Surg Endosc (2012) 26:3355–3366
DOI 10.1007/s00464-012-2382-5

REVIEW

Which is the best laparoscopic approach for inguinal hernia repair: TEP or TAPP? A systematic review of the literature with a network meta-analysis

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Received: 28 September 2011 / Accepted: 14 May 2012 / Published online: 16 June 2012

Abstract
Background Totally extraperitoneal (TEP) repair and transabdominal preperitoneal (TAPP) repair are the most used laparoscopic techniques for inguinal hernia treatment. However, many studies have shown that laparoscopic hernia repair compared with open hernia repair (OHR) may offer less pain and shorter convalescence. Few studies compared the clinical efficacy between TEP and TAPP technique. The purpose of this study is to provide a comparison between TEP and TAPP for inguinal hernia repair to show the best approach.
Methods We performed an indirect comparison between TEP and TAPP techniques by considering only randomized, controlled trials comparing TEP with OHR and TAPP with OHR in a network meta-analysis. We considered the following outcomes: operative time, postoperative complications, hospital stay, postoperative pain, time to return to work, and recurrences.
Results The two techniques improved some short outcomes (such as time to return to work) with respect to OHR. In the network meta-analysis, TEP and TAPP were equivalent for operative time, postoperative complications, postoperative pain, time to return to work, and recurrences, whereas TAPP was associated with a slightly longer hospital stay compared with TEP.
Conclusions TEP and TAPP improved clinical outcomes compared with OHR, but the network meta-analysis showed that TEP and TAPP efficacy is equivalent. TAPP was associated with a slightly longer hospital stay compared with TEP.

Keywords Inguinal hernia · Laparoscopy · Open surgery

Inguinal hernia repair is one of the top three operations in most western countries [1]. The best hernia repair procedure should be simple, rapid, and safe; it should result in less surgical trauma, postoperative pain, and low recurrence rate [2]. Laparoscopic hernia repair (LHR) compared with open hernia repair (OHR) may offer less pain and shorter convalescence [3]. The most used laparoscopic techniques are transabdominal preperitoneal (TAPP) and totally extraperitoneal (TEP) repair. There is limited evidence showing no significant difference in persisting pain (TEP vs. OHR) or recurrence (TEP and TAPP vs. OHR) [4]. A specific meta-analysis comparing TAPP versus TEP (including eight nonrandomized studies) stated that data were insufficient to make conclusions, but suggested that TAPP is associated with higher rates of port-site hernias and visceral injuries, whereas there appear to be more conversions with TEP [5]. In the European Hernia Society

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(EHS) guidelines on the treatment of inguinal hernia, the authors recommended (grade D) that TEP approach is used for endoscopic inguinal hernia operation [6].

To best of our knowledge, the last review [5], which compared TAPP and TEP collected data since 2004, included nonrandomized studies and concluded that there were insufficient data to allow definitive conclusions about the best approach. In light of this, the purpose of this study was to compare the clinical efficacy of TAPP and TEP for hernia repair based on data reported by only randomized, controlled trials (RCTs). Because of the lack of an appropriate number of RCTs comparing directly the TAPP to the TEP technique, we compared indirectly TAPP to TEP through a network meta-analysis [7].

Materials and methods

Study design

In planning this study, we considered the PRISMA statement [8], so we decided to limit our search to RCTs only and we assessed a checklist to select studies. We also considered only RCTs in the English language. We conducted a network meta-analysis to compare TAPP to TEP.

Search strategy

We performed an electronic search using Medline and Cochrane databases. Moreover, we performed a linear search among references of selected papers. Keywords adopted in our search were: "inguinal"; "hernia"; "repair"; "laparoscopy"; "open" and "surgery" in combination with the Boolean operators and/or. Three investigators independently analyzed the full texts of each paper to assess the coherence with the objective of the study.

Comparison method

In our search, we did not find an appropriate number of RCTs comparing directly the TAPP to the TEP technique focusing on the same outcomes, so we did not perform a meta-analysis matching TAPP to TEP directly. When two procedures have not been compared directly in enough RCTs, but have each been compared with the same benchmark treatment, it is possible to compare the first two using network meta-analysis if the RCTs have recruited patients with homogeneous inclusion and exclusion criteria and have compared the same outcomes [7]. We adopted a network design called "anchored indirect treatment comparison" [9] (Fig. 1), which requires the exclusion of RCTs directly comparing TEP to TAPP. These studies are reported in the "Discussion" section of this paper to compare and discuss results.

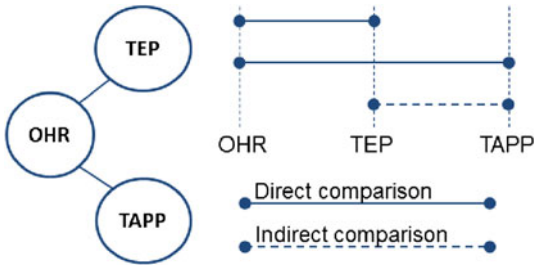

Fig. 1 Network design called "anchored indirect treatment comparison"

Trials selection

To assess the RCTs, we prepared a checklist with five questions:

(1) Is the paper in English language?
(2) Is the paper coherent with the objective of our study?
(3) Are the treatment group and the control group responding to the requirements of our study?
(4) Are the outcomes of interest described in the paper with enough statistical data?
(5) Are the surgeons who performed the interventions experts in these techniques?

This last criterion was eliminated from the checklist, because only a few studies provided quantitative information about surgeon experience. Therefore, we chose not to exclude any study based on this criterion because of lack of information, as argued in the "Discussion" section.

To perform the indirect comparison described earlier, we included in our study only RCTs that compared TEP or TAPP versus OHR, and we excluded studies in three arms comparing TEP, TAPP, and OHR, which were considered benchmarks to comment on our results. The papers included in this study focused on both short-term outcomes and recurrences. We also considered the intraoperative complications and conversions, which were not meta-analyzed because of the lack of sufficient data. The short-term outcomes that were meta-analyzed are operative time, hospital stay, postoperative complications, time to return to work, and postoperative pain assessed by visual analogic scale (VAS). Recurrences were assessed with a follow-up from 1 month to 5 years.

Statistical analysis

For intraoperative complications and conversions, we referred to the total number and percentages. In both meta-analyses, continuous outcomes, such as operative time, duration of hospital stay, time to return to work, and postoperative VAS, were expressed by mean differences, with the relative 95 % confidence interval (CI). Binaries

outcomes, such as complications and recurrences, were expressed as relative risk (RR), with the relative 95 % CI. We assessed the heterogeneity by using the χ^2 test; $P < 0.05$ was considered statistically significant. Because the heterogeneity was statistically significant, we used the random-effect model [10]. We used the software, meta-analyst, to process data [11]. We represented the results obtained by forest plot and we looked at funnel plot to assess potential for publication bias. Finally, the effect size of TAPP and TEP was assessed by using network meta-analysis [7]. To determine the variation between studies, we used the statistic χ^2 as the difference of the overall heterogeneity and the measures of the heterogeneity in the two primary meta-analyses [12].

Results

By responding to the questions above, we found 11 papers [13–23] comparing TEP versus OHR and seven papers [24–30] comparing TAPP versus OHR. In some cases, two papers comparing TEP versus OHR referred to the same RCT: the first focused on short-term outcomes [14, 18] and the second on recurrences [15, 23]. We excluded 22 of the 50 papers found, because they were not coherent with the objective of this meta-analysis, focusing only on costs or the stress responses related to laparoscopic surgery in the hernia repair. One article was excluded, because it was not in English. Four papers were excluded, because they did not report sufficient data for statistical analysis. We found five RCTs in three arms comparing TEP, TAPP, and OHR [31–35]. Table 1 summarizes the number of papers included and excluded.

As shown in Table 2, study group consisted of 3,355 patients with a diagnosis of unilateral, bilateral, and recurrent inguinal hernia. Of these, 1,209 were treated by TEP, 395 by TAPP, and 1,751 by OHR. We assessed the intraoperative complications and the conversions, which were not meta-analyzed because of the lack of sufficient data.

Conversions

As shown in Table 3, of a total of 1,209 patients, there were 13 conversions from TEP procedure to OHR and 6 to the TAPP procedure. Of a total of 395 patients, there were 3 conversions from TAPP to OHR.

Table 1 Studies selection

Paper	#
Total papers retrieved	50
Total papers not coherent with the objective	22
Papers not in English	1
Papers with insufficient data	5
Papers with more than two arms	4
Total papers included	18

Table 2 Study population

Study	Years	TEP	TAPP	Open
Kouhia	2009	49	–	47
Eklund	2008–2009	665	–	706
Butters	2007	–	81	76
Gokalp	2003	61	–	62
Colak	2003	67	–	67
Mahon	2003	–	60	60
Andersson	2003–2008	81	–	87
Douek	2003	–	122	120
Pawanindra	2003	25	–	25
Suter	2002	19	–	20
Bringman	2003	92	–	207
Sarli	2001	–	20	23
Picchio	1999	–	52	52
Beets	1999	–	42	37
Khoury	1998	150	–	142
Heikkinen	1998	–	18	20
Total		1,209	395	1,751

Table 3 Conversion

TEP to open (*n*/N)	TEP to TAPP (*n*/N)	TAPP to open (*n*/N)
13/1,209	6/1,209	3/395
Conversion rate (TEP group)		Conversion rate (TAPP group)
1.57 %		0.75 %

Operative time

Operative time data were available from nine RCTs [13, 14, 16–22] comparing the TEP versus OHR (Fig. 2) and from five RCTs [24–28] comparing TAPP versus OHR (Fig. 3). The mean duration (MD) of operative time, assessed in minutes, was significantly longer for the TEP technique compared with the OHR: MD = 10.6 (4, 17.2; $P < 0.05$). Also the TAPP technique showed an increase in the operative time compared with OHR; however, this difference was not statistically significant: MD = 3.41 (−11.57, 18.4; $P > 0.05$).

Hospital stay

We considered only RCTs reporting hospital stay data as continuous outcomes. We identified six papers [13, 16–20] comparing hospital stay between the TEP and OHR (Fig. 4) and three papers [24, 26, 28] comparing TAPP to OHR (Fig. 5).

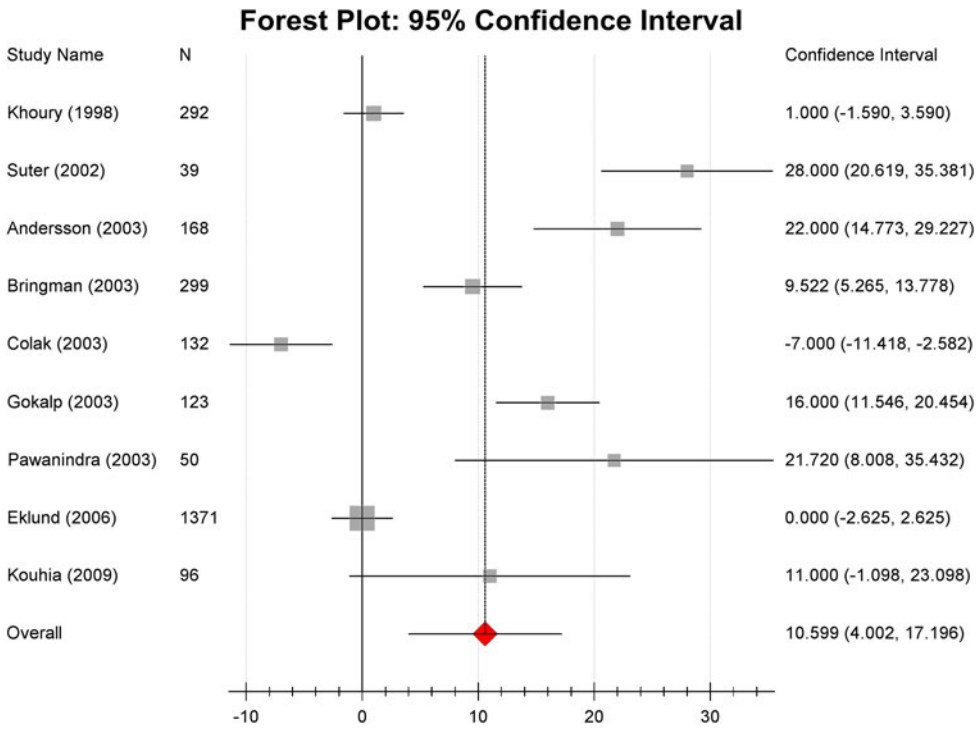

Fig. 2 Operative time: TEP versus OHR

We found that the TEP procedure was related to a reduction of the hospital stay, assessed in days, but this difference was not statistically significant compared with OHR: MD = − 0.19 (−0.41, 0.03; $P > 0.05$). There was a significant difference in hospital stay between the TAPP technique and the OHR (MD = 0.12; 0.1, 0.13; $P < 0.05$).

Intra- and postoperative complications

Not all of the studies included reported intraoperative complications, so we did not meta-analyze this outcome. As far as the studies comparing TEP and OHR, Gokalp et al. [16] reported one intraoperative complication in the open group and two complications in the TEP group; Eklund et al. [14] reported two complications in the TEP group and two in the open group. Andersson et al. [18] described three types of intraoperative complications (epigastric artery bleeding, ECG or heart rhythm change, injury to peritoneum, acute airways obstruction, and serosal tear in the colon), but he did not report the total number of cases. Khoury [22] reported two cases of conversion from TEP to the open procedure due to intraoperative complications. As far as the studies comparing TAPP and OHR, Mahon et al. [24] reported two complications in the TAPP group, and Beets et al. [27] reported one complication in the TAPP group. Picchio et al. [26] described intraoperative complications, but he did not report the total number of cases.

We meta-analyzed postoperative complications. Eight RCTs [13, 14, 16–18, 20–22] compared TEP with OHR (Fig. 6) and three RCTs [24, 25, 28] compared TAPP with OHR (Fig. 7). Comparing TEP versus OHR, the RR pooled was 0.83 (0.71, 0.97; $P < 0.05$), and this difference was statistically significant. Comparing TAPP versus OHR, the RR pooled was 0.79 (0.54; 1.17, $P > 0.05$).

Pain

To compare the pain related to TEP and TAPP techniques with respect to the OHR, we meta-analyzed data extracted by four RCTs [16, 17, 19, 20] for the TEP (Fig. 8) and by 5 RCTs [24–28] for the TAPP (Fig. 9). The mean pain, assessed by VAS, was less for the TEP technique compared with the OHR: MD = − 0.47 (−2.09, 1.15; $P > 0.05$). Also the TAPP technique showed a reduction of the postoperative pain with respect to the OHR, and this difference was not statistically significant: MD = − 0.98 (−2.39, 0.44; $P > 0.05$).

Time to return to work

In evaluating the time to return to work, we extracted data from eight RCTs [13, 14, 16–19, 21, 22] that compared the TEP technique with OHR (Fig. 10) and five RCTs [24–28] that compared TAPP with OHR (Fig. 11). Comparing TEP versus OHR, the MD pooled was −4.52 days (−6.42,

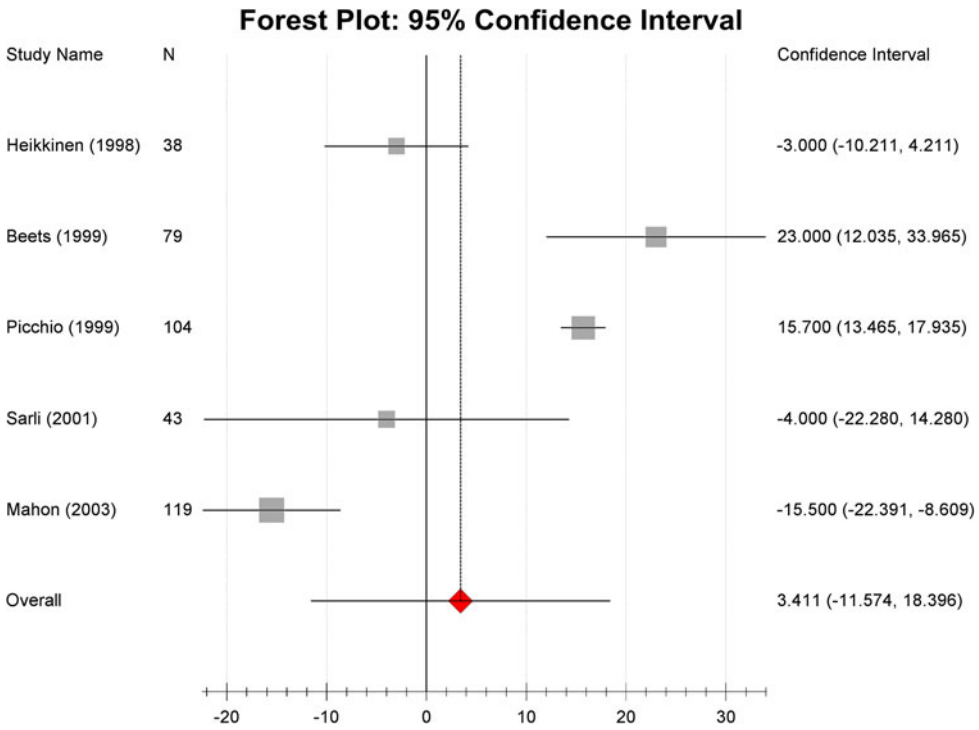

Fig. 3 Operative time: TAPP versus OHR

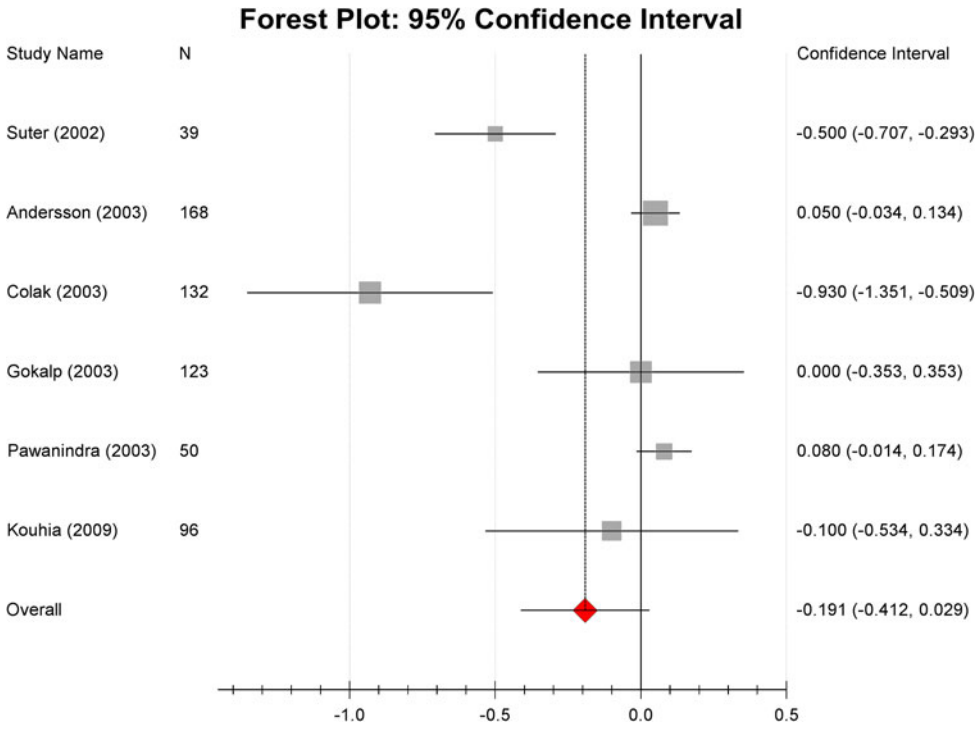

Fig. 4 Hospital stay: TEP versus OHR

-2.62; $P < 0.05$); comparing TAPP versus OHR, the MD pooled was -12.22 days (-22.8, -1.67; $P < 0.05$).

Recurrences

Eight RCTs [13, 15–19, 21, 22] comparing TEP versus OHR and six RCTs [24, 25, 27–30] comparing TAPP versus OHR reported this outcome. The mean time for which the recurrences were evaluated was 26.8 ± 20.8 months and 25.5 ± 18.1 months, respectively, in the TEP and TAPP groups, with no statistical difference between the two groups ($P = 0.91$).

Data analysis showed that there was no significant difference between TEP and OHR for the recurrences rate

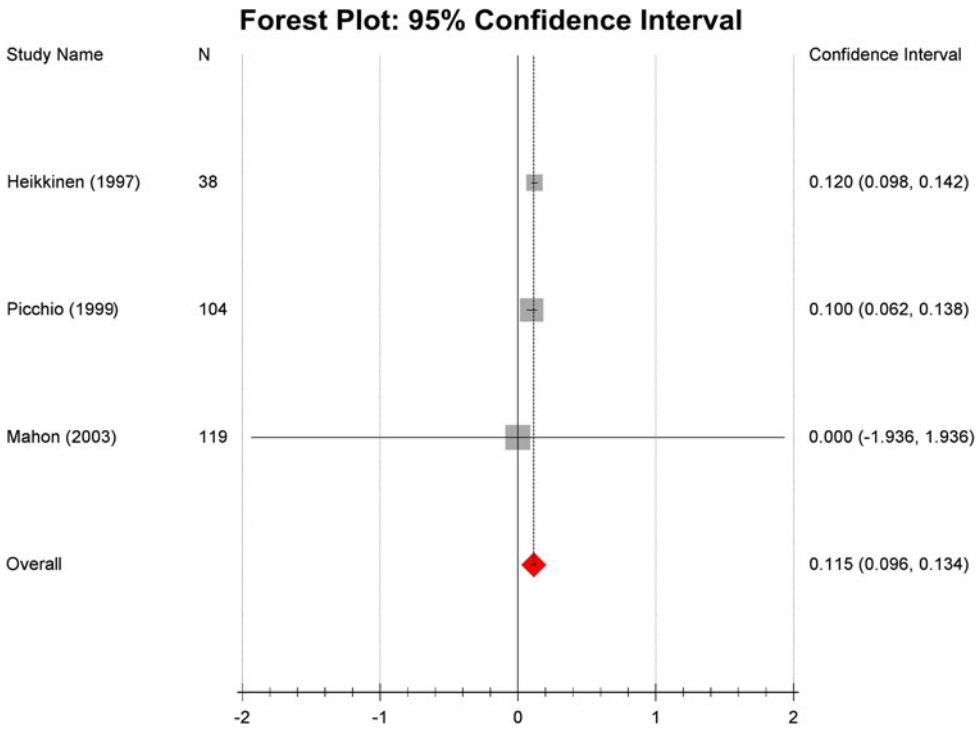

Fig. 5 Hospital stay: TAPP versus OHR

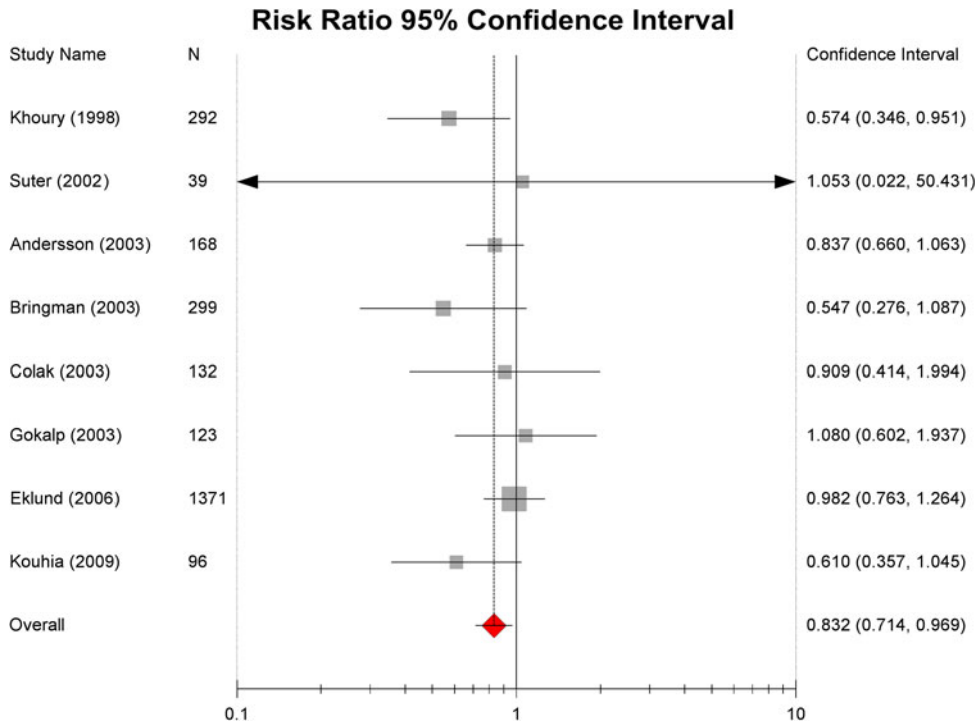

Fig. 6 Postoperative complications: TEP versus OHR

(RR = 1.39; 0.66, 2.89; $P > 0.05$; Fig. 12). We obtained the same result comparing TAPP with OHR (RR = 1.61; 0.61, 4.27; $P > 0.05$; Fig. 13).

The results obtained by the network meta-analysis, reported in Tables 4 and 5, showed no statistically significant differences between the two techniques with regards to all the outcomes considered, except for hospital stay.

Discussion

After the introduction of minimally invasive approaches to the repair of inguinal hernias, numerous studies revealed that patients who underwent laparoscopic repair had low recurrences rate, fewer postoperative complications, were discharged earlier, and were able to return to their usual

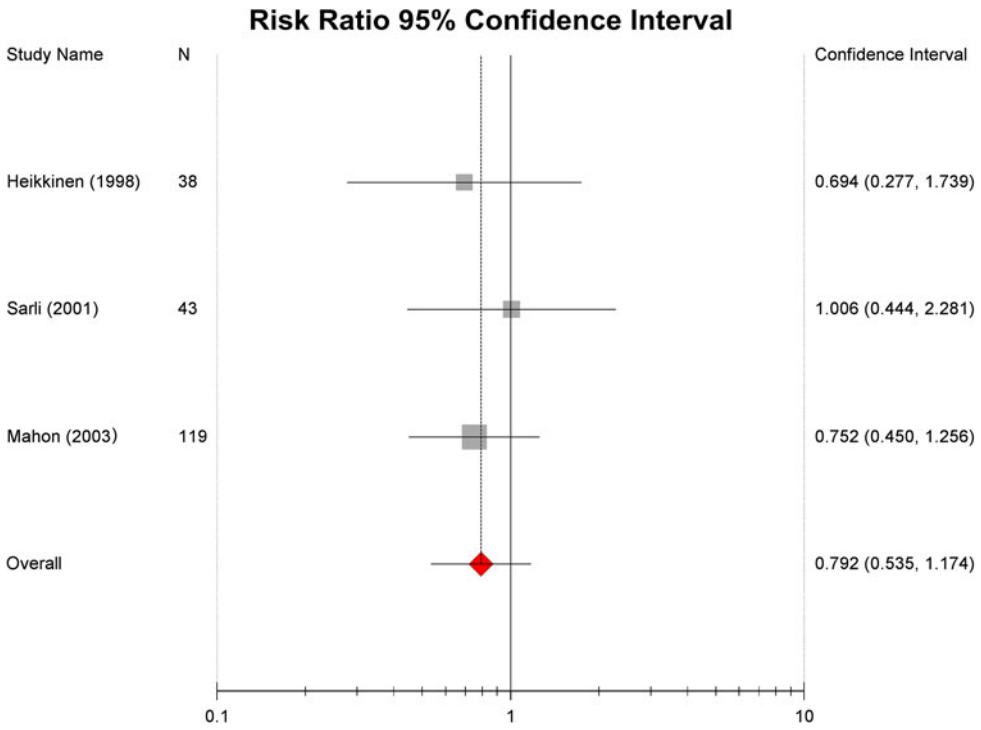

Fig. 7 Postoperative complications: TAPP versus OHR

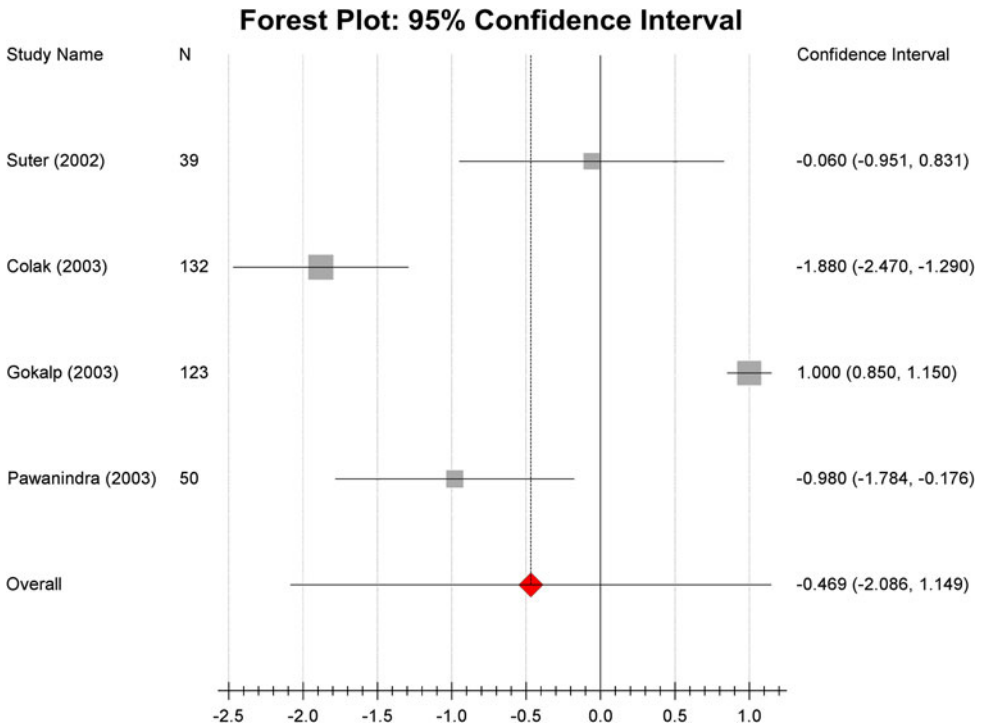

Fig. 8 Postoperative pain: TEP versus OHR

activities more quickly than patients who underwent open repair [32]. In the EHS Guidelines [6], the authors concluded (Level 1A) that endoscopic inguinal hernia techniques result in an earlier return to normal activities or work than the OHR. They recommended (grade A) that an endoscopic approach is considered if quick postoperative recovery is particularly important. However, they did not clarify which is the best laparoscopic approach for inguinal hernia repair, although (with grade D) the TEP approach for endoscopic inguinal hernia operation was recommended.

For each of the selected outcomes, we report some considerations by comparing our results with the last systematic review comparing TEP and TAPP by Wake et al.

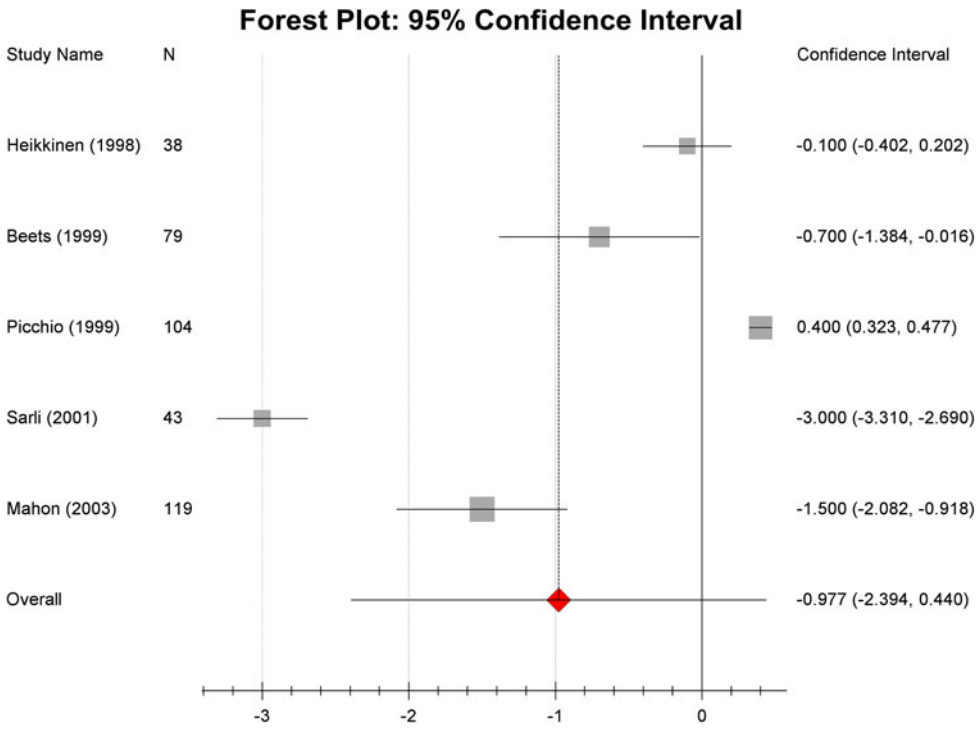

Fig. 9 Postoperative pain: TAPP versus OHR

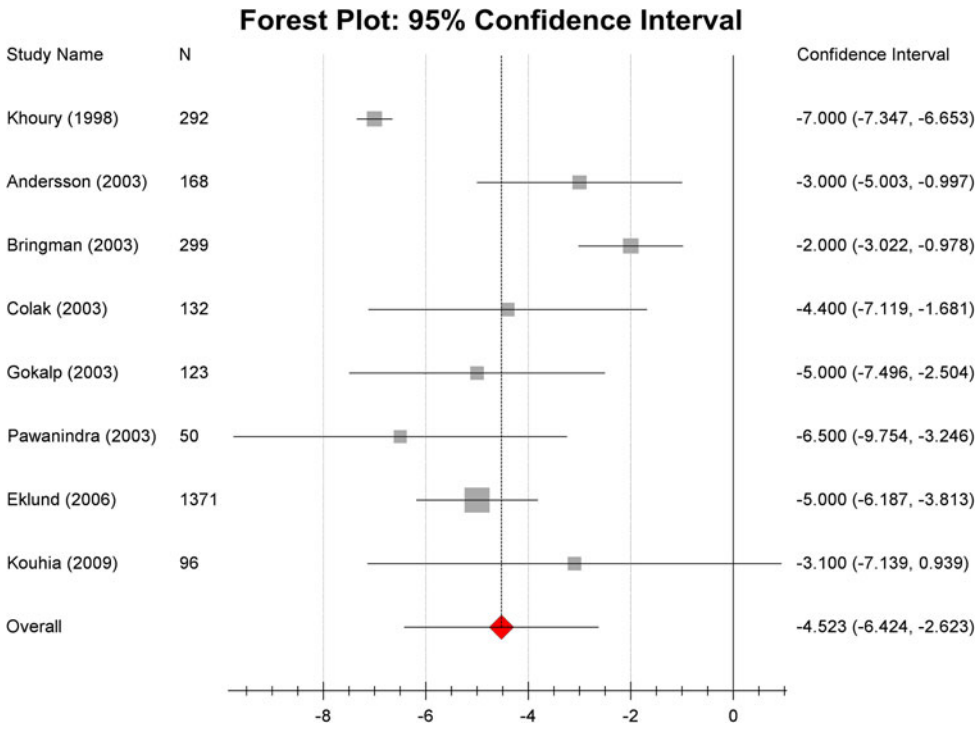

Fig. 10 Time to return to work: TEP versus OHR

[5], as of November 8, 2004 and including nonrandomized clinical trials, and with the few RCTs [31–34] published after 2004, which provided information for the direct comparison between TEP and TAPP.

For operative time, we found that TEP is more time-consuming than TAPP, even if this difference is not significant. These findings are consistent with the results of the review by Wake et al. [5], which reported that for experienced operators (between 30 and 100 procedures) the estimated duration of operation are 40 min for TAPP and 55 min for TEP; this difference was not significant. The reason for longer operative time for TEP versus TAPP

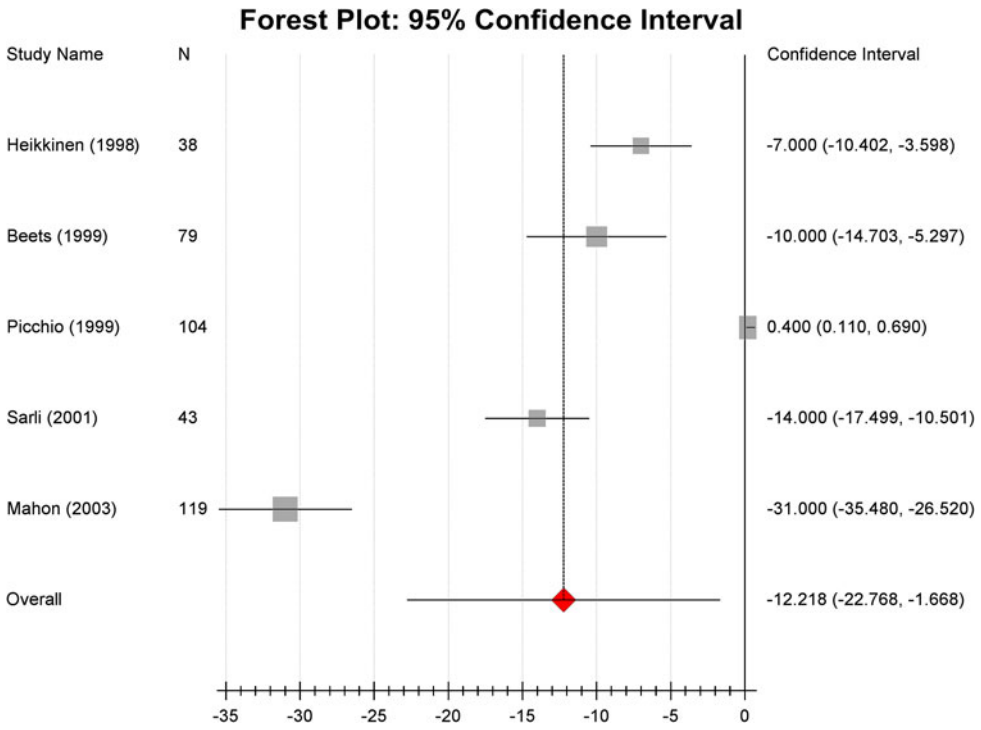

Fig. 11 Time to return to work: TAPP versus OHR

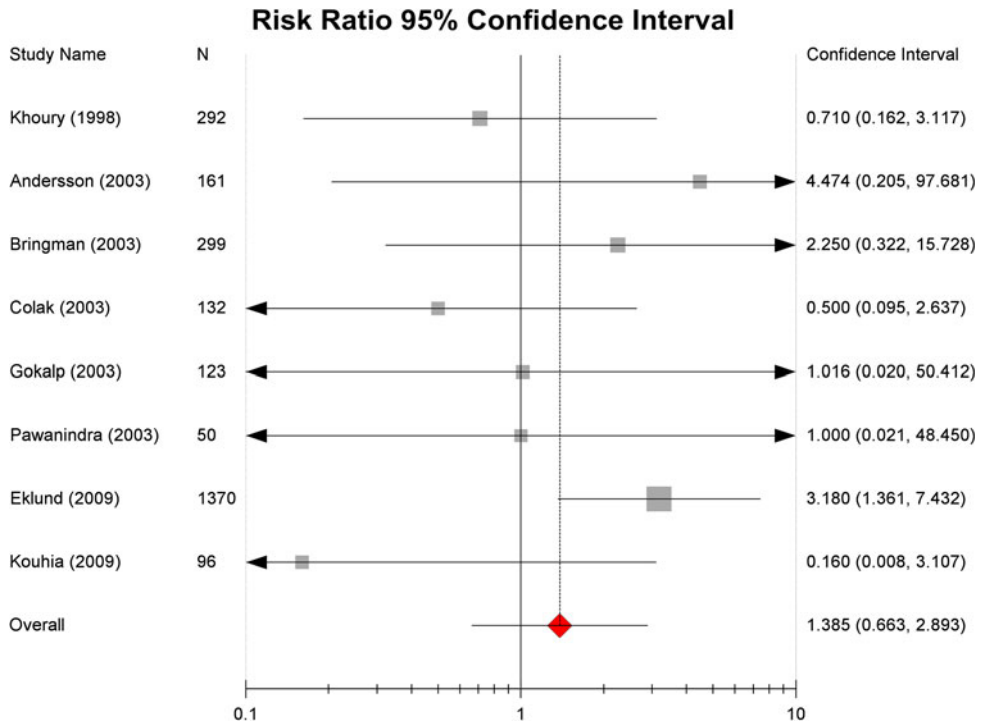

Fig. 12 Recurrences: TEP versus OHR

could be due to a limited working space and different appreciation of the usual anatomical landmarks seen from inside the peritoneal cavity [6]. However, one RCT [33] comparing TAPP versus TEP directly showed a significantly longer operative time for TAPP.

Not all the studies included reported intraoperative complications. One of the main arguments against the laparoscopic technique has been the increased risk for rare intra-abdominal complications, such as major bowel, bladder, and vascular injuries. A meta-analysis of both

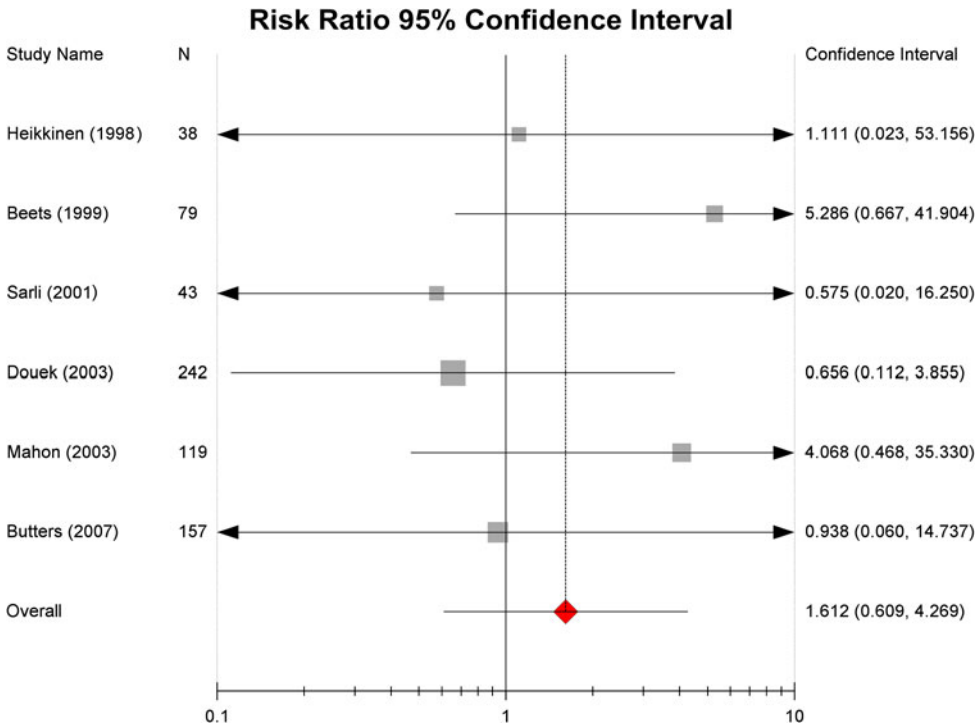

Fig. 13 Recurrences: TAPP versus OHR

Table 4 Results for continuous outcomes

	TEP vs. open (MD, 95 % CI, *P* value)	TAPP vs. open (MD, 95 % CI, *P* value)	TAPP vs. TEP (MD, 95 % CI, *P* value)
Operative time (min)	10.6 (4, 17.2) $P < 0.05$	3.41 (−11.57, 18.4) $P > 0.05$	−7.19 (−23.49, 9.1) $P > 0.05$
Postoperative (VAS)	−0.47 (−2.09, 1.15) $P > 0.05$	−0.98 (−2.39, 0.44) $P > 0.05$	−0.51 (−2.43, 1.42) $P > 0.05$
Hospital stay (days)	−0.19 (−0.41, 0.03) $P > 0.05$	0.12 (0.1, 0.13) $P < 0.05$	0.31 (0.082, 0.53) $P < 0.01$
Time to return to work (days)	−4.52 (−6.42, −2.62) $P < 0.05$	−12.22 (−22.8, −1.67) $P < 0.05$	−7.7 (−18.44, 3.05) $P > 0.05$

Table 5 Results for binary outcomes

	TEP vs. open (RR, 95 % CI, *P* value)	TAPP vs. open (RR, 95 % CI, *P* value)	TAPP vs. TEP (RR, 95 % CI, *P* value)
Postoperative complications	0.83 (0.71, 0.97) $P < 0.05$	0.79 (0.54, 1.17) $P > 0.05$	0.95 (0.62, 1.45) $P > 0.05$
Recurrences	1.39 (0.66, 2.89) $P > 0.05$	1.61 (0.61, 4.27) $P > 0.05$	1.16 (0.34, 3.95) $P > 0.05$

approaches versus OHR [4] report very low incidence of intraoperative complication during an endoscopic approach. However, the risk for these complications seems to be associated with TAPP rather than TEP [6].

For postoperative complications, we did not find difference between both groups. One potential postoperative complication with TAPP is the risk of bowel occlusions caused by adhesions at the site of peritoneal closure [35]. In the EHS Guidelines, the authors recommended (grade D) that, due to the risk of intestinal adhesion and bowel obstruction, the TEP approach is used for endoscopic inguinal hernia operation [6]. In another study [36], the RR of postoperative intestinal obstruction after hernia surgery was 2.8 with TAPP and 0.6 with TEP compared with that for patients who underwent the Lichtenstein procedure. Although an inadequately powered randomized comparison, the review by Wake et al. [5] reported no differences between TAPP and TEP in terms of vascular haematomas injuries and deep/mesh infections, but it reported an increased number of port-site hernias and visceral injuries associated with TAPP rather than TEP. Finally, two recent studies [32, 33] showed no differences both for intra- and postoperative complication between the two laparoscopic approaches.

Concerning the conversion rate, there is a lack of data to perform a meta-analysis. However, we found a higher number of conversions with TEP (1.57 %) compared with TAPP (0.75 %), consistent with the findings by Wake et al. [5].

In terms of pain, we did not find a significant difference between both groups, consistent with the results of the reviews by Wake et al. [5], Hamza et al. [31], Dedemadi et al. [34], and Gunal et al. [33]. Finally, the problem of pain after LHR seems to decrease, avoiding fixation of the mesh with staples using fibrin glue without increasing the risk for hernia recurrence [35].

TEP is associated with a significantly shorter hospital stay than TAPP: −0.31 days (0.082–0.53; $P < 0.01$). This is the only outcome significantly different from the network. Nonetheless, it has to be highlighted that this result is in part due to a nonsignificant pooled outcome obtained comparing TAPP with OHR. In fact, TAPP was associated with a nonsignificant increase of hospital stay (0.115 day, $P > 0.05$) compared with OHR, whereas TEP was related to a significant reduction (−0.191 day, $P < 0.01$). Nonetheless, as stated by Hamza et al. [31], hospital stay may be an elusive parameter for the evaluation of hernia surgery treatment, because it is largely dependent on the trend in medical practice, the local traditions, the way the healthcare provider is financed, and the patient housing conditions. Moreover, hernia operations are currently performed as 1-day surgery. No significant difference was found for time to return to work, consistent with the findings by Wake et al. [5], Hamza et al. [31], and Dedemadi et al. [34].

There were no differences in terms of recurrences between TAPP versus TEP. Dedemadi et al. [34] reported that they were not able to establish the exact recurrences rate because of the small number of patients in each group. Heikkinen et al. [35] reported that both TEP and TAPP have a low risk for hernia recurrence if proper mesh sides are used. Gunal et al. [33] found no significant differences between the considered arms in terms of recurrence. The review by Wake et al. [5] showed no difference in terms of hernia recurrence; however, they concluded that there were insufficient data to allow definitive conclusions about the best approach.

Few studies provided quantitative information about surgeon experience. Therefore, we choice not to exclude any study basing on this criterion because of lack of information. Among the RCTs included in this study, only three reported a minimum number of surgeries to be considered an experienced surgeon: 25 in Eklund et al. [14, 15], 50 in Sarli et al. [25], assisting in 10 procedures and being supervised in another 5 in Douek et al. [30]. No relevant information about surgeon experience was reported in six studies [16, 17, 20, 22, 24]. The remaining studies just reported qualitative information, such as "the procedures were performed by experienced surgeons" or "the surgeons were experienced in both techniques." Only one paper stated that: "all the operations were done by a junior surgeon with special interest and moderate experience in open and laparoscopic hernia surgery" [28]. For that reason, we strongly recommend that the authors, and also the editors, state clearly surgeon expertise in RCT papers reporting the minimum number of surgeries performed for each technique. Moreover, the results of the indirect comparison were similar to those of the few RCTs that provided data for direct comparisons [31–34], as shown in this section. However, we underline that indirect comparisons are considered less reliable than direct ones [37] and therefore should be interpreted with greater caution.

We conclude that TAPP and TEP achieved similarly results in five of the six outcomes analyzed in this study. TEP is associated with a significantly shorter hospital stay than TAPP, but this result is in part based on a nonsignificant difference between TAPP and OHR. According to these findings, both methodologies seem to be more effective than OHR, although there is not yet sufficient evidence to recommend the use of TEP rather than TAPP. This choice could be performed according to the surgeon's skills, which should be clearly stated in the literature.

Disclosures The authors have no conflict of interest to declare. This study was funded with structural funds of the authors' institutions, which are public institutions.

References

1. Testini M, Lissidini G, Poli E, Gurrado A, Lardo D, Piccinni G (2010) A single-surgeon randomized trial comparing sutures, *N*-butyl-2-cyanoacrylate and human fibrin glue for mesh fixation during primary inguinal hernia repair. Can J Surg 53:155–160
2. Vatansever U, Acunas B, Demir M, Karasalihoglu S, Ekuklu G, Ener S, Pala O (2002) Nucleated red blood cell counts and erythropoietin levels in high-risk neonates. Pediatr Int 44:590–595
3. Tolver MA, Strandfelt P, Rosenberg J, Bisgaard T (2011) Pain characteristics after laparoscopic inguinal hernia repair. Surg Endosc 25:3859–3864
4. Schmedt CG, Sauerland S, Bittner R (2005) Comparison of endoscopic procedures vs Lichtenstein and other open mesh techniques for inguinal hernia repair: a meta-analysis of randomized controlled trials. Surg Endosc 19:188–199
5. Wake BL, McCormack K, Fraser C, Vale L, Perez J, Grant AM (2005) Transabdominal pre-peritoneal (TAPP) vs totally extraperitoneal (TEP) laparoscopic techniques for inguinal hernia repair. Cochrane Database Syst Rev 1:CD004703
6. Simons MP, Aufenacker T, Bay-Nielsen M, Bouillot JL, Campanelli G, Conze J, de Lange D, Fortelny R, Heikkinen T, Kingsnorth A, Kukleta J, Morales-Conde S, Nordin P, Schumpelick V, Smedberg S, Smietanski M, Weber G, Miserez M (2009) European Hernia Society guidelines on the treatment of inguinal hernia in adult patients. Hernia 13:343–403
7. Lumley T (2002) Network meta-analysis for indirect treatment comparisons. Stat Med 21:2313–2324

8. Moher D, Liberati A, Tetzlaff J, Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Br Med J 339:b2535
9. Jansen JP, Fleurence R, Devine B, Itzler R, Barrett A, Hawkins N, Lee K, Boersma C, Annemans L, Cappelleri JC (2011) Interpreting indirect treatment comparisons and network meta-analysis for health-care decision making: report of the ISPOR Task Force on Indirect Treatment Comparisons Good Research Practices. Part 1. Value Health 14:417–428
10. Sutton A, Abrams K, Jones D, Sheldon T, Song F (2000) Methods for meta-analysis in medical research. Wiley, Chichester
11. Wallace BC, Schmid CH, Lau J, Trikalinos TA (2009) Meta-analyst: software for meta-analysis of binary, continuous and diagnostic data. BMC Med Res Methodol 9:80
12. Bucher HC, Guyatt GH, Griffith LE, Walter SD (1997) The results of direct and indirect treatment comparisons in meta-analysis of randomized controlled trials. J Clin Epidemiol 50: 683–691
13. Kouhia ST, Huttunen R, Silvasti SO, Heiskanen JT, Ahtola H, Uotila-Nieminen M, Kiviniemi VV, Hakala T (2009) Lichtenstein hernioplasty versus totally extraperitoneal laparoscopic hernioplasty in treatment of recurrent inguinal hernia: a prospective randomized trial. Ann Surg 249:384–387
14. Eklund A, Rudberg C, Smedberg S, Enander LK, Leijonmarck CE, Osterberg J, Montgomery A (2006) Short-term results of a randomized clinical trial comparing Lichtenstein open repair with totally extraperitoneal laparoscopic inguinal hernia repair. Br J Surg 93:1060–1068
15. Eklund AS, Montgomery AK, Rasmussen IC, Sandbue RP, Bergkvist LA, Rudberg CR (2009) Low recurrence rate after laparoscopic (TEP) and open (Lichtenstein) inguinal hernia repair: a randomized, multicenter trial with 5-year follow-up. Ann Surg 249:33–38
16. Gokalp A, Inal M, Maralcan G, Baskonus I (2003) A prospective randomized study of Lichtenstein open tension-free versus laparoscopic totally extraperitoneal techniques for inguinal hernia repair. Acta Chir Belg 103:502–506
17. Colak T, Akca T, Kanik A, Aydin S (2003) Randomized clinical trial comparing laparoscopic totally extraperitoneal approach with open mesh repair in inguinal hernia. Surg Laparo Endo Per 13:191–195
18. Andersson B, Hallen M, Leveau P, Bergenfelz A, Westerdahl J (2003) Laparoscopic extraperitoneal inguinal hernia repair versus open mesh repair: a prospective randomized controlled trial. Surgery 133:464–472
19. Pawanindra L, Kajla RK, Chander J, Saha R, Ramteke VK (2003) Randomized controlled study of laparoscopic total extraperitoneal versus open Lichtenstein inguinal hernia repair. Surg Endosc 17:850–856
20. Suter M, Martinet O (2002) Postoperative pulmonary dysfunction after bilateral inguinal hernia repair: a prospective randomized study comparing the Stoppa procedure with laparoscopic total extraperitoneal repair (TEPP). Surg Laparosc Endosc Percutan Tech 12:420–425
21. Bringman S, Ramel S, Heikkinen TJ, Englund T, Westman B, Anderberg B (2003) Tension-free inguinal hernia repair: TEP versus mesh-plug versus Lichtenstein: a prospective randomized controlled trial. Ann Surg 237:142–147
22. Khoury N (1998) A randomized prospective controlled trial of laparoscopic extraperitoneal hernia repair and mesh-plug hernioplasty: a study of 315 cases. J Laparoendosc Adv Surg Technol A 8:367–372
23. Hallen M, Bergenfelz A, Westerdahl J (2008) Laparoscopic extraperitoneal inguinal hernia repair versus open mesh repair: long-term follow-up of a randomized controlled trial. Surgery 143:313–317
24. Mahon D, Decadt B, Rhodes M (2003) Prospective randomized trial of laparoscopic (transabdominal preperitoneal) vs. open (mesh) repair for bilateral and recurrent inguinal hernia. Surg Endosc 17:1386–1390
25. Sarli L, Iusco DR, Sansebastiano G, Costi R (2001) Simultaneous repair of bilateral inguinal hernias: a prospective, randomized study of open, tension-free versus laparoscopic approach. Surg Laparosc Endosc Percutan Tech 11:262–267
26. Picchio M, Lombardi A, Zolovkins A, Mihelsons M, La Torre G (1999) Tension-free laparoscopic and open hernia repair: randomized controlled trial of early results. World J Surg 23: 1004–1009
27. Beets GL, Dirksen CD, Go PM, Geisler FE, Baeten CG, Kootstra G (1999) Open or laparoscopic preperitoneal mesh repair for recurrent inguinal hernia? A randomized controlled trial. Surg Endosc 13:323–327
28. Heikkinen TJ, Haukipuro K, Hulkko A (1998) A cost and outcome comparison between laparoscopic and Lichtenstein hernia operations in a day-case unit. A randomized prospective study. Surg Endosc 12:1199–1203
29. Butters M, Redecke J, Koninger J (2007) Long-term results of a randomized clinical trial of Shouldice, Lichtenstein and transabdominal preperitoneal hernia repairs. Br J Surg 94:562–565
30. Douek M, Smith G, Oshowo A, Stoker DL, Wellwood JM (2003) Prospective randomised controlled trial of laparoscopic versus open inguinal hernia mesh repair: five-year follow-up. Br Med J 326:1012–1013
31. Hamza Y, Gabr E, Hammadi H, Khalil R (2010) Four-arm randomized trial comparing laparoscopic and open hernia repairs. Int J Surg 8:25–28
32. Pokorny H, Klingler A, Schmid T, Fortelny R, Hollinsky C, Kawji R, Steiner E, Pernthaler H, Függer R, Scheyer M (2008) Recurrence and complications after laparoscopic versus open inguinal hernia repair: results of a prospective randomized multicenter trial. Hernia 12:385–389
33. Gunal O, Ozer S, Gurleyik E, Bahcebasi T (2007) Does the approach to the groin make a difference in hernia repair? Hernia 11:429–434
34. Dedemadi G, Sgourakis G, Karaliotas C, Christofides T, Kouraklis G (2006) Comparison of laparoscopic and open tension-free repair of recurrent inguinal hernias: a prospective randomized study. Surg Endosc 20:1099–1104
35. Heikkinen T, Bringman S, Ohtonen P, Kunelius P, Haukipuro K, Hulkko A (2004) Five-year outcome of laparoscopic and Lichtenstein hernioplasties. Surg Endosc 18:518–522
36. Bringman S, Blomqvist P (2005) Intestinal obstruction after inguinal and femoral hernia repair: a study of 33,275 operations during 1992–2000 in Sweden. Hernia 9:178–183
37. Song F, Loke YK, Walsh T, Glenny AM, Eastwood AJ, Altman DG (2009) Methodological problems in the use of indirect comparisons for evaluating healthcare interventions: survey of published systematic reviews. Br Med J 338:b1147