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Risk Factors for Mesh-related Infections After Hernia Repair Surgery: A Meta-analysis of Cohort Studies

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Abstract Mesh infection, although infrequent, is a devastating complication of mesh hernioplasties. The aim of this study was to systematically review and synthesize the available evidence on risk factors for synthetic mesh infection after hernioplasty. A systematic search was performed in PubMed and Scopus databases. The extracted data were synthesized with the methodology of meta-analysis. We identified six eligible studies that reported on 2,418 mesh hernioplasties. The crude mesh infection rate was 5%. Statistically significant risk factors were smoking (risk ratio [RR] = 1.36 [95% confidence interval (CI): 1.07, 1.73]; 1,171 hernioplasties), American Society of Anesthesiologists (ASA) score ≥3 (RR = 1.40 [1.15, 1.70]; 1,682 hernioplasties), and emergency operation (RR = 2.46 [1.56, 3.91]; 1,561 hernioplasties). Also, mesh infections were significantly correlated with patient age (weighted mean difference [WMD] = 2.63 [0.22, 5.04]; 2,364 hernioplasties), ASA score (WMD = 0.23 [0.08, 0.38]; 1,682 hernioplasties), and the duration of the hernioplasty (WMD = 44.92 [25.66, 64.18]; 833 hernioplasties). A trend toward higher mesh infection rates was observed in obese patients (RR = 1.41 [0.94, 2.11]; 2,243 hernioplasties) and in patients operated on by a resident (in contrast to a consultant; RR = 1.18 [0.99, 1.40]; 982 hernioplasties). Mesh infections usually resulted in mesh removal, and common pathogens included *Staphylococcus* spp., *Enterococcus* spp., and gram-negative bacteria. Patient age, ASA score, smoking, and the duration and emergency setting of the operation were found to be associated with the development of synthetic mesh infection. The heterogeneity of the available evidence should be taken under consideration. Prospective studies with a meticulous follow-up are warranted to further investigate mesh-related infections.

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Introduction

Abdominal hernia repair is one of the most common procedures in general surgery; over a million operations with an estimated cost of $2.5 (€1.8) billion are performed annually in the USA [1]. The implementation of prosthetic meshes has substantially changed the surgical management of abdominal hernias. At first, the use of mesh prostheses was considered by the surgeons reluctantly due to the high rate of complications [2] and, thus, reserved for specific indications. However, the development of synthetic and biologic materials and surgical training have reduced complication rates [3, 4]. Mesh repairs are currently

considered the standard technique for hernioplasty and have a lower recurrence rate and shorter length of stay compared to nonmesh repairs [1, 5–9].

The increasing use of meshes in hernia repairs has introduced the potential for mesh-related complications, including seromas, adhesions, migration of the mesh, and mesh infections [2, 4, 10, 11]. Mesh infection after hernia repair is a devastating complication. Reported incidence ranges from 0 (which has been criticized) in some series to 10.2% in others (even 38.9% in complex, contaminated hernioplasties) [4, 12, 13]. Treatment usually requires administration of systemic antibiotics and reoperation for mesh removal that may lead to hernia recurrence and the need for additional operations [11, 14–19].

Two recent meta-analyses concluded that a laparoscopic approach is superior to an open procedure for ventral and incisional hernia repair with regard to surgical site infection [20, 21]. There is also evidence that the development of mesh infection may be related to the type of material used [22–25] and the positioning of the mesh [26, 27]. The effect of antibiotic prophylaxis remains unclear [28–31]. Several studies have attempted to identify additional risk factors for mesh infection after hernia repair, mostly retrospectively [13, 32–37]. The reported findings are often conflicting and controversial. Moreover, the relatively small sample size of the individual studies may not be sufficient to reveal all potential associations. In this context we sought to systematically review and synthesize the available evidence on the risk factors for mesh-related infections after hernioplasty using the methodology of meta-analysis.

Methods

Data sources

A systematic review of the literature in PubMed and Scopus databases up to July 2011 was performed. The primary search was conducted with the following pattern: (mesh*) and (infection* or infectious or infective) and (risk or predict*). There was no limit for the year of publication. Furthermore, we reviewed the references of the included studies to identify additional resources. Unpublished studies reported as abstracts in conferences were not included in this review [38]. We also excluded articles written in languages other than English, Spanish, German, French, Italian, or Greek.

Study selection

Two investigators (MNM, PKM) independently searched the literature and assessed the relevant articles for potential inclusion in this review. All publications that studied risk factors for the development of mesh-related infection after mesh hernioplasty were considered for inclusion in this meta-analysis. Studies reporting on hernioplasties with biologic meshes were excluded. Both retrospective and prospective studies were considered eligible.

Data extraction

Two investigators (MNM, PKM) independently extracted the relevant data: study design, population characteristics (age, gender, body mass index [BMI], and comorbidity), hernia characteristics (site, size, and recurrence), surgical procedure details (American Society of Anesthesiologists [ASA] physical status classification, elective or emergency surgery, contamination, antibiotic prophylaxis, hernioplasty technique, and operating surgeon), mesh characteristics (size and material), and any additional risk factors examined by the included studies. Furthermore, we extracted data regarding the incidence and characteristics (time to development, pathogens identified) of mesh infections and the associated outcomes (mesh removal). Any disagreement was resolved by consensus. The corresponding authors of the included studies were emailed to ask for additional data when necessary.

Definitions and outcomes

Mesh infections are considered to be deep incisional (DIS) surgical site infections (SSI) that involve the mesh prosthesis. The Centers for Disease Control and Prevention (CDC)/National Healthcare Safety Network (NHSN) defines DIS as an infection occurring within 1 year of operation (when a prosthesis is used), is related to the procedure, and involves deep soft tissues (e.g., fascial and muscle layers) of the incision, and the patient must have at least one of the following: (1) purulent drainage, (2) a deep incision that spontaneously dehisces or is deliberately opened by a surgeon and is culture-positive, (3) an abscess or other evidence of infection involving the deep incision, and (4) diagnosis of a DIS by a surgeon or attending physician [39]. Two of the included studies used the CDC definition of deep SSI [13, 35], in two studies diagnosis was based on the identification of pathogens after aspiration of a periprosthetic fluid collection [33, 34], one study reported on infections necessitating mesh removal [36], and the remaining study did not define mesh infection [32]. Investigators' definitions and outcomes were accepted for all the included studies.

The primary outcome of our study was the development of mesh infection. Secondary outcomes included the characteristics and the outcome of the infection.

Data analysis and statistical methods

The statistical analyses were performed with Review Manager (RevMan) ver. 5.0 (Nordic Cochrane Centre, the Cochrane Collaboration, Copenhagen, 2008). We compared the risk factors of the patients who developed a mesh infection with those of the patients who did not. All risk factors (reported in ≥2 studies) were compared independently in a univariate model. Heterogeneity between studies was assessed by using a χ^2 test and I^2 and was considered significant when there was either $P < 0.10$ for the χ^2 test or I^2 was above 50%. We did not assess publication bias due to the small number of included trials [40]. For parametric continuous variables (i.e., BMI), we used the z table to calculate the percentage of patients above a predefined cutoff (i.e., obesity = BMI >30). Pooled risk ratios (RR) and 95% confidence intervals (CI) were calculated for dichotomous variables (i.e., gender and smoking) using the Mantel–Haenszel fixed-effect model (FEM) or the DerSimonian-Laird random-effects model (REM), as appropriate [41, 42]. Accordingly, the weighted mean difference (WMD) was calculated for continuous variables (i.e., age).

Results

In Fig. 1 we present a flow diagram that shows the selection process followed to identify the pool of studies included in the meta-analysis. The database search yielded 1,516 potentially relevant articles. In total, of the seven studies that examined risk factors for mesh-related infections after hernioplasty and fulfilling the inclusion criteria, six were included in the meta-analysis (the remaining study did not report any extractable data [37]).

Table 1 summarizes the main characteristics of the publications included in this meta-analysis, which studied a total of 2,418 meshes used in 1,657 ventral and 761 groin hernia repairs. Mesh infections occurred in 119 of the 1,657 (7.2%) ventral and 2 of the 761 (0.3%) groin hernioplasties.

Five studies had a retrospective cohort design [13, 33–36] and one was prospective [32] (Table 1). Four studies reported on the surgical wound classification [33–36], and 91% of the operations were classified as clean. Five studies reported on the repair of ventral hernias [13, 33–36], while one included both groin and ventral hernias [32]. Ventral hernias were repaired laparoscopically in 19% of cases. When an open approach was performed, the sublay technique (retromuscular, preperitoneal, or intraperitoneal [IPOM]) was performed most often (85%), followed by the onlay (9%) and the inlay techniques (5%). Most meshes were composed of polypropylene (PPL, 74%); less common materials included a combination of polypropylene and expanded polytetrafluoroethylene (PPL/ePTFE, 20%), ePTFE (3%), and others. Part of the population of one study [34] was also analyzed in another [33]. For all analyses (except for mesh type), we used the data presented in the first study [33] because of the scarcity of relevant data in the latter study [34]. None of the studies reported to have used antibiotic irrigation of the wound.

Table 2 presents the pooled estimates for all risk factors reported in two or more studies. Statistically significant risk factors for the development of mesh infection were tobacco smoking (RR = 1.36 [95% CI: 1.07, 1.73], $P = 0.01$; 1,171 hernioplasties), ASA score ≥3 (RR = 1.40 [1.15, 1.70], $P < 0.001$; 1,682 hernioplasties), and emergency setting (RR = 2.46 [1.56, 3.91], $P < 0.001$; 1,561 hernioplasties). Furthermore, mesh infections were significantly correlated to patient age (WMD = 2.63 [0.22, 5.04], $P = 0.03$; 2,364 hernioplasties), ASA score (WMD = 0.23 [0.08, 0.38], $P = 0.002$; 1,682 hernioplasties), and the duration of the hernioplasty (WMD = 44.92 [25.66, 64.18], $P < 0.001$; 833 hernioplasties). There was a trend toward higher mesh infection rates in obese patients (RR = 1.41 [0.94, 2.11], $P = 0.09$; 2,243 hernioplasties) and when the patient was operated on by a resident (in contrast to a consultant; RR = 1.18 [0.99, 1.40], $P = 0.06$; 982 hernioplasties). The forest plots for all variables on which data from four or more studies were pooled are presented in Fig. 2.

A subanalysis of ventral hernioplasties was also performed, excluding the study that reported on both groin and ventral hernioplasties [32]. This subanalysis corroborated most of the findings of the main analysis; emergency setting of operation was not statistically significant (RR = 1.58 [0.58, 4.29]; 506 hernioplasties). In addition, the trend toward increased infections in obese patients was not verified in this subanalysis (RR = 1.20 [0.90, 1.60]; 1,188 hernioplasties).

Culture was reported in 76 cases (Table 1); the most common pathogen was *S. aureus* (40 cases, 53%). Other pathogens included coagulase-negative *Staphylococcus* spp. (16 cases, 21%), *Enterococcus* spp. (9 cases, 12%), *P. aeruginosa* (6 cases, 8%), and others. Mesh removal was performed in 90 of 129 cases (70%, one study did not provide relevant data). Excluding the study that defined mesh infections as infections necessitating mesh removal [36], the prosthesis was eventually explanted in 48 of 87 cases (55%, Table 1). Mesh removal was necessary in all seven cases of infection where an ePTFE prosthesis was used, but in variable degrees for other types of mesh.

Discussion

The main finding of this study is that advanced age, a high ASA score, tobacco smoking, emergency operation and

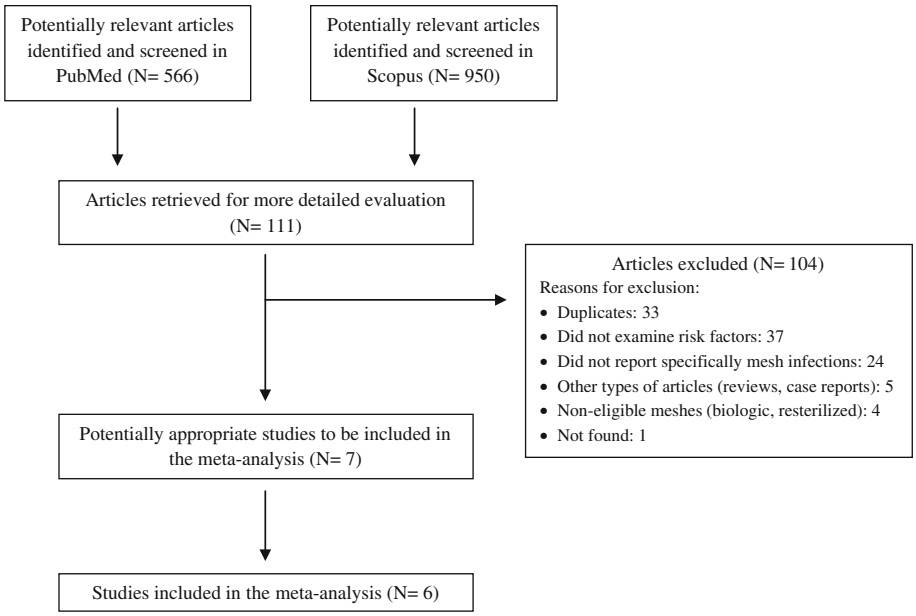

Fig. 1 Flow diagram of included studies

longer operative time are risk factors significantly associated with the development of mesh infection after hernioplasty. Of note, most of the individual studies failed to identify the majority of these risk factors due to small individual sample sizes. Likewise, the fact that we found no difference in several other factors (i.e., diabetes, obesity, and immunosuppression) might be attributed to the small pooled sample size, since only a few studies provided relevant data.

Interestingly, tobacco smoking was significantly associated with mesh infection (RR = 1.36 [1.07, 1.73]; 1,171 hernioplasties), but only three studies provided relevant data. In addition, one might note that previous hernia recurrence was not associated with mesh infection (RR = 1.02 [0.36, 2.90]; 2,158 hernioplasties) despite the adequate sample size. Our findings do not differ from the reported risk factors for other kinds of prostheses. With regard to prosthetic joint infections, identified risk factors included extreme age, diabetes mellitus, obesity, poor nutritional status, immunosuppression, prior surgery at the site of the prosthesis, local pathology, psoriasis, long-term urinary catheterization, and surgical site infection [43].

Our findings also outline the actual possibility of a late mesh infection, many years after the hernioplasty. Some would advocate that mesh infection is a complication observed in the early postoperative period. In fact, the CDC/NHSN definition of deep prosthesis infection extends up to 1 year postoperatively. Although the first postoperative year may account for the majority of mesh infections in some studies, there is solid evidence that mesh infections also occur later. In addition to the studies included in our review [13, 33, 34, 36], other articles have also highlighted this fact. A study that looked at risk factors for mesh explantation reported a median of 7.5 months (interquartile range = 1–27 months) between the hernioplasty and the explantation (which was due to an infectious complication in 84% of cases) [44]. Furthermore, a case series of five patients with late-onset mesh infections (2–4.5 years after inguinal hernioplasty) has been published [45], while numerous case reports have also been reported [46, 47].

Notably, we observed a considerable difference in mesh infection rate between ventral and groin hernioplasties (7.2 vs. 0.3%). It should be emphasized that only one study provided data on groin hernioplasties, and the mesh infection rate after ventral hernioplasty in that study was 4.8% [32]. Therefore, we cannot speculate on whether this difference in mesh infection rate could be attributed to different patient characteristics or inherent infection risk of the operation. During the literature search, we did not identify any other studies that properly assessed the incidence or characteristics of mesh infection after groin hernioplasties. There is evidence that groin hernioplasties are somehow "protected" from infection; however, the reasons are not clear. Although the infection rate after groin hernioplasties seems to be significantly lower than that of ventral hernioplasties, the risk factors for the development of infection are probably identical. Therefore, we pooled data from all hernioplasties for the identification of potential risk factors for mesh infection. To confirm our hypothesis, we also performed a subanalysis that excluded the study on groin hernioplasties. This subanalysis yielded similar results with our original analysis (the minor differences are probably attributed to the smaller sample size).

In theory, mesh type could influence the development of infection [22]. Microporous meshes are considered to be at increased risk since small pores (<10 μm) are permeable to

Table 1 Characteristics of reviewed studies

Study, year [ref]	Study design, *N* of meshes, FU	Hernia site	Surgical technique[a]	Mesh type	Risk factors examined	Incidence and time point of mesh infection	Microbial pathogen	Mesh removal
Petersen [33]	Retrospective, 121, mean FU: 23 months	Ventral	Open: sublay (Stoppa-Rives)	PPL HW (64%), ePTFE (31%), polyester (6%)	Age, gender, BMI, ASA, diabetes, **COPD**, recurrent, progressive pneumoperitoneum, wound classification, mesh type, duration, drainage (ml)	8/121 (6.6%), mean 4.5 months	*S. aureus*: 4/8, CoNS: 2/8, *A. baumanii*: 3/8, *Enterococcus* spp.: 2/8, Other: 2/8	3/8
Petersen[b] [34]	Retrospective, 175, mean FU: 20 months	Ventral	Open: sublay	PPL HW (67%), PPL LW (7%), polyester (5%), ePTFE (21%)	Technique (IPOM vs. preperitoneal vs. retromuscular), mesh type	11/175 (6%)	NR	3/11
Swenson [36]	Retrospective, 506, FU: NR	Ventral	Lap (56%), open (44%)	NR	Use of drapes, gender, age, **laparoscopic**, incarceration, ***recurrent***, surgeon, emergent, wound classification, **ASA**, race, comorbidities (diabetes, ***smoking***, dyspnea, steroids, chemotherapy, **BMI**, etc.), serum albumin, serum Cr, ***duration***	42/506 (8.3%) median ~ 3 months	*Streptococcus* spp., *Staphylococcus* spp., or *Candida* spp.: 7/29	42/42
Cobb [13]	Retrospective, 206, mean FU: 27.6 months (44% > 1 year)	Ventral	Open: IPOM	Composite (PPL + ePTFE)	Age, BMI, smoking, diabetes, mesh size, drain, duration	21/206 (10.2%), mean 10.9 months	*S. aureus*: 17/21 [*MRSA*: 11], Gram(-): 3/21, none: 1/21	19/21
Bueno-Lledo [32]	Prospective, 1055, FU: up to 9 months	Groin (72.1%), ventral (27.9)	Open: retromuscular 87%, preperitoneal 8.3%, IPOM 3.7%	PPL (98%), ePTFE (1.7%), composite (0.3%)	Age, gender, **obesity**, **diabetes**, ASA, recurrent, **hernia site**, **emergency**, **mesh type**, **mesh size**, **duration**	Groin: 2/761, ventral: 14/294 (4.8%), mean 38.5 days	*S. aureus*: 9/16, Enterobacteria: 3/16, *P. aeruginosa*: 1/16, mixed: 3/16	9/16
Stremitzer [35]	Retrospective, 476, median FU: 44 months	Ventral	Lap IPOM (7%), Open: sublay (44%), onlay (21%), inlay (12%), IPOM (13%)	Composite (34%), PPL LW (33%), PPL HW (19%), other (13%)	Age, **BMI**, serum albumin, hernia size, **mesh size**, ***duration***, gender, diabetes, immunosuppression, smoking, serum Cr, recurrent, surgeon, additional surgery, absorbable sutures, wound irrigation, drainage, intra-op antibiotics, post-op antibiotics, technique, mesh type	31/476 (6.5%), median 12 days	CoNS: 14/31, *S.aureus*: 10/31 [*MRSA*: 2], *E. faecalis*: 7/31, *Corynebacterium* spp.: 6/31, *P. aeruginosa*: 5/31, Other: 6/31	14/31

The factors showing a significant association with the development of infection in univariate analysis ($p < 0.05$) are in bold. The factors showing a significant, independent association in multivariate analysis are in bold italics

ref reference, *N* number, *FU* follow-up, *PPL* polypropylene, *HW* heavy-weight, *ePTFE* expanded polytetrafluoroethylene, *postop* postoperatively, *NR* not reported, *BMI* body mass index, *ASA* American Society of Anesthesiologists physical status classification, *COPD* chronic obstructive pulmonary disease, *CoNS* coagulase-negative Staphylococci, *LW* low-weight, *IPOM* intraperitoneal onlay mesh, *lap* laparoscopic, *Cr* creatinine, *intraop* intraoperatively

[a] The operative technique applies to ventral hernia repairs

[b] Part of the population of this study [34] was analyzed in another study [33]

Table 2 Pooled estimates for risk factors for mesh-related infection

Factor	Studies	Totals	Statistical method	Pooled estimate	*P*
Patient demographics and comorbidity					
Age[a]	5	2364	WMD (IV, FEM)	2.63 [0.22, 5.04]	0.03
Gender (female)	3	1682	RR (M-H, FEM)	1.02 [0.84, 1.23]	0.87
Diabetes mellitus	5	2362	RR (M-H, FEM)	1.34 [0.90, 2.01]	0.15
Smoking[a]	3	1171	RR (M-H, FEM)	1.36 [1.07, 1.73]	0.01
Obesity	4	2243	RR (M-H, REM)	1.41 [0.94, 2.11]	0.09
Body mass index	3	803	WMD (IV, REM)	1.12 [−2.06, 4.30]	0.49
Immunosuppression or steroid use	2	795	RR (M-H, FEM)	1.56 [0.83, 2.92]	0.16
Preoperative variables					
Recurrent hernia	4	2158	RR (M-H, REM)	1.02 [0.36, 2.90]	0.97
ASA score ≥ 3[a]	3	1682	RR (M-H, FEM)	1.40 [1.15, 1.70]	<0.001
ASA score[a]	3	1682	WMD (IV, FEM)	0.23 [0.08, 0.38]	0.002
Clean surgical wound (class I vs. II, III, IV)	3	1103	RR (M-H, FEM)	1.02 [0.95, 1.09]	0.58
Operative details					
Surgeon (resident vs. consultant)	2	982	RR (M-H, FEM)	1.18 [0.99, 1.40]	0.06
Setting (emergency vs. elective)[a]	2	1561	RR (M-H, FEM)	2.46 [1.56, 3.91]	<0.001
Placement of drains	2	682	RR (M-H, FEM)	1.05 [0.90, 1.21]	0.55
Duration of operation[a]	3	833	WMD (IV, FEM)	44.92 [25.66, 64.18]	<0.001
Mesh type					
PPL (all)	3	1704	RR (M-H, REM)	0.31 [0.04, 2.38]	0.26
PPL (heavy-weight)	3	1650	RR (M-H, REM)	0.25 [0.04, 1.66]	0.15
Combined (PPL/ePTFE)	2	1349	RR (M-H, REM)	2.88 [0.09, 90.35]	0.55
ePTFE	2	1230	RR (M-H, REM)	4.79 [0.34, 68.01]	0.25

WMD Weighted mean difference, *IV* inverse variance, *FEM* fixed-effects model, *RR* risk ratio, *M–H* Mantel–Haenszel, *REM* random-effects model, *ASA* American Society of Anesthesiologists, *PPL* polypropylene, *ePTFE* expanded polytetrafluoroethylene

[a] Variable had a statistically significant ($P < 0.05$) association with the development of mesh infection. The fixed-effect model was used when there was no significant heterogeneity (defined as $P < 0.10$) between studies; otherwise, the random-effects model was used

bacteria, but not to macrophages and neutrophils [25]. Accordingly, multifilament meshes are prone to infection (in contrast to monofilament meshes), as shown in animal models [23, 24, 48]. Moreover, upon infection, microporous meshes always need to be removed, which might be unnecessary for macroporous mesh infection. The association of particular mesh materials with potential complications is currently being examined, with an FDA investigator claiming that although the available evidence is significantly limited, an association seems possible [49]. Unfortunately, the remarkable heterogeneity among the studies included in this review with regard to the mesh type precludes any safe conclusions. We found no difference between microporous and macroporous meshes with regard to the development of mesh infection, but this is probably due to numerous confounding factors and small sample size. Similarly, ePTFE was not found to be associated with a higher mesh infection rate in our analysis; still, all cases of ePTFE mesh infection necessitated mesh explantation.

The existing evidence regarding the impact of the surgical approach to hernia repair on the development of mesh infection is controversial. It appears that the laparoscopic approach is preferable in terms of risk for prosthesis infection. Two recent meta-analyses provided additional confirmation; the laparoscopic approach was significantly associated with lower surgical site infection rates, and there was a trend toward fewer infections requiring mesh removal (although only 11 infections in 526 operations were pooled) [20, 21]. On the other hand, studies that analyzed large cohorts of laparoscopic appendectomies reported that although the laparoscopic technique was associated with fewer surgical site infections, it was also significantly and independently associated with the development of deep organ-space infections on multivariate analysis [50–52]. Therefore, more studies, carefully designed and controlled for several factors, are warranted to determine the precise impact of the laparoscopic technique on mesh infection after hernioplasty. When an open approach is used for a ventral hernioplasty, the sublay technique (mesh placed below the rectus abdominis) appears to be associated with fewer infectious complications than the onlay technique (mesh placed on top of the rectus abdominis) [26, 53].

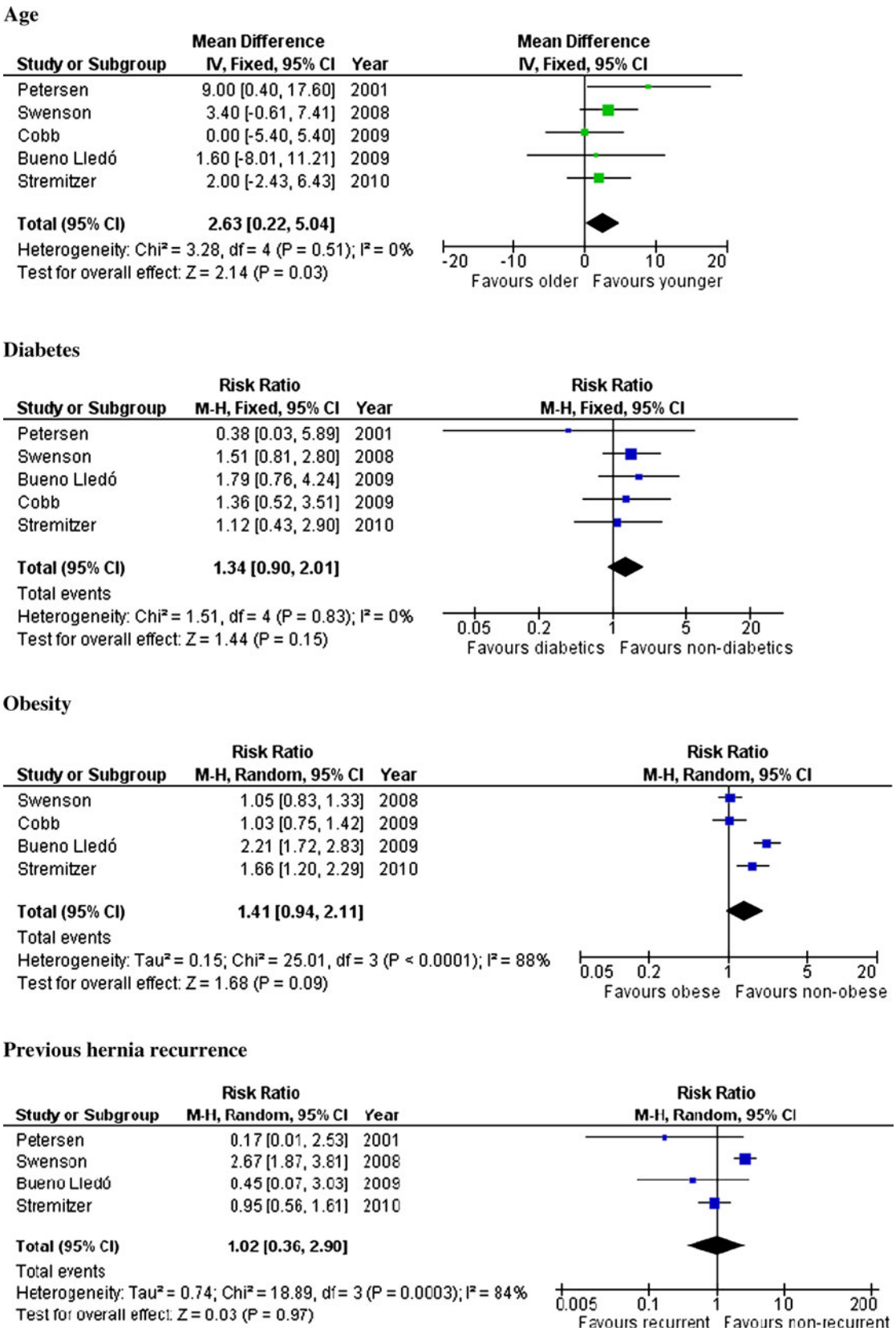

Fig. 2 Forest plots for all variables with data pooled from four or more studies. *Vertical line*, "no difference" point between the two regimens; *squares*, RRs; *horizontal lines*, 95% CIs; *diamond*, pooled RR for studies

Another issue of controversy is the use of antibiotic prophylaxis for uncomplicated hernia repair. The two most recent meta-analyses on this subject reached contradictory conclusions although they synthesized the same data; this was due mainly to the use of different statistical methods [28, 29, 31]. Some investigators proposed that although only a few patients will benefit from the antibiotic prophylaxis, antibiotics may still be beneficial due to the considerable morbidity derived from a potential prosthesis infection [30]. Other interventions currently examined to reduce the risk of mesh infections include the concomitant placement of antibiotic-impregnated collagen tampons [54], meshes impregnated with older (i.e., cefazolin, silver/chlorhexidine, vancomycin) [55–58] or novel antimicrobial agents against *S. aureus* (lysostaphin) [59–62], the use of surgical drapes [36], and topical application of povidone-iodine solution (betadine) [63].

One factor that has not been sufficiently addressed is the effect of the surgeon's expertise on the postoperative outcomes. Several studies have proposed that the surgeon's experience has a statistically significant impact on hernia recurrence after hernioplasty [64, 65]; in addition, some stated that the surgeon's age (>45 years) is also predictive of recurrence [64]. We addressed this issue in our analysis; although only two studies provided relevant data [35, 36], there was a trend toward increased risk for mesh infection when patients were operated on by a resident (or low-volume surgeon), in contrast to a consultant (or high-volume surgeon) (RR = 1.18 [0.99, 1.40], $P = 0.06$).

Our study bears important clinical implications. The patient should attempt to modify modifiable risk factors such as tobacco smoking, and surgeons should keep in mind that longer operative time is associated with an increased mesh infection rate. In addition, identification of high-risk patients could help researchers target this group in the investigation of potential anti-infective interventions such as antimicrobial prophylaxis and the use of antibiotic-impregnated meshes or concomitant antibiotic-releasing materials along with the mesh [54–62]. More importantly, such additional precautions may be beneficial for patients at high risk for infection, while unnecessary (or even potentially harmful) for low-risk patients.

Our study should be interpreted in view of certain limitations. First, five of the six studies had a retrospective cohort design. Apart from the suboptimal quality of data this design provides, this could also lead to underestimation of the true incidence of mesh infections, especially when combined with a short follow-up period or a mediocre follow-up policy. Furthermore, our meta-analysis provides data based on univariate analyses only. Only two studies performed a multivariate analysis; a recurrent hernia, smoking, and operative time were considered individual risk factors for mesh infection in the first [36], and operative time was the sole individual predictor in the other study [35]. In addition, the definitions for mesh infection varied among the studies. Finally, although a total of six studies were included in our meta-analysis, not all studies provide eligible data for all risk factors examined.

In conclusion, although the interpretation of our findings may be restrained by the heterogeneity and other methodological limitations of the available evidence, our findings suggest that patient age, ASA score, smoking, and the duration and emergency setting of the operation are associated with the development of synthetic mesh infection. Furthermore, there was a trend toward higher mesh infection rates in obese patients and when a resident or low-volume surgeon performed the operation (in contrast to a consultant or high-volume surgeon). Additional studies with a prospective design and a meticulous follow-up are needed to precisely determine both the actual incidence of mesh infections and the potential risk factors.

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Conflicts of interest The authors have no conflicts of interest to declare.

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