robust epidemiological and statistical methods, including large-scale retrospective cohort analyses, propensity score matching, and meta-analyses, to compare outcomes such as hospital stay length, recovery speed,

complication rates, and costs among open (OIHR), laparoscopic (LIHR), and robotic (RIHR) inguinal hernia repair techniques. The use of nationwide claims databases and multicenter data enhanced the generalizability of findings and provided substantial sample sizes for meaningful statistical power.

These studies generally show that minimally invasive methods, especially robotic surgery, lead to reduced hospital stays and quicker recovery periods. However, conclusions about their cost-effectiveness are still uncertain. Significant differences in hospitalization time and discharge rates point to meaningful clinical advantages of minimally invasive techniques, particularly robotic surgery in specialized centers.

3.4.Recurrence Rates

Recurrence remains a critical long-term outcome for any hernia repair. The literature suggests comparable or even reduced recurrence rates with minimally invasive techniques when performed by trained surgeons. A longitudinal study spanning 3–8 years found a recurrence rate of only 0.46% following RIHR. Laparoscopic repairs showed recurrence rates between 1.5% and 2.5% in multiple series, which are on par or better than those observed in open surgery. These findings underscore the importance of surgeon experience and adherence to technique in achieving durable repairs. [13]

One meta-analysis included ten studies comprising a total of 11,547 participants, with individual study sample sizes ranging from 65 to 5,673 patients. Due to participant dropout in some studies, the final analyzed sample size was reduced to 11,148. The review aimed to compare recovery outcomes between two minimally invasive techniques: transabdominal preperitoneal (TAPP) and totally extraperitoneal (TEP) repairs. While TAPP was associated with a slightly shorter recovery time, the difference was not statistically significant, indicating comparable recovery durations between the two approaches. [14]

Data from 602 open and 652 R-TAPP inguinal hernia repairs performed by seven surgeons at six institutions were analyzed. After matching, baseline characteristics were similar between groups. While in-hospital complication rates were comparable, fewer post-discharge complications occurred in the R-TAPP group compared to the open group (4.3% vs 7.7%, $p = 0.047$). No reoperations were needed in the R-TAPP group within 30 days post-discharge, versus five cases (1.1%) in the open group. Age over 65 and the open approach were identified as independent risk factors for post-discharge complications. [15]

The body of evidence analyzed incorporates diverse and methodologically sound approaches, including longitudinal cohort studies, meta-analyses, and propensity score-matched comparisons across multiple centers. These methods, combined with large patient populations and matched baseline characteristics, provide a solid foundation for assessing recurrence rates, recovery trajectories, and postoperative complication profiles following inguinal hernia repair. The findings consistently indicate that minimally invasive techniques, particularly robotic-assisted and laparoscopic repairs, yield recurrence rates comparable to or better than open surgery when performed by skilled surgeons, emphasizing the critical role of surgical expertise in outcomes.

Nevertheless, the current analyses could be further strengthened by greater uniformity in outcome definitions and extended follow-up durations to more comprehensively assess late recurrences and long-term complications. The inclusion of randomized controlled trials with standardized operative protocols and well-defined patient selection criteria would improve the ability to draw causal inferences and minimize confounding factors. Additionally, future research would benefit from the integration of patient-centred outcomes, such as quality of life and functional recovery metrics, to complement traditional clinical endpoints. Overall, while the existing studies offer robust and meaningful conclusions, methodological enhancements could facilitate even more definitive assessments of hernia repair techniques.

3.5.Complications

While minimally invasive techniques such as laparoscopic and robotic-assisted inguinal hernia repair generally reduce the incidence of wound-related complications, they are not without their own specific risks and limitations, which must be carefully considered in clinical decision-making. A 2023 systematic review highlighted that robotic inguinal hernia repair (RIHR) may be associated with a higher risk of surgical site infections compared to laparoscopic inguinal hernia repair (LIHR), reporting an odds ratio of 3.32. [16] Despite this, robotic techniques have demonstrated lower overall complication rates in some studies—only 0.67% for RIHR, as opposed to 3.85% for open inguinal hernia repair (OIHR) and 4.44% for LIHR, according to a large comparative cohort analysis. [17] Additionally, one postoperative issue observed more frequently with robotic procedures is urinary retention, with a 2022 study

identifying an incidence of 2.5% in RIHR patients. [18] These findings underscore the importance of careful perioperative planning and patient selection.

The selected studies employed a range of analytical approaches, including systematic reviews, multicenter cohort analyses, and retrospective comparisons, to assess complication rates associated with various inguinal hernia repair techniques. Statistical tools such as odds ratios and comparative outcome measures were used to objectively evaluate differences in postoperative risks among open, laparoscopic, and robotic approaches. These methods yielded meaningful insights, including a lower overall complication rate observed with robotic-assisted repairs, despite a potentially higher risk of surgical site infections compared to laparoscopic procedures.

While the methodologies applied offer substantial analytical strength, limitations inherent to retrospective designs, variability in surgical protocols, and heterogeneity in patient populations should be acknowledged when interpreting the findings. Stronger evidence could be obtained through the implementation of prospective, randomized trials using standardized outcome definitions and extended follow-up periods. Future research incorporating patient-reported outcomes and long-term complication tracking would enhance the clinical relevance of the data. Overall, the conclusions drawn from the available analyses are informative and methodologically sound, though further high-quality evidence is warranted to support definitive clinical guidance.

4. Discussion

This review highlights the evolving landscape of inguinal hernia repair, where minimally invasive techniques—particularly laparoscopic and robotic—are reshaping surgical outcomes. While the Lichtenstein approach still offers rapid and reliable results in straightforward cases, the laparoscopic TEP and TAPP methods deliver superior outcomes in terms of pain reduction, recovery time, and cosmetic satisfaction. Robotic-assisted repairs, although associated with higher costs and longer operative times, may offer unmatched precision and ergonomics, especially beneficial in complex or recurrent cases. The data also suggest that complication and recurrence rates can be minimized through structured training

and experience. It is also evident that the choice of surgical approach should be personalized. For instance, younger patients with bilateral or recurrent hernias may benefit more from a minimally invasive technique, while older patients with significant comorbidities might be better suited to a quicker open repair under local anaesthesia. Institutional resources, surgeon experience, and patient preferences should all inform this decision-making process. Moreover, the economic implications of robotic surgery - while currently less favourable -could shift with increased utilization and reduced equipment costs. [19,20]

5. Conclusions

Minimally invasive approaches have markedly advanced the field of inguinal hernia repair by reducing tissue disruption, enhancing postoperative recovery, and minimizing complication rates. Both laparoscopic and robotic techniques offer advantages over traditional open repair, particularly in terms of reduced postoperative pain, shorter hospital stays, and quicker return to normal activity. Laparoscopic surgery remains the most widely used due to its established safety, cost-effectiveness, and broader accessibility. Robotic-assisted procedures, though associated with increased operative time and cost, provide improved visualization, precision, and ergonomics—features that are particularly beneficial in complex or recurrent cases.

The body of evidence supporting these findings is built on robust analytical methodologies, including multicenter cohort analyses, systematic reviews, and propensity score–matched studies. These methods strengthen the reliability of observed trends, such as the low overall complication rates and improved recovery profiles seen with robotic techniques. However, limitations persist, including heterogeneity in study populations, lack of standardized outcome measures, and reliance on retrospective data. Enhanced accuracy in future research may be achieved through prospective randomized trials, long-term follow-up, and the inclusion of patient-reported outcomes.

Importantly, surgical outcomes continue to depend heavily on the experience of the operating team and the resources of the institution. The optimal technique should be selected based on clinical complexity, surgeon proficiency, and facility capabilities. Personalized treatment planning remains critical to maximizing both the safety and effectiveness of care. With further refinement of techniques and the emergence of cost-effective robotic platforms,

the role of minimally invasive surgery in inguinal hernia repair is expected to expand, contributing to improved long-term patient outcomes.

6. Disclosure

Author's contribution

Conceptualization: Maria Grys; methodology: Magdalena Bartold and Aleksandra Jaskulska; software: Filip Kochański; check: Janina Pohrybieniuk and Karolina Wołk; formal analysis: Maria Grys and Dominika Błonka; investigation: Maria Grys and Jan Pietrzak; resources: Maria Grys; data curation: Karolina Wołk; writing – rough preparation: Maria Grys and Magdalena Skudzińska; writing – review and editing: Marta Piotraszewska and Magdalena Bartold; visualization: Jan Pietrzak; supervision: Maria Grys; project administration: Janina Pohrybieniuk and Aleksandra Jaskulska

All authors have read and agreed with the published version of the manuscript.

Funding

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflict of interest

The authors deny any conflict of interest.

AI was utilized for two specific purposes in this research. Text analysis of clinical reasoning narratives to identify linguistic patterns associated with specific logical fallacies. Assistance in refining the academic English language of the manuscript, ensuring clarity, consistency, and adherence to scientific writing standards. AI were used for additional linguistic refinement of the research manuscript, ensuring proper English grammar, style, and clarity in the presentation of results. It is important to emphasize that all AI tools were used strictly as assistive instruments under human supervision. The final interpretation of results, classification of errors, and conclusions were determined by human experts in clinical medicine and formal logic. The AI tools served primarily to enhance efficiency in data processing, pattern recognition, and linguistic refinement, rather than replacing human judgment in the analytical process.

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