World J Surg (2016) 40:826–835
DOI 10.1007/s00268-015-3311-2

ORIGINAL SCIENTIFIC REPORT

Suture Versus Mesh Repair in Primary and Incisional Ventral Hernias: A Systematic Review and Meta-Analysis

Tim Mathes[1] · **Maren Walgenbach**[1] · **Robert Siegel**[2]

Published online: 12 November 2015

Abstract

Background Today, ventral hernia repair is predominantly performed with meshes. There is no meta-analysis of high quality evidence that compares the results of suture to mesh repair. The objective of this systematic review with meta-analysis is to compare patient centred outcomes of suture versus mesh repair.

Methods A systematic literature search was performed in EMBASE, MEDLINE and CENTRAL (inception to 06/2014). Furthermore a hand search was performed. RCTs comparing suture versus mesh repair in primary and incisional ventral hernia repair were included. Data on patient characteristics, interventions and results were extracted in standardized tables. Risk of bias was assessed with the cochrane risk of bias tool. Results of studies were pooled with a meta-analysis. All steps were performed by two reviewers. Discrepancies were discussed until a consensus.

Results The search in the databases resulted in 1560 hits. After screening, 10 randomized controlled trials including 1215 patients satisfied all inclusion criteria. Risk of bias was moderate to high. The relative risk for recurrence was 0.36 [95% CI (0.27, 0.49); $I^2 = 0$; heterogeneity $p = 0.70$]. Other complications did not differ significantly. Results for chronic pain were heterogeneous across studies.

Conclusion Mesh repair reduces the number of recurrences significantly. In patients without recurrence mesh repairs seem to be associated with a risk of chronic pain especially if the mesh is fixed sublay.

Introduction

Ventral hernia repair is one of the most common surgical procedures in abdominal surgery [1]. With an increasing number of procedures in abdominal surgery, especially the prevalence of incisional hernias is further increasing. Incisional hernias occur in about 20 % of all cases after laparotomy [2–6].

The surgical outcomes of primary ventral or incisional hernia repair depend on the applied technique. In the last decades, ventral hernia repair has been predominantly performed with the use of prosthetic meshes for reinforcement of the abdominal wall.

Electronic supplementary material The online version of this article (doi:10.1007/s00268-015-3311-2) contains supplementary material, which is available to authorized users.

✉ Tim Mathes
tim.mathes@uni-wh.de

[1] Faculty of Health-School of Medicine, Institute for Research in Operative Medicine, Witten/Herdecke University, Ostmerheimer Str. 200, Building 33, 51109 Cologne, Germany

[2] Department of General, Visceral and Cancer Surgery, HELIOS Klinikum Berlin-Buch and Faculty of Health-Witten/Herdecke University, HELIOS Klinikum, Schwanebecker Chaussee 50, 13125 Berlin, Germany

To date, there is no meta-analysis of randomized controlled trials (RCTs) that compares suture to mesh repair in primary or incisional ventral hernias.

The comparative effectiveness between the two techniques is still not sufficiently evaluated regarding recurrence. Moreover, the presumed advantage of mesh repair is often not sufficiently balanced against possible negative effects on other patient centred outcomes, which might be higher by the implementation of a prosthetic mesh.

The objective of this systematic review with meta-analysis of RCT is to compare patient centred long-term outcomes (recurrence and chronic pain) of suture versus mesh repair.

Methods

Search strategy

The systematic review was prepared according to the standards of the cochrane collaboration and reported following PRISMA [7, 8].

To identify RCTs on ventral hernia repair, a systematic electronic literature search was performed in MEDLINE (via Pubmed), Embase (via Embase) and CENTRAL (via Cochrane Library) from inception to 06/2014 (the full search strategy is provided in Supplement 1). No limits were applied in the search (e.g. language or time). Additionally, to identify grey literature and further relevant articles that were not identified by the electronic literature search, a hand search was made using various sources (08–10/2014). The references of all included publications and identified systematic reviews on the same topic were cross-checked. Conference abstracts of the International Congress of the European Hernia Society, Congress of the European Association of Endoscopic Surgery and the Annual meeting of the American Hernia Society were screened (2000–2014). A search was performed in the journals Hernia, Surgical Endoscopy, British Journal of Surgery, Journal of the American College of Surgeons, and World Journal of Surgery (2009–2014). Moreover, the trial registers ClinicalTrials.gov and World Health Organization (WHO) International Clinical Trials Registry Platform were searched (TM).

Inclusion criteria

1. *Patients* Adult patients (≥18) with primary or incisional ventral hernia
2. *Intervention/comparison* Comparison of suture versus mesh repair
3. *Outcomes* Recurrence (primary), overall or long-term complications, quality of life or pain
4. *Study type* RCT
5. *Language* Article in English or German

Study selection

The titles and abstracts of the publications identified by the literature search, and in case of relevance, the full-text versions were screened according to pre-defined inclusion criteria independently by two reviewers (TM, MW). Discrepancies were resolved in a discussion, in case of insolvable inconsistency with involvement of a third reviewer. Authors were contacted if the inclusion criteria of articles were unclear.

Data collection and analysis

Data were extracted in a-priori piloted standardized tables. Data on inclusion/exclusion criteria that characterize patients and details of the applied technique of suture and mesh repair, respectively, and the results were extracted in these tables. Because we focused on patient centred outcomes only information for recurrences, overall complications, long-term complications, quality of life and pain were extracted. If primary endpoints were defined by the authors, they were reported in addition. Information on age, BMI and gender (patient characteristics) were only extracted if the study groups were very heterogeneous. For dichotomous outcomes, only results for the last follow-up were extracted given that the measure was a cumulative observation.

The primary outcomes of this systematic review were recurrence and chronic pain (pain still persists 6 weeks after surgery). One reviewer extracted data and a second reviewer controlled all extractions for quality assurance (TM, MW).

Risk of bias of included trials was assessed using the cochrane risk of bias (RoB) tool [9]. Recent research indicates that rating "unclear" "becomes the default for the risk of RoB regarding reliability" [10]. Furthermore, research has shown that there is a "statistical significant difference in effect sizes (…) between studies with a high or unclear risk of bias and those with a low risk of bias" [11]. Therefore, we decided not to rate "unclear". RoB was assessed independently by two reviewers and discrepancies discussed until a consensus was reached if necessary involving a third reviewer (TM, MW).

A significance-level of $p < 0.05$ was considered as statistical significant.

A meta-analysis was performed (TM) for the same outcomes, outcome measures and comparable measurement time points/follow-up. Appropriateness for meta-analysis was assessed by two of the reviewers. For dichotomous outcomes (e.g. recurrence), risk ratios (RRs) with 95 %

confidence intervals (CIs) were calculated using the Mantel-Haenszel methods (random-effect model). For trials that compared more than one mesh or suture group (e.g. suture versus onlay mesh and sublay mesh), results were combined (e.g. sublay and onlay was treated as one group).

In order to quantify heterogeneity, the I^2 statistics was calculated. To assess publication bias, a funnel plot was prepared.

Depending on the degree of heterogeneity, a meta-analysis within subgroups (primary vs. secondary hernias and size of hernias) or a meta-analysis that combine all or several subgroups was planned.

Data were entered into RevMan 5.3 using the double data entry method (TM).

There was no protocol for this review.

Results

Literature search

Excluding duplicates the search in electronic databases resulted in 1560 hits. After screening of titles and abstracts, 48 articles were retrieved for detailed comparison against the inclusion criteria. Most articles were excluded because allocation to groups was not randomized. Ten trials (11 articles) satisfied all inclusion criteria and were included in the analysis [3, 4, 12–20]. The process of study selection is illustrated in Fig. 1. The search of additional sources and grey literature did not reveal further relevant studies. For the trial of Weber et al. [19], there was only an article in Hungarian available. The data extraction and risk of bias were therefore performed based on the English abstract and graphics.

Risk of bias

Risk of bias was moderate to high. Selective reporting was the only item complied in each study. Because blinding of delivering the intervention is not possible, the related item was judged high risk of bias throughout. Except for the publication by Ammar et al. [12] blinding of outcome assessment failed also in all trials. For the study of Weber et al. [19], "minus" means that the risk of bias item was not reported in the abstract. The risk of bias for each study is presented in Table 1.

Study characteristics

Three trials analysed only incisional hernias [4, 15, 17], five only primary hernias [3, 12, 13, 16, 20] and two both types (incisional and primary hernias) [14, 18, 19]. One trial analysed only large incisional hernias [17], two trials complicated (para-) umbilical hernias [3, 12] and four only small or uncomplicated hernias [14, 15, 18, 20]. In the other trials, the hernia was not predefined regarding size and/or other inclusion criteria describing grade of complexity. Most studies compared suture repair with onlay or sublay mesh (polypropylene) fixation.

The results and characteristics of included studies are presented in Table 2. The publication by Burger et al. [14] provides the long-term follow-up of the Luijendijk trial [18] and is therefore shown in the subsequent row.

Results of meta-analysis

It was decided to pool only the results for recurrence because the definition/measurement and length of follow-up for wound complications and postoperative pain were too heterogeneous.

The RR for recurrence was 0.36 [95 % CI (0.27, 0.49)] in favour of mesh repair (Fig. 2). This difference was highly statistical significant ($p < 0.00001$). There was no heterogeneity between the included trials ($I^2 = 0$, test for heterogeneity $p = 0.70$).

A subgroup analysis was not performed because no heterogeneity existed between studies.

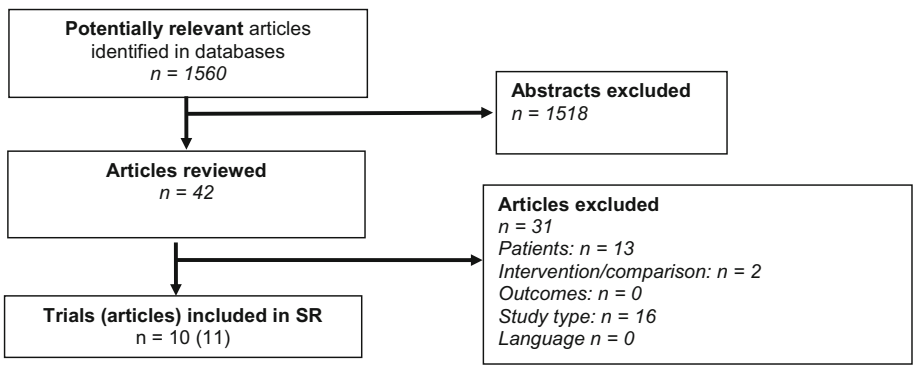

Fig. 1 Flow chart

Table 1 Risk of bias

Study	Generation of allocation sequence	Allocation concealment	Blinding of outcome assessment	Blinding of participants and personnel	Incomplete outcome data	Selective reporting	Other sources of bias
Abdel-Baki et al. 2007 [3]	−	+	−	−	+	+	+
Ammar 2010 [12]	+	+	+	−	−	+	+
Arroyo et al. 2001 [13]	+	−	−	−	+	+	+
Lal et al. 2012 [20]	−	+	−	−	+	+	+
Luijendijk et al. 2000 [18]	−	−	−	−	+	+	−
Burger et al. 2004 [14]	−	−	−	−	+	+	+
De Vries et al. 2007 [17]	−	+	−	−	−	+	+
Korenkov et al. 2002 [15]	−	+	−	−	+	+	+
Polat et al. 2005 [16]	−	−	−	−	−	+	+
Venclauskas et al. 2010 [4]	−	−	−	−	+	+	+
Weber et al. 2010 [19]	−	−	−	−	−	+	+

+ low risk of bias; −high/unclear risk of bias

The funnel plot was slightly asymmetric, indicating a publication bias of studies that favour suture repair (Fig. 3).

Results of included studies

All trials reported the incidence of recurrence and showed a defect direction in favour of mesh repair (follow-up 6 months–5 years).

De Vries et al. [17] and Korenkov et al. [15] defined the number of recurrences as their primary endpoint but did not show a statistical significant result for this outcome. Out of the eight remaining trials all but one reported statistical significant differences [3, 4, 12–14, 16, 18–20]. However, in the trial of Venclauskas et al. [4], only the results for the comparison of suture with sublay repair were statistical significant but not for suture with onlay repair.

Korenkov et al. [15], Burger et al. and Luijendijk et al. [14, 18], Polat et al. [16] and Venclauskas et al. [4] analysed pain measures. In the comparison of suture repair with onlay polypropylene mesh repair, Korenkov et al. [15] found a statistical significant result for pain between the groups at 6 weeks in favour for suture repair (fewer patients with long-term pain). Although effect direction remained, all endpoints were not statistical significant after one year follow-up. In the trial of Luijendijk et al. [18], the rates of patients presented with pain 1 month postoperative was similar. Burger et al. [14] distinguished between scar pain and abdominal pain. The effect direction was with one exception for all six pain measures in favour of mesh repair. A statistical significant result was presented for mean abdominal pain and proportions of patients with pain in favour for mesh repair for both recall periods (last month and last years, follow-up at least 5 years). The difference for scar pain was not statistically significant. Polat et al. [16] analysed mean pain with two different pain scores (McGill score and visual analogue results). Using the McGill, score resulted in the statistical significant results for mean pain after the first, second and seventh postoperative day between groups to the disfavour for onlay mesh repair. Measured with the visual analogue results were heterogeneous depending on measurement time point. Venclauskas et al. [4] reported significant higher pain in the onlay group at rest and also during physical activity.

Overall, other long-term complications than recurrences were seldom. None of the trials showed a statistical significant result. Also postoperative wound complications (e.g. surgical site infection or seroma) after hernia repair were mostly not statistical significant different. Only Venclauskas et al. [19] found a statistical significant difference between groups for the total number of postoperative wound complications. However, there was only a difference between suture and onlay repair, but not between suture and sublay repair. Detailed results are presented in Table 2.

Discussion

Risk of bias of the trials was moderate to high. In all comparisons (Luijendijk et al. and Burger et al. counted only once), suture repair was associated with more recurrent hernias than mesh repair. Nine comparisons were statistical significant [3, 4, 12–14, 16, 18–20]. Suture repair was statistical significant associated with more recurrences in the meta-analysis. The effect in our meta-analysis was

Table 2 Study characteristics and results

TT	Patients (*n*)	Hernia type/inclusion	Exclusion	Intervention	Control	Results
Abdel-Baki et al. [3]	Randomised: 21/21 Analysed: 21/21	Acutely incarcerated paraumbilical hernia	Generalized peritonitis	Mesh (onlay, polypropylene)	Suture (non-absorbable)	Number of recurrences (1 year) 0 versus 4; 0.036 Number of long term complications (mean 16 months) 0/0; NA
Ammar [12]	Randomised: 40/40 Analysed:35/37	Complicated umbilical hernia (non-recurrent) Liver cirrhosis Child-pugh class A or B	Chronic renal insufficiency severe heart disease Diabetes mellitus Malignancy BMI > 30	Mesh (onlay, polypropylene)	Suture (non-absorbable)	Number of recurrences (6–28 months) 1 versus 5; < 0.05
Arroyo [13]	Randomised:100/100 Analysed: 100/100	Primary umbilical hernia	Significant anaesthetic risk Need for emergency surgery	Mesh (extra-peritoneal, polyester)	Suture (non-absorbable)	Number of recurrences (64 months) 1 versus 11; 0.0015 Number of other complications (mean follow-up 64 months) 1 versus 2; NS
De Vries 2007[20]	Randomised: 19/18 Analysed: 19/18	Incisional hernia after midline laparotomy (length craniocaudal $\geq$ 20 cm)	Perioperative gross contamination of operative field $\geq$ 80 years	Mesh (underlay, e-PTFE)	Suture (polydioxanone,, components separation technique)	Number of recurrences (36 months) 4 versus 10; 0.592 Number of major wound complications (36 months) 13 versus 10; NS Number of wound complications (36 months) 1 versus 1; NS

Table 2 continued

TT	Patients (*n*)	Hernia type/inclusion	Exclusion	Intervention	Control	Results
Korenkov [18]	Randomised: 33/39/28 Analysed: 33/39/28	Simple incisional hernia (< 10 cm diameter)	General contraindications for laparotomy or laparoscopy	Suture	Mesh (onlay polypropylene)	Number of recurrences (9 months) 4 versus 3 versus 4; NS Number of complications (10 days) 3 versus 7versus 5; NR Proportion of patients with pain (VAS > 0, 6 weeks) 13.33 versus 42.10 versus 14.28; 0.01 Median pain intensity (VAS scaling NR, 1 year) 0 versus 0 versus 0; 0.11 Proportion of patients with pain (VAS > 0, 1 year) 25 versus 40 versus 17.39; 0.17
					Onlay autodermal skin graft	Mean quality of life (GIQL 0-100, 1 year) 72 versus 75 versus 77; 0.63
Lal 14]	Randomised: 32/30 Analysed: 32/30	Uncomplicated, reducible Para-Umbilical hernia	Defect of < 4 cm in linea alba Unfit for general anesthesia	Mesh (onlay, polypropylene)	Suture (non-absorbable)	Number of recurrences (12 months) 0 versus 3; NR Long term complications (12 months) 0/0; NA
Luijendijk [17]	Randomised: 84/97 Analysed: 84/97 (recurrence)	Primary or first time recurrent vertical midline incisional hernia (≤ 6 cm)	>1 hernia Infection signs Prior hernia repair with mesh Plans to repair the hernia as part of another intra-abdominal procedure	Mesh (sublay, polypropylene)	Suture (polypropylene)	Number of recurrences (3 years) 17 versus 39; 0.005 Proportion of patients with pain (one month) 18 % versus 20 %; NR

Table 2 continued

TT	Patients (*n*)	Hernia type/inclusion	Exclusion	Intervention	Control	Results
Burger [15]	Randomised: 84/97 Analysed: 84/97 (recurrence) Analysed: 66/60 (complications)	Primary or first time recurrent vertical midline incisional hernia (≤ 6 cm)	> 1 hernia Infection signs Prior hernia repair with mesh Plans to repair the hernia as part of another intra-abdominal procedure	Mesh (sublay, polypropylene)	Suture (polypropylene)	Number of recurrences (at least 5 years) 27 versus 54; < 0.001 17 versus 8; 0.17 Scar pain (at least 5 years) + Proportion of patients (last month): 20 versus 27; 0.53 + Proportion of patients (past years): 20 versus 23; 0.83 + Mean (VAS 0-10, last month): 1.12 versus 1.17; 0.68 + Mean (VAS 0-10, past years): 1.3 versus 1.12; 0.75 + Proportion of patients (past years): 18 versus 39; 0.01 + Mean (VAS 0-10, last month): 1.0 versus 1.9; 0.04 + Mean (VAS 0-10, past years): 1.0 versus 2.2; 0.009
Polat [16]	Randomised: 17/18/15 Analysed: 17/18/15	Umbilical hernia	Strangulated hernia Recurrent hernia Omphalitis- or periumbilica fistulas Defects > 4 cm ASA score IV Concomitant diseases	Prolene Hernia System (IG)	Suture (mayo repair, polypropylene + polyglactin, CG1)	Number of recurrences (follow-up 6-44 months) 0 versus 2 versus 0; NR Mean pain (McGill 0-5) + day 1: 1.9 versus 2.0 versus 2.4; NS (IG vs. CG1); < 0.05 (IG vs. CG2); < 0.05 (CG1 vs. CG2) + day 2: 1.0 versus 1.3 versus 1.6; NS (IG versus CG1); < 0.05 (IG vs. CG2); < 0.05 (CG1 vs. CG2)
					Mesh (onlay, polypropylene + polyglactin, CG2)	Mean pain (VAS 0-100) + day 1: 24.7 versus 31.1 versus 37.3; NS + day 2: 12.6 versus 17.2 versus 22.6; < 0.05 (IG vs. CG1); NS (IG vs. CG2); NS (CG1 vs. CG2) + day 7: 2.3 versus 5.2 versus 11.7; NS (IG versus CG1) < 0.05 (IG vs. CG2); NS (CG1 vs. CG2)

Table 2 continued

TT	Patients (*n*)	Hernia type/inclusion	Exclusion	Intervention	Control	Results
Venclauskas [4]	Randomised: 54/57/50 Analysed: 54/56/50 (2 weeks) Analysed: 50/53/49 (12 months)	Middle incisional hernia	None	Suture (non-absorbable, keel technique, IG)	Mesh (onlay, polypropylene + polyglecaprone CG1)	Number of recurrences (12 months) 12 versus 6 versus 1; NS (IG vs. CG1); 0.002 (IG vs. CG2); NS (CG1 vs. CG2) Total number of wound complications (12 months) 12 versus 28 versus 12; 0.004 (IG vs. CG1); NS (IG vs. CG2); 0.007 (CG1 vs. CG2) Mean intraabdominal pressure due surgery (mmHg, time point NR) 5.66 versus 1.88 versus 1.76; < 0.001(IG vs. CG1); < 0.001 (IG vs. CG2); NS (CG1 vs. CG2)
					Mesh (sublay, CG2)	+ day 7: 0.6 versus 0.6 versus 0.9; NS (IG vs. CG1); < 0.05 (IG vs. CG2); < 0.05 (CG1 vs. CG2)
Weber et al. 2010 [19]	Randomised: 247/247 Analysed: 180/184	Ventral hernias ≤25 cm^2	NR	Mesh (sublay)	Suture	Number of recurrences (5 years) 15 (8 %) vs. 50 (27 %); <0.001

CG control group, *IG* Intervention group, *NA* not applicable, *NR*, not reported; *NS* not significant, *VAS* visual analogue scale

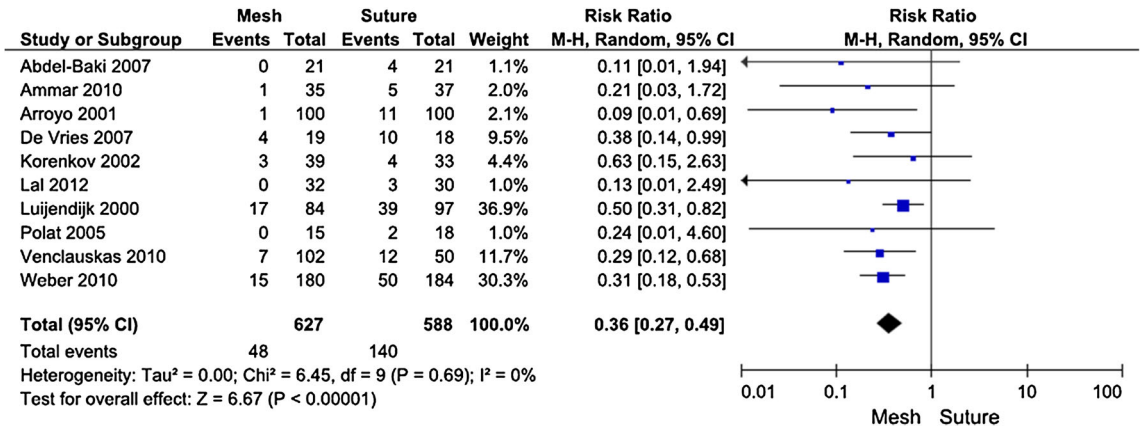

Fig. 2 Forest-plot

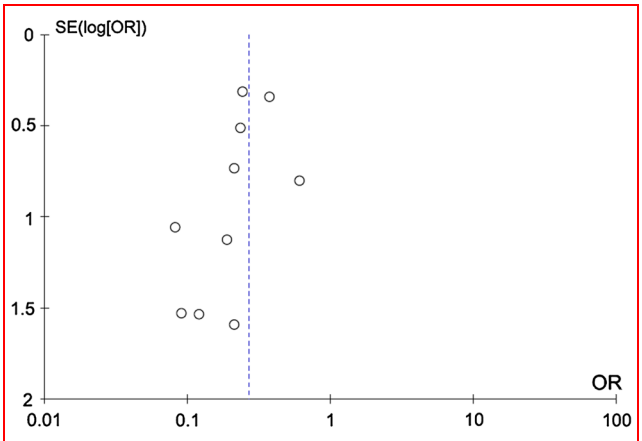

Fig. 3 Funnel plot

even stronger [Odds ratio: 0.27, 95% CI (0.19, 0.39)] than in a previous review that included only primary hernias [Odds ratio: 0.35 (0.21–0.60)] [21]. Therefore, it might be concluded that effects are larger in incisional hernias. However, the largest effect sizes could be observed in umbilical hernia repair [12, 20]. Thus, attributable for the stronger effect in our systematic review is probably that more of the included trials consider exclusively large hernias. Furthermore causal may be the following methodological flaws of the previous review. First, not all relevant studies on the topic were identified that satisfied the inclusion criteria of the review. Second, uncontrolled and retrospective studies (i.e. study designs at higher risk of bias) were included. The effect size of our meta-analysis is even larger than calculated in a previous systematic review on open suture versus mesh incisional hernia repair [22]. This suggests that results of mesh repair might be even better if the implantation is performed laparoscopically. The funnel plot for recurrence was slightly asymmetric indicating a publication bias towards studies that favour mesh repair. Reporting bias was low. As expected all included trials reported the incidence of recurrence.

Complications mostly did not differ between groups. Similar results showed a prior meta-analysis of three RCTs and cohort trials that estimated statistical significant differences in recurrences but not in complications for the repair of umbilical hernias [23, 24]. There were more postoperative complications in onlay than sublay repair, suggesting that the difference between suture and mesh repair for this outcome is especially more relevant for onlay repair [4]. This observation is also supported by a meta-analysis on the comparison of sublay versus onlay mesh repair [24].

Pain was less in the mesh repair groups in two trials [4, 14]. But two trials showed contrary results [15, 16]. In both trials that showed less pain in the mesh group the meshes were fixed in onlay position. This may suggest that chronic pain seems to be higher in sublay position than onlay position. In the included trials that analysed pain, the meshes were fixed with additional sutures. A systematic review on different fixation techniques showed that pain can be reduced with tacker mesh fixation. Thus, the differences in pain might become less significant with new fixation techniques [25].

Mesh repair reduces the number of recurrences significantly. However, in patients without recurrence, mesh repairs seems to be associated with a risk of chronic pain especially if the mesh is fixed sublay.

The meta-analysis presented, is based on best available evidence (RCTs) and is therefore a good basis for recommendations (level of evidence 1a) in surgical evidence-based clinical practice guidelines.

More research is needed to analysis the influence of different mesh positions and fixation techniques (e.g. tacks, sutures or fibrin glue) on recurrences and chronic pain.

Author contributions Tim Mathes: Idea for the review, literature search, selection of literature, data extraction, risk of bias assessment, preparation of meta-analysis, writing of manuscript. Maren Walgenbach: Selection of literature, data extraction, risk of bias assessment, review of manuscript. Robert Siegel: Clinical expertise, interpretation of data, revision of manuscript.

Complaince with ethical standards

Conflict of interest Nothing to declare.

Disclosure None

Funding There was no funding for this systematic review.

References

1. Sauerland S, Walgenbach M, Habermalz B et al (2011) Laparoscopic versus open surgical techniques for ventral or incisional hernia repair. Cochrane Database Syst Rev 16(3):CD007781
2. Itani KM, Hur K, Kim LT et al (2010) Comparison of laparoscopic and open repair with mesh for the treatment of ventral incisional hernia: a randomized trial. Arch Surg 145(4):322–328
3. Abdel-Baki NA, Bessa SS, Abdel-Razek AH (2007) Comparison of prosthetic mesh repair and tissue repair in the emergency management of incarcerated para-umbilical hernia: a prospective randomized study. Hernia 11(2):163–167
4. Venclauskas L, Maleckas A, Kiudelis M (2010) One-year follow-up after incisional hernia treatment: results of a prospective randomized study. Hernia 14:575
5. DeMaria EJ, Moss JM, Sugerman HJ (2000) Laparoscopic intraperitoneal polytetrafluoroethylene (PTFE) prosthetic patch repair of ventral hernia. Prospective comparison to open prefascial polypropylene mesh repair. Surg Endosc 14(4):326–329
6. LeBlanc KA, Booth WV (1993) Laparoscopic repair of incisional abdominal hernias using expanded polytetrafluoroethylene: preliminary findings. Surg Laparosc Endosc 3(1):39–41
7. Moher D, Liberati A, Tetzlaff J et al (2009) Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Ann Intern Med 151(4):264–269
8. Higgins JPT, Green S (eds) (2011). Cochrane handbook for systematic reviews of interventions Version 5.1.0. The cochrane collaboration. http://www.cochrane-handbook.org. Accessed Mar 2011
9. Higgins JP, Altman DG, Gotzsche PC et al (2011) The cochrane collaboration's tool for assessing risk of bias in randomised trials. BMJ 343:d5928
10. Hartling L, Hamm MP, Milne A et al (2013) Testing the risk of bias tool showed low reliability between individual reviewers and across consensus assessments of reviewer pairs. J Clin Epidemiol 66(9):973–981
11. Hartling L, Ospina M, Liang Y et al (2009) Risk of bias versus quality assessment of randomised controlled trials: cross sectional study. BMJ 339:b4012
12. Ammar SA (2010) Management of complicated umbilical hernias in cirrhotic patients using permanent mesh: randomized clinical trial. Hernia 14(1):35–38
13. Arroyo A, Garcia P, Perez F et al (2001) Randomized clinical trial comparing suture and mesh repair of umbilical hernia in adults. Br J Surg 88(10):1321–1323
14. Burger JW, Luijendijk RW, Hop WC et al (2004) Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. Ann Surg 240(4):578–583
15. Korenkov M, Sauerland S, Arndt M et al (2002) Randomized clinical trial of suture repair, polypropylene mesh or autodermal hernioplasty for incisional hernia. Br J Surg 89(1):50–56
16. Polat C, Dervisoglu A, Senyurek G et al (2005) Umbilical hernia repair with the prolene hernia system. Am J Surg 190(1):61–64
17. de Vries Reilingh TS, van Goor H, Charbon JA et al (2007) Repair of giant midline abdominal wall hernias: "components separation technique" versus prosthetic repair : interim analysis of a randomized controlled trial. World J Surg 31(4):756–763. doi:10.1007/s00268-006-0502-x
18. Luijendijk RW, Hop WC, van den Tol MP et al (2000) A comparison of suture repair with mesh repair for incisional hernia. N Engl J Med 343(6):392–398
19. Weber G, Baracs J, Horvath OP (2010) ["Onlay" mesh provides significantly better results than "sublay" reconstruction. Prospective randomized multicenter study of abdominal wall reconstruction with sutures only, or with surgical mesh–results of a five-years follow-up]. Magy Seb 63(5):302–311
20. Lal K, Laghari ZH, Laghari AA et al (2012) A comparative study of anatomical repair versus mesh repair in paraumbilical hernia. Med Channel 19(2):110–113
21. Nguyen MT, Berger RL, Hicks SC et al (2014) Comparison of outcomes of synthetic mesh vs suture repair of elective primary ventral herniorrhaphy: A systematic review and meta-analysis. JAMA Surg 149(5):415–421
22. den Hartog D, Dur AH, Tuinebreijer WE et al (2008) Open surgical procedures for incisional hernias. Cochrane Database Syst Rev 16(3):CD006438
23. Aslani N, Brown CJ (2010) Does mesh offer an advantage over tissue in the open repair of umbilical hernias? A systematic review and meta-analysis. Hernia 14(5):455–462
24. Timmermans L, de Goede B, van Dijk SM et al (2014) Meta-analysis of sublay versus onlay mesh repair in incisional hernia surgery. Am J Surg 207(6):980–988
25. Sajid MS, Parampalli U, McFall MR (2013) A meta-analysis comparing tacker mesh fixation with suture mesh fixation in laparoscopic incisional and ventral hernia repair. Hernia 17(2):159–166