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REVIEW

Management and outcomes of obturator hernias: a systematic review and meta-analysis

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Abstract

Purpose Obturator Hernia (OH) is a rare type of abdominal wall hernia. It usually occurs in elderly women with late symptomatic presentation, increasing mortality rates. Surgery is the standard of care for OH, and laparotomy with simple suture closure of the defect is commonly used. Given the rarity of this disease, large studies are lacking, and data to drive management are still limited. This systematic review and meta-analysis aimed to describe current surgical options for OHs, with a focus on comparing the effectiveness and safety of mesh use with primary repair.

Methods PubMed, EMBASE, and Cochrane were searched for studies comparing mesh and non-mesh repair for OH. Postoperative outcomes were assessed by pooled analysis and meta-analysis. Statistical analysis was performed using RevMan 5.4.

Results One thousand seven hundred and sixty studies were screened and sixty-seven were thoroughly reviewed. We included 13 observational studies with 351 patients surgically treated for OH with mesh or non-mesh repair. One hundred and twenty (34.2%) patients underwent mesh repair and two hundred and thirty-one (65.81%) underwent non-mesh repair. A total of 145 (41.3%) underwent bowel resection, with the majority having a non-mesh repair performed. Hernia recurrence was significantly higher in patients who underwent hernia repair without mesh (RR 0.31; 95% CI 0.11–0.94; $p = 0.04$). There were no differences in mortality (RR 0.64; 95% CI 0.25–1.62; $p = 0.34$; $I^2 = 0\%$) or complication rates (RR 0.59; 95% CI 0.28–1.25; $p = 0.17$; $I^2 = 50\%$) between both groups.

Conclusion Mesh repair in OH was associated with lower recurrence rates without an increase in postoperative complications. While mesh in clean cases is more likely to offer benefits, an overall recommendation regarding its use in OH repair cannot be made due to potential bias across studies. Given that many OH patients are frail and present emergently, the decision to use mesh is complex and should consider the patient's clinical status, comorbidities, and degree of intraoperative contamination.

Keywords Obturator hernia · Hernia repair · Mesh · Primary repair · Suture repair

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Introduction

Obturator hernia (OH) is a rare type of abdominal hernia that occurs when abdominal structures protrude through the obturator foramen. It is responsible for less than 2% of all hernia cases [1, 2]. Women represent more than 97% of OH patients, with a mean BMI of 17.9 and mean age of 78.8 years [3]. The female predominance is likely due to women's oblique and larger pelvic anatomy, fat tissue loss, and laxity of the pelvic floor with advanced age [3, 4]. Due to the lack of specific symptoms in the early stages, patients with obturator hernias often present with late signs of intestinal obstruction and require emergency surgery, with mortality reported as high as 50–70% in strangulated cases [1–4]. Therefore, early diagnosis and surgical intervention are crucial to avoid morbidity and mortality [1, 3].

A range of surgical approaches is currently used for the treatment of OH. Open surgery via laparotomy is still the most common approach, as patients are often operated on in emergency conditions and may require bowel resection [2, 3]. Recently, some studies have reported that laparoscopic repairs are increasingly used and associated with decreased morbidity [5]. Primary suture closure (non-mesh) is the most common type of repair for OH, especially in emergent cases, but a growing number of studies suggest that mesh repair is safe and can lower recurrence rates [2, 3].

Due to the rarity of OH, high-quality data surrounding the topic are scarce, and most of the literature consists of small case series. To date, no study with a significant number of patients, retrospective or prospective, has been published. Additionally, a meta-analysis comparing different OH repair techniques does not exist in the available literature. Therefore, a systematic review and meta-analysis is warranted to summarize the different surgical techniques and compare the efficacy of mesh and non-mesh repair for OH.

Materials and methods

Eligibility criteria

Studies meeting the following criteria were included: (1) retrospective or prospective studies; (2) involving patients undergoing obturator hernia repair; (3) studies that compared mesh repair of OH with primary suture repair; and (4) reported any of the clinical outcomes of interest. We excluded studies with: (1) overlapping populations; (2) patients with other hernia types; (3) no comparison of mesh repairs with non-mesh repairs; (4) lack of the outcomes of interest; and (5) lack of reporting of outcomes of interest for both groups.

Search strategy and data extraction

The search was conducted via PubMed, EMBASE, and Cochrane Central Register of Controlled Trials on studies that met the eligibility criteria published from inception to October 2022. The search strategy consisted of "Obturator hernia" and was conducted by three authors (M.B., C.G., and I.C.). References from the included studies were manually reviewed. No filters or language restrictions were applied to the search. Two authors (M.B. and C.G.) independently extracted baseline characteristics and outcome data based on predefined search criteria. Disagreements among the authors were resolved by consensus. PROSPERO registered the prospective meta-analysis protocol in November 2022 with the following ID: CRD42022371935.

Outcomes of interest

Study design, country of the study, patient demographics (including age, body mass index (BMI), and gender), surgical technique (type of surgical repair, use of mesh, mesh type), need for bowel resection, follow-up duration, and postoperative outcomes (recurrence, mortality, and complication rates) were analyzed.

Risk of bias assessment

An objective assessment of trials was performed using the Cochrane Handbook of Systematic Reviews for assessing randomization, concealment, blinding, intention to treat, baseline comparisons, concomitant interventions, and completeness of follow-up [6]. All the trials, non-randomized, were evaluated using the revised tool to assess the risk of bias in non-randomized studies of interventions (ROBINS-I) [7]. Each study received a score of critical, serious, moderate, and low risk of bias in each domain. Two authors independently performed the risk of bias assessment (M.B. and C.G.). Disagreements were resolved by consensus after discussing the reasons for the divergence with a third author (I.C.).

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) tool was used to assess the certainty of the evidence as high, moderate, low, or very low for each study in the following outcomes: OH recurrence rates after repair; mortality rates; and complication rates [8]. The grading of recommendations' strengths was carried out by two independent authors (M.B. and I.C.) using the GRADE Guideline Development Tool [8]. Disagreements were settled by a third author (C.G.).

Statistical analyses

The systematic review and meta-analysis were performed in line with recommendations from the Cochrane Collaboration and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement guidelines [9]. Binary endpoints were collected as the number of events and number of individuals at risk to produce summary effects of both surgical hernia repair methods in terms of relative risks (RRs) with 95% confidence intervals (CIs). Cochran Q test, I^2 statistics, and visual inspection of the forest plots were used to assess heterogeneity. If the visual inspection was suggestive of heterogeneity in effect size, the p value < 0.10 or I^2 statistics was $\geq 25\%$, heterogeneity was considered significant, and a random-effect model was used. Otherwise, we use a fixed-effects model. The statistical analysis was conducted using Review Manager 5.4 (Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen, Denmark).

Results

Study selection and characteristics

The primary search generated 1760 results, 674 articles were duplicates and 1019 were excluded by unrelated titles or abstracts. We thoroughly reviewed 67 studies, of which 54 were excluded by eligibility criteria. The remaining 13 articles were included in this systematic review and meta-analysis. The flow diagram of study screening and selection is shown in Fig. 1. The characteristics of individual studies are presented in Table 1. All studies were retrospective [4, 10–21]. We included 351 patients, and more than 93% were females. One hundred and twenty-eight (36.5%) patients underwent mesh repair and two hundred and twenty-four (63.8%) underwent non-mesh repair. All the studies with available mean age reported values above 70 years. OH was diagnosed preoperatively in the majority of the cases (71.3%), most commonly through computed tomography (CT). Intraoperative diagnosis occurred in 89 cases (22.4%), which included incidentally found hernias and intestinal obstruction of unknown origin. The method of diagnosis for the remaining 25 (6.3%) cases was unspecified.

Polypropylene mesh was the most commonly used mesh, but other synthetic and bioprosthetic mesh were also reported. Open surgery, primarily via an abdominal incision, was the most common surgical technique performed in 268 (76.3%) patients. Laparoscopic repairs, including transabdominal preperitoneal (TAPP) and totally extraperitoneal (TEP) approaches, were performed in 62 (17.7%) patients and reported in 8 studies [10, 13–17, 19, 20]; the procedure type was not specified in the remaining 21 (6%) patients [11]. Bowel resection was performed in 145 (41.3%)

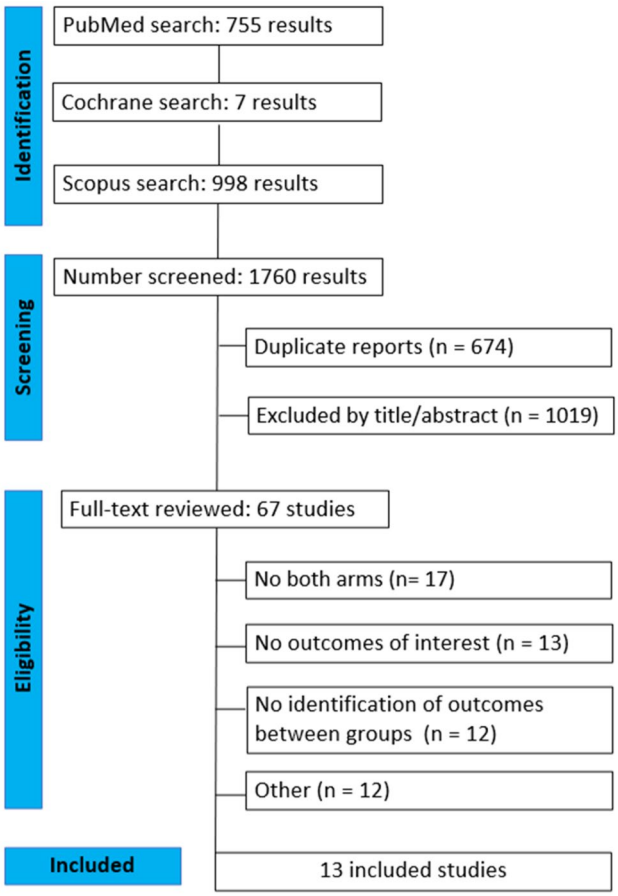

Fig. 1 PRISMA flow diagram of study screening and selection

patients. Nine studies provided information on the type of repair used in these patients: nineteen (13.1%) patients underwent mesh repair and seventy-four (51%) underwent a non-mesh repair [4, 10–14, 16, 17, 19, 20]. However, the remaining 52 (35.9%) bowel resection patients had no available information about the type of repair used in the last 4 studies [12, 15, 18, 21]. The follow-up duration was between 1 and 13 years.

Pooled analysis of all studies

Hernia recurrence

All the studies compared the incidence of hernia recurrence for mesh and non-mesh repair [4, 10–21]. Among the 128 patients who received mesh treatment, only 2 (1.56%) experienced recurrence during their follow-up period. Conversely, out of the 252 non-mesh OH surgeries performed in 224 patients, 25 (10%) of the hernias had recurrences over a follow-up period ranging from 1 to 13 years. Our results showed an increased hernia recurrence in patients who underwent hernia repair without mesh compared to

Table 1 Baseline characteristics of included studies

Study; year	Country	Design	Patients (n, %)	Age (years)	BMI (kg/m^2)	Female (n, %)	Surgical technique	Mesh Type	Bowel resection (n, %)	Follow-up (months)
Hayama et al. [10]	Japan	R	Mesh: 11 (92) No mesh: 1 (8)	Open: 85 (80–90) TAPP: 83.5 (49–87)	Open: 17.0 (13.5–22.1) TAPP: 17.5 (14.7–20.8)	Mesh: 6 (50) No mesh: 6 (50)	Mesh: open (abdominal incision) preperitoneal or laparoscopic TAPP No mesh: laparoscopic simple peritoneal closure	Permanent synthetic	Mesh: 2 (33) No mesh: 0	Open: 34 (29–59) TAPP: 34 (29–59)
Hisamatsu et al. [11]	Japan	R	Mesh: 8 (38.1) No mesh: 13 (61.9)	83.3 (71–93)	16.9 (13–23.1)	20 (95.2)	Mesh: not specified No mesh: closure of obturator foramen	Polypropylene (Bard)	Mesh: 2 (25) No mesh: 6 (46)	NA
Karasaki et al. [12]	Japan	R	Mesh: 24 (30) No mesh: 56 (70)	84 (43–94)	18.1 (13.3–25.2)	68 (97)	Mesh: open via abdominal or inguinal incision No mesh: open (abdominal or inguinal incision) with closure of sac, suture pectineus muscle to pubic periosteum, or covering defect with adjacent organ	Polypropylene or patch with memory recoil ring (modified Kugel patch)	35 (44)	Mesh: 17 (0–19) No mesh: 30 (0–142)
Karashima et al. [13]	Japan	R	Mesh: 9 (41) No mesh: 13 (59)	Mesh: 86 No mesh: 87	NA	22 (100)	Mesh: laparoscopic TEP No mesh: open closure of obturator foramen via abdominal incision	Polypropylene (Parietex)	Mesh: 0 No mesh: 12 (100)	43

Table 1 (continued)

Study; year	Country	Design	Patients (n, %)	Age (years)	BMI (kg/m^2)	Female (n, %)	Surgical technique	Mesh Type	Bowel resection (n, %)	Follow-up (months)
Kawanaka et al. [14]	Japan	R	Mesh: 11 (35) No mesh: 20 (65)	Open: 84.5 (57–92) Lap: 83 (66–94)	Open: 17.4 (12.8–21.1) Lap: 18.3 (12.8–25.6)	30 (96.8)	Mesh: open (abdominal incision), laparoscopic TAPP or TEP No mesh: open suture closure of obturator canal via abdominal incision	Polypropylene (Bard Soft or 3D Max)	Mesh: 0 No mesh: 16 (80)	24.5
Leung et al. [15]	Hong Kong	R	Mesh: 1 (33) No mesh: 2 (67)	NA	NA	NA	Mesh: laparoscopic TEP No mesh: laparoscopic broad ligament repair	NA	1 (33)	14
Li et al. [4]	China	R	Mesh: 14 (19) No mesh: 59 (81)	79.47 (59–103)	16.78 (11.38–29.03)	71 (97.3)	Mesh: open via inguinal incision No mesh: open simple closure of peritoneum via abdominal incision	NA	Mesh: 0 No mesh: 24 (40.7)	36
Liu et al. [16]	China	R	Mesh: 9 (90) No mesh: 1 (10)	72.1 (57–86)	17.8 (14.1–20.8)	10 (100)	Mesh: laparoscopic TAPP No mesh: laparoscopic converted to open high hernia sac ligation, and closure of defect	Synthetic	Mesh: 0 No mesh: 1 (100)	31 (6–54)

Table 1 (continued)

Study; year	Country	Design	Patients (n, %)	Age (years)	BMI (kg/m^2)	Female (n, %)	Surgical technique	Mesh Type	Bowel resection (n, %)	Follow-up (months)
Mantoo et al. [17]	Singapore	R	Mesh: 4 (67) No mesh: 2 (33)	88.8 (76–96)	15.5 (13.5–19.5)	6 (100)	Mesh: open via abdominal incision or laparoscopic TAPP No mesh: open simple suture closure of obturator canal (abdominal incision)	Prolene	Mesh: 3 (75) No mesh: 0	< 20
Mena et al. [18]	Spain	R	Mesh: 4 (33) No mesh: 8 (67)	73 (19–88)	NA	11 (100)	Mesh: open preperitoneal repair (abdominal or inguinal incision) No mesh: open simple closure and peritoneal apposition (abdominal or inguinal incision)	Polypropylene	7	156
Nasir et al. [19]	USA	R	Mesh:7 (23) No mesh: 23 (73)	82 (31–94)	18.6 (16–32)	29 (97)	Mesh: open via abdominal incision or laparoscopic TEP No mesh: open primary tissue repair via abdominal incision	Synthetic or bioprosthetic	Mesh: 2 (29) No mesh: 12 (52)	24 (0–660)

Table 1 (continued)

Study; year	Country	Design	Patients (n, %)	Age (years)	BMI (kg/m^2)	Female (n, %)	Surgical technique	Mesh Type	Bowel resection (n, %)	Follow-up (months)
Ng et al. [20]	Hong Kong	R	Mesh: 7 (20) No mesh: 28 (80)	83 (53–96)	NA	35 (100)	Mesh: laparoscopic intraperitoneal (GoreTex) or extraperitoneal (Prolene) repair No mesh: open (broad ligament or primary closure) or laparoscopic broad ligament repair	GoreTex or Prolene	10 (29)	Open: 43 (0–158) Lap: 68 (45–105)
Rodríguez-Hermosa et al. [21]	Spain	R	Mesh:11 (69) No mesh: 5 (31)	82.6 (63–95)	16.6 (13.3–18.4)	16 (100)	Mesh: open via abdominal or inguinal incision No mesh: open simple apposition of peritoneum (abdominal or inguinal incision)	Polypropylene	Mesh: 9 (81) No mesh: 3 (60)	1–24

Numbers reported as mean/median (range) unless otherwise specified. *BMI* body mass index, *Lap* laparoscopic, *MPO* myopectineal orifice, *NA* not available, *R* retrospective, *TAPP* transabdominal preperitoneal, *TEP* totally extraperitoneal, *USA* United States of America, *3D* three-dimensional

mesh repair (RR 0.31; 95% CI 0.11–0.94; $p = 0.04$; $I^2 = 13\%$; Fig. 2).

There were 11 studies that compared the mortality rate between mesh (5%) and non-mesh (9.6%) repair patients [4, 10–13, 15–18, 20, 21]. There was no difference in mortality rates between these two groups (RR 0.64; 95% CI 0.25–1.62; $p = 0.34$; $I^2 = 0\%$; Fig. 3).

Complication rates

There were eight studies comparing the complication rates between mesh repair (28%) and non-mesh repair patients (32.3%), such as surgical site infection, pneumonia, exacerbation of baseline comorbidities, and overall complications [4, 10, 12, 13, 16, 18, 20, 21]. There was no difference in complication rates between these two groups (RR 0.59, 95% CI 0.28–1.25; $p = 0.17$; $I^2 = 50\%$; Fig. 4).

Risk of bias assessment

The risk of bias evaluation of each non-randomized study included in this meta-analysis according to the ROBINS-I tool is presented in Fig. 5. Two studies were rated as critical risk of bias (both due to selection of the participants), and the others exhibited a serious risk of bias, mainly because of confounding bias.

Supported by the GRADE tool, the overall certainty of the evidence for the outcomes assessed was initially low, as all the included studies were non-randomized, and further downgraded in some cases according to the severity of the risk of bias effect, inconsistency, and imprecision, or upgrade by one or two points due to large magnitude of the effect. One of the endpoints assessed resulted in low certainty of evidence, and two presented very low. Table 2 summarizes the GRADE assessment and the findings from this review.

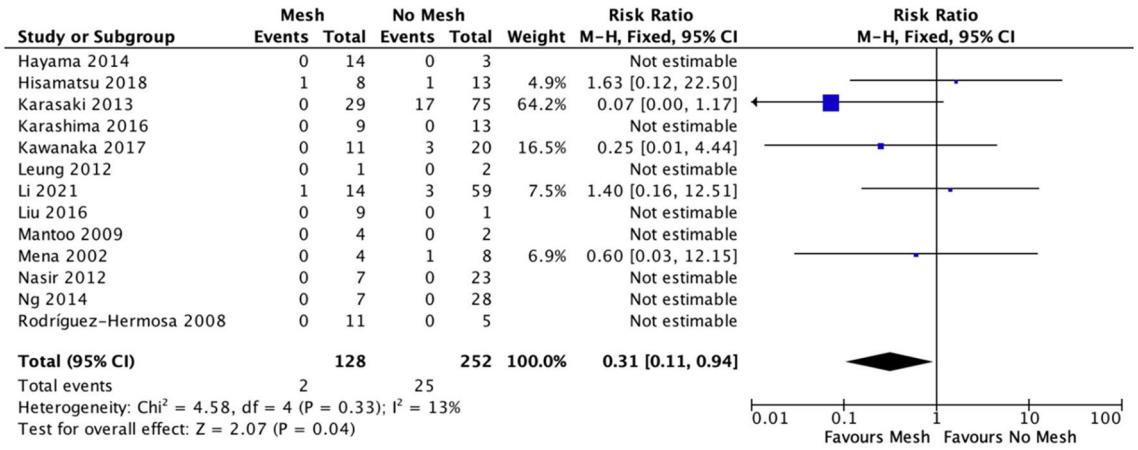

Fig. 2 Recurrence rates after OH repair with mesh versus non-mesh

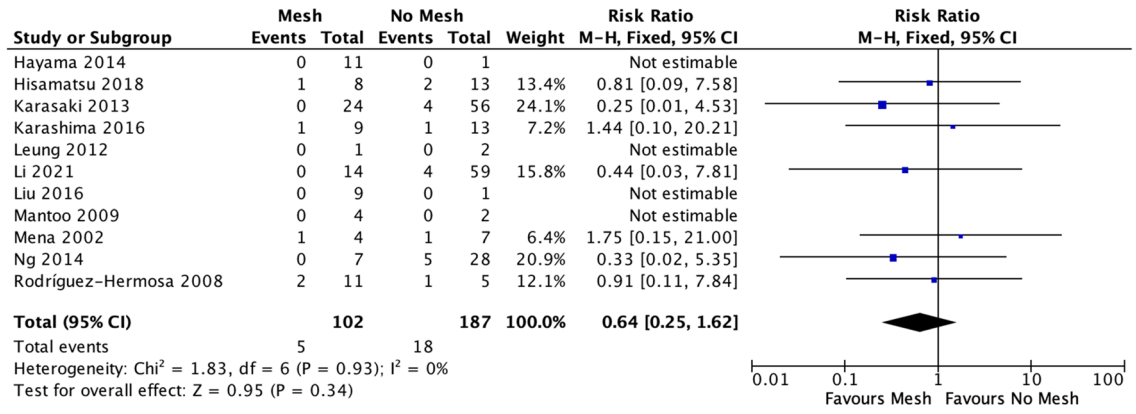

Fig. 3 Mortality after OH repair with mesh versus non-mesh

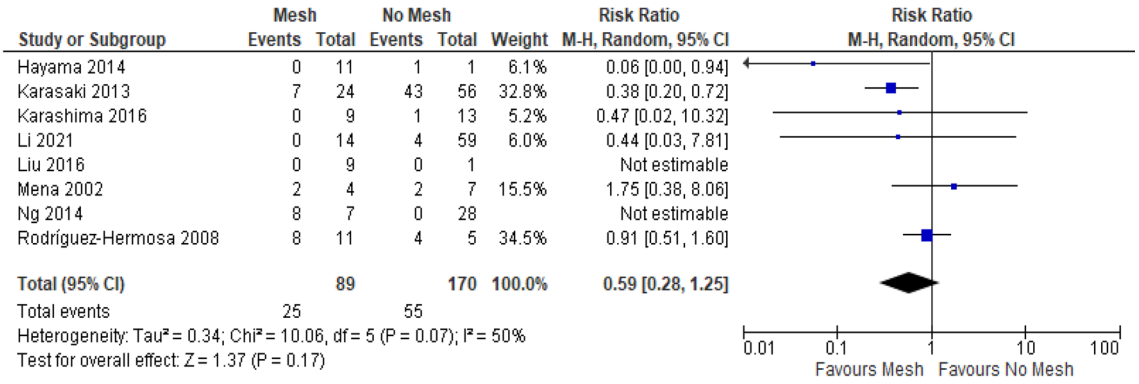

Fig. 4 Complication rates after OH repair with mesh versus non-mesh

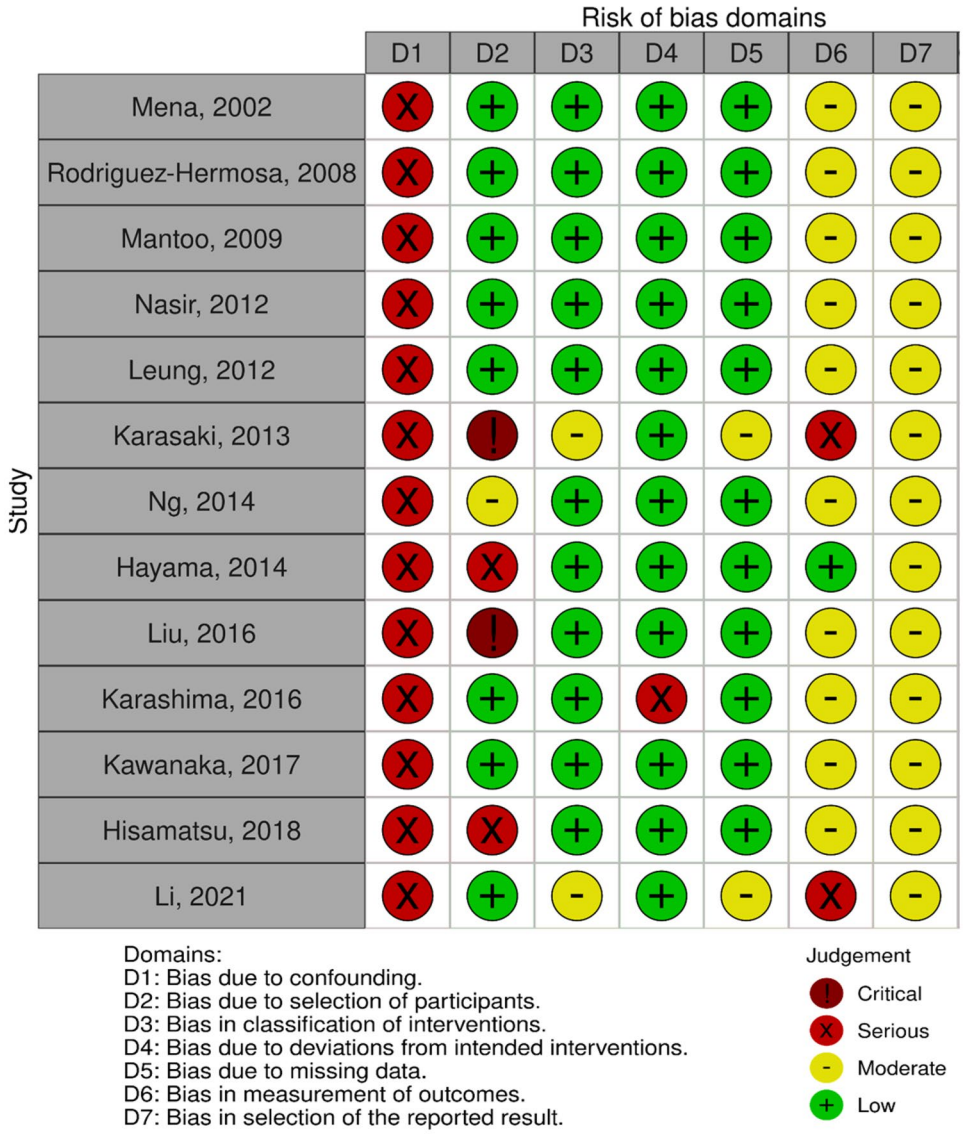

Fig. 5 Critical appraisal according to the ROBINS-I tool for assessing risk of bias

Table 2 GRADE assessment and summary of findings of the main reported outcomes: recurrence, mortality, and complications

Outcomes	№ of participants (studies) Follow-up	Certainty of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with placebo	Risk difference with overall
Recurrence	352 (13 observational studies)	⨁⨁◯◯ Low[a,b]	RR 0.31 (0.11 to 0.94)	237 per 1,000	163 fewer per 1,000 (211 fewer to 14 fewer)
Mortality	289 (11 observational studies)	⨁◯◯◯ Very low[a,b]	RR 0.64 (0.25 to 1.62)	96 per 1,000	35 fewer per 1,000 (72 fewer to 60 more)
Complications	259 (8 observational studies)	⨁◯◯◯ Very low[a,b,c]	RR 0.59 (0.28 to 1.25)	324 per 1,000	133 fewer per 1,000 (233 fewer to 81 more)

*The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI)

CI confidence interval, *RR* risk ratio

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect

Moderate certainty: we are moderately confident in the effect estimate that the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different

Low certainty: our confidence in the effect estimate is limited, i.e., the true effect may be substantially different from the estimate of the effect

Very low certainty: we have very little confidence in the effect estimate that the true effect is likely to be substantially different from the estimate of effect

[a]Outcome significantly carried out by studies with high risk of bias. Downgraded by two levels for risk of bias

[b]Insufficient number of events (intervention + control < 300 participants). Downgraded by one level for imprecision

[c]High heterogeneity ($I^2 > 50\%$). Downgraded by one level for inconsistency

Discussion

In this systematic review and meta-analysis of 13 retrospective studies involving 351 patients, we summarized the operative techniques and compared mesh and non-mesh OH repair. Our results demonstrated that mesh repair was associated with lower hernia recurrence rates and had similar mortality and complication rates compared to non-mesh repair. However, it is important to emphasize that rates of bowel resection differed considerably between the mesh and non-mesh groups, which introduces a confounder and limits the generalizability of our findings to contaminated cases.

Early surgery is crucial for resolving the most common complications of OH, such as incarceration and strangulation [2, 4]. Currently, there is an ongoing debate among surgeons regarding the most appropriate technique for the treatment of OH, as there is still no consensus. As demonstrated in a recent scoping review, open surgery is widely used for OH repair with more than 70% of the included 1299 OH patients, mainly through a midline incision and suture repair of the hernia defect [2, 4]. Given that most patients with OH are elderly and frail, open surgery can present significant morbidity, and studies have shown fewer complications and shorter length of hospital stays in patients undergoing laparoscopic OH repair [5, 13, 14, 20, 22]. Kohga et al. [23] reported a 9% complication rate with laparoscopic repair of incarcerated OH, while open repairs had a 61.1% complication rate, with open surgery being an independent risk factor for postoperative complications. Ng et al. retrospectively evaluated 35 OH patients and reported that 42.1% of open surgery patients experienced complications, while there were no major complications in the laparoscopic group. The open surgery group also had a mortality rate of 26.3% while there were no deaths in the laparoscopic group [20]. This suggests that a laparoscopic approach, when feasible, may be a less morbid option for OH repair. Nevertheless, it is still important to recognize that many cases are not appropriate for laparoscopic techniques, as patients can present with hemodynamic instability, inability to tolerate pneumoperitoneum, or strangulation with the need for bowel resection. Furthermore, we acknowledge the lack of randomization in these past studies and potential confounders; patients who underwent open surgery were generally more likely to require bowel resection or present in worse condition.

Regardless of the operative approach, mesh use is an important consideration for patients undergoing OH repair. Kawanaka et al. retrospectively evaluated 31 OH participants, and none of the 11 patients who underwent mesh repair had recurrences, while simple suture repair patients had a 25% recurrence rate in 3 years and 40% in 5 years [14]. In addition, Liu et al. conducted a study of patients who underwent emergency surgery for incarcerated OH, and mesh repair was performed in 90% of the patients with no reported recurrences over a mean follow-up of 31 months [16]. In one of the largest OH studies, Karasaki et al. reported a 22.7% recurrence rate in patients undergoing

non-mesh OH repair with a median follow-up of 30 months, and no recurrences were noted in patients that underwent mesh repair with a median follow-up of 17 months [12]. This data is in accordance with the results of our meta-analysis, which showed a significantly lower rate of recurrence with mesh repair when compared to non-mesh repair.

Although mesh repair for OH appears promising, its appropriate use should be determined on a case-by-case basis. Traditionally, it has been contraindicated in cases with contamination (i.e., intestinal perforation or strangulation requiring bowel resection), as it may increase the risk of mesh infection and associated complications [24]. Current international guidelines for groin hernias recommend avoidance of mesh repair in contaminated surgical fields to reduce the risk of infection [24]. Oida et al. found no difference in complications, including infection, when comparing mesh and non-mesh repairs of emergent inguinal hernia repairs but still argued against using prosthetic mesh in the setting of intestinal perforation due to concerns of infection [25]. However, more recent studies have challenged this teaching; Karasaki et al. evaluated the use of mesh in five patients who underwent OH repair with small bowel resection due to non-viable bowel and reported no complications postoperatively [12]. This represents an extension of mesh use into clean-contaminated cases, although application to contaminated and dirty wounds has yet to be determined.

Our meta-analysis showed similar complication and mortality rates between mesh and non-mesh repairs in OH repair. Still, it is essential to highlight that most patients requiring bowel resection underwent non-mesh repairs, which represents a significant limitation within our study. Karashima et al., for example, reported that all OH cases with bowel resection underwent a non-mesh repair [13]. As previously mentioned, this introduces potential confounders regarding the degree of contamination and complexity of the case. The rarity of OH has limited available studies to smaller retrospective cohorts and precludes the implementation of a randomized controlled trial. Although a subgroup analysis comparing mesh and non-mesh repair in patients who underwent a bowel resection may address this limitation, the number of patients who had mesh placed in the setting of a bowel resection was too small to do so. Considering these limitations, we are unable to provide an overall recommendation regarding mesh use in OH. In clean cases, mesh repair is likely more appropriate given the benefit of reducing OH recurrence. However, decisions in the setting of contamination and need for bowel resection are more complex, as there are additional factors of patient stability and serious infection risk to warrant greater consideration of suture repair.

Another limitation was the variability of surgical techniques implemented across studies. OH repairs could be performed open through a midline abdominal or inguinal incision or laparoscopically via TAPP or TEP techniques. Many studies simply described these operative techniques without providing the distribution of patients across the various approaches. Consequently, we were unable to perform further subgroup analyses comparing outcomes of open and laparoscopic repairs.

Conclusion

As the first systematic review and meta-analysis comparing mesh and non-mesh repair outcomes in OH patients, our study provides important insight regarding available surgical techniques and the utilization of mesh. Mesh repair was associated with a lower recurrence rate in patients undergoing OH repair, with similar complication and mortality rates compared to non-mesh repair. However, it is important to interpret these findings with awareness of potential bias since most patients with bowel resections underwent non-mesh repairs. Because many patients with OH are elderly, frail, and present as surgical emergencies, the decision to proceed with mesh placement during OH repair is complex and should be individualized according to the degree of contamination and the patient's clinical status.

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Author contributions All authors contributed to the study's conception and design. MMB, CPG, and IC performed material preparation, data collection, and analysis. The first draft of the manuscript was written by MMB, CPG, IC, SMPF, and R-MDM. All authors critically reviewed previous versions of the manuscript. All authors read and approved the final manuscript. All authors agree to be accountable for all aspects of the work.

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Data availability Because this meta-analysis was based on data extracted from previously published research, all the data and study materials are available in the public domain. The authors of this meta-analysis do not have access to patient-level data of the individual studies. Researchers with an interest in individual-level data from the studies included in this meta-analysis are encouraged to contact the corresponding author from each study for such request.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose. Dr. Sergio Mazzola Poli de Figueiredo and Dr. Rui-Min Diana Mao have no disclosures. Dr. Richard Lu received payment/honoraria for lectures and presentations from Intuitive Surgical that are unrelated to this work.

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent to publish Not applicable.

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