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Original Research Article

Optimal port site skin closure method following minimally-invasive surgery: A systematic review and network meta-analysis of randomised clinical trials

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A B S T R A C T

Background: For minimally-invasive surgery (MIS), there are numerous acceptable port-site closure techniques with no consensus on the method used.
Aim: To identify optimal port site postoperative wound closure method following MIS with respect to complication rates and cosmetic outcome.
Methods: Network meta-analysis (NMA) was performed in accordance with PRISMA-NMA guidelines for RCTs comparing at least two methods of port-site closure.
Results: Nineteen RCTs were identified evaluating eight methods of wound closure in 1,932 patients; across three types of suture, three forms of tissue glue, staples and paper-tape. At NMA, there was no significant difference in wound complication, infection, dehiscence or pain rate irrespective of closure method, albeit a trend towards higher rate of dehiscence for adhesives. At NMA, wound cosmesis was superior for adhesives at both early and late postoperative follow-up.
Conclusion: This study validates the use of tissue adhesives with respect to primary closure of port sites following MIS while highlighting potential associated risks.

1. Introduction

In the contemporary era, minimally Invasive surgery (MIS) has evolved as the cornerstone of abdominal surgery, where feasible. Initially implemented in the elective setting, MIS has now become adopted as commonplace in the emergency setting, with consensus guidelines suggesting a laparoscopy-first approach for stable patients undergoing emergency abdominal procedures.[1]

Many distinct methods of primary wound closure exist, with tissue adhesive, staples (STP), adhesive paper tape (APT) and sutures among the most common methods deployed in contemporary practice.[2] Tissue adhesives composed of octylcyanoacrylate (OCA) (most commonly Dermabond © (Dermabond, Ethicon; Summerville, NJ)) and n-butyl-cyanoacrylate (Liquiband © (Liquiband, Medlogic Global Ltd, Plymouth, UK) (LB)) have been employed due to their speed in postoperative wound edge apposition and ease of use.[2,3] Likewise, STP are said to be advantageous for their speed and ease of closure; up to three times faster than sutures,[4] and have the added benefit of cost effectiveness.[2] APT (most commonly Steri-strips (Steri-Strip; 3M Health Care, St. Paul, MN, USA)), like adhesives, is regarded as a safe alternative to sutures while reducing time to closure and saving on costs,[5] and has also been used as an adjunct to sutures and other closure methods.[6]

Sutures are considered by many to be standard of care for wound closure methods,[7] which is likely due to a reduced rate of wound dehiscence being previously reported in comparison to other closure methods, even for smaller wounds such as port sites.[5] Subcuticular sutures (ID) have become popularised due to evidence highlighting their superiority in terms of cosmetic outcomes relative to alternative wound closure methods.[8,9] Subcutaneous (SC) sutures are often employed in combination with a more superficial suture technique such as ID or Transcutaneous sutures (TC) but are sometimes used alone.[10]

To date, there has been no network meta-analysis of prospective, randomised clinical trials (RCTs) performed to evaluate the optimal closure method for port-sites following MIS, and as such, is the genesis of this network meta-analysis (NMA) of RCTs evaluating conventional wound closure methods. The authors' null hypothesis is wound closure with ID will correspond to optimal cosmetic outcomes, in keeping with previous work.[11]

2. Methods

A systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Network Meta-Analyses (PRISMA-NMA) guideline (extension statement for reporting of systematic reviews incorporating NMAs of healthcare interventions[12]).This study was registered with the International Prospective Register of

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2.1. Search strategy

A formal systematic search was performed in December 2023 using the PubMed, Embase and Cochrane databases to identify relevant titles. Search strategy details are depicted by flowsheet (Supplementary Fig. 1). The search was performed using the search terms (laparoscop* OR laparoscopic surgery OR keyhole OR celioscop* OR coelioscop* OR abdominoscop* OR peritoneoscop* OR minimally invasive surgery) AND (port OR port site OR keyhole) AND (close OR closure OR skin OR paper OR tape OR adhesive OR glue OR suture OR stitch OR staple). All studies that were not of prospective, randomised design were excluded. For the purposes of this review, only port site closure methods implemented in isolation were included. Combined closure techniques were not considered for ease of comparison. Manual screening of reference lists from relevant previous systematic reviews, meta-analyses and included studies was undertaken to ensure all eligible RCTs published were included, and a list of eligible titles from the three databases was collated.

Duplicate studies were manually removed, followed by RCT title screening. Eligible studies then underwent abstract and full text review in accordance with the inclusion criteria and outcome measures of interest. Finally, data extraction of relevant parameters was performed. Relevant parameters denoted included patient clinicopathological and treatment characteristics. Title, abstract and full-text screening was performed by two independent reviewers (E.P.K. and L.B.M.). Any discrepancies in opinion were resolved by a third reviewer acting as an independent arbitrator (M.G.D.).

2.2. Population, intervention comparison, outcomes (PICO)

The population, intervention, comparison, outcomes (PICO)[13] framework was utilised to address the following components of the study:

Population - all patients who underwent MIS.

Intervention – any patient who underwent laparoscopic port site wound closure using any primary wound closure method.

Comparison - any patient who underwent laparoscopic port site wound closure using any other primary wound closure method.

Outcomes – outcomes of interest included:

- Overall postoperative wound complication rates
- Postoperative wound infection
- Postoperative wound dehiscence
- Postoperative wound pain per patient
- Postoperative wound pain, expressed using a Visual Analogue Scale (VAS)[14]
- Scar cosmesis by VAS[14] and Hollander Wound Evaluation Scale (HWES)[15]

2.3. Eligibility criteria

All published studies with full-text manuscripts comparing outcomes of two or more methods of surgical closure of MIS port site wounds were included. RCTs only were included in this review. MIS was defined as a surgical procedure undertaken through a port site, integrating laparoscopic general surgical, urological, gynaecological, and video-assisted thoracic surgery (VATS). All studies pertaining to any form of MIS meeting this definition were regarded as eligible for inclusion, and were not excluded based on type of procedure or setting (elective or emergency). Studies utilising port site closure techniques implemented in isolation were eligible for inclusion in this review to allow direct comparisons between closure methods. Studies pertaining to closure methods used in combination for minimally invasive surgery were excluded, along with studies concerning open surgical site closure. Studies were not excluded based on patient factors or type of MIS performed. Included RCTs had to be published in the English language and have a full-text manuscript available.

2.4. Data quality assessment

Risk of bias was assessed in the included RCTs using the Jadad Scale.[16]

2.5. Statistical analysis

Descriptive statistics were used to detail relevant characteristics of included studies. Rates of postoperative complications, infection, dehiscence, pain and cosmesis by HWES were expressed as dichotomous or binary outcomes, and reported as odds ratios (ORs) expressed with 95 % confidence intervals (CI). Crude-event RCT data were used to determine ORs so interventions could be compared using per-protocol data, where possible. Wound Cosmesis by VAS were expressed as continuous outcomes for analysis, and analysed using mean and standard deviation (SD) values. Netmeta and Shiny packages for R were utilised to carry out NMA. Effect sizes were denoted by 95 % CI. Results were considered statistically significant if $P < 0.050$ and the 95 % CI did not include the value of one. Mean and SD were determined using standard statistical methods where feasible.[17,18] Once computed, confidence in estimated outcomes was estimated using the Confidence in Network Meta-Analysis (CINeMA) tool.[19]

2.6. Closure methods

For clarity, 1932 patients were included in our review, however some patients underwent more than one wound closure method. For example, in Park et al.'s study,[10] 77 patients were included, each of which had 2 abdominal port site incisions. Their first wound was closed with glue (LS) and the second was closed with suture (TC). As such, this study contributed 77 patients to our total, but each of the 77 patients were included in both TC and LS subgroups.

Additionally, some patients had more than one wound site. For example, in Sebesta et al.'s study[20] there were close to 4 port sites per patient, with 30 patients undergoing ID closure of 118 abdominal port sites (i.e. 30 patients, 118 sites) and 29 patients having OCA closure of 110 laparoscopy sites (i.e. 29 patients, 110 sites). For the purposes of our systematic review and network meta-analysis we have reported total and individual complications per patient and also per wound site to ascertain if any additional observations can be drawn.

2.7. Scar cosmesis

Scar cosmesis was assessed using VAS and HWES. Both are validated clinical tools used to assess subjective satisfaction with wound healing on a standardised scale to aid in comparing cosmesis for wound closure methods in larger cohorts. HWES is a cosmetic tool based on six criteria (step-off borders, contour irregularity, scar width, edge inversion, inflammation, and overall cosmesis); with an optimal score of 6/6.[15]

VAS is a clinical tool which has been clinically validated and is widely utilised.[21] It is a subjective method for patients to rate their satisfaction with wound healing and varies from a 5 to 10 or 100-point scale. For the sake of comparison in our analysis VAS was standardised as a 10-point scale, with 0 representing the best possible cosmetic outcome and 10 representing the worst. All included data were converted to a 10 point scale (0–10); as subjectively identified by patients themselves. One study that utilised a separate 5 point patient scar-evaluation scale called the Stony Brook Scar Evaluation Scale[22] was also standardised and included.[23] Subjective VAS from patients only was included and VAS from observer (surgeon) was excluded due to relative paucity of data reported in this format in included studies.

3. Results

3.1. Literature search

In total, 12,203 studies were provisionally identified via systematic search, followed by removal of 2317 duplicates. Study titles and abstracts were then screened resulting in 38 studies being identified as eligible for full text screening. Of these, 19 met the eligibility criteria and were included,[10,11,20,23–38] as detailed in the PRISMA flowsheet (Supplementary Fig. 1).

3.2. Study characteristics

Overall 1932 patients were included spanning 8 discrete closure techniques, which included 3 methods of suturing (TC, ID, SC), 3 types of tissue adhesive (OCA, LB, Leukosan®Adhesive, BSN Hamburg, Germany (LS)), APT and STP. Total number of patients was denoted for all studies; and total port site number was denoted for 13 out of 19 studies. Overall, 10 of the included RCTs were from European translational research facilities (52.6 %), 4 from North America (21.1 %), 3 from Asia (15.8 %), and 1 from each of Africa and Australia (both 5.3 %). Publication dates spanned 26 years from 1997 to 2023 (Supplementary Table 1).

3.3. Patient and surgical demographics

Of the 1932 patients included, mean age was 45.23 years (N = 1779) and 71.8 % (1265/1763) of patients were female (16 studies). There was a non-significant difference in patient groups for baseline characteristics which may confound outcomes relative to wounds, including diabetes mellitus, active smoking, previous smoking, and patient body mass indices (BMI) at the time of surgery (all $p > 0.050$). 16.4 % of patients (108/660) were classified as active smokers, while 59.9 % of patients (434/724) were never smokers (4 studies). 2.9 % of patients (18/623) were diagnosed with diabetes mellitus.

Regarding operative setting, thirteen out of nineteen studies included elective surgical procedures alone[10,11,24–29,33,34,36–38] and two studies included emergency procedures in their reported data.[31,35] It was unclear whether a delineation was made for four studies.[20,23,30,32] Data on operative procedure was available for 1298 patients (15/19 studies). 60.4 % of patients included underwent general surgical procedures (784/1298), the majority of which were cholecystectomy (500/784) but also included hernia repair (106/784), diagnostic laparoscopy (66/784) and appendicectomy (53/784). 26.0 % of patients underwent a gynaecological surgical procedure (337/1298). 9.0 % of patients underwent urological procedures (117/1298), and 4.6 % of patients underwent VATS procedures (60/1298). Mean site length was 9.7 mm across 2023 sites (5 studies). Where specified, mean port site length was heterogeneous, and equalled <12 mm for all except two studies,[10,24] one of which examined single port site laparoscopy.[10] Data on surgical procedures and port sites are available in Table 1.

3.4. Closure methods

As described, 8 separate closure techniques were included. As mentioned in the methods section, some patients underwent more than one wound closure method. As such, there were 1932 patients in total in our review, however when the number of patients who received each wound closure method is totalled it equals 2174. OCA glue was the most prevalent wound closure method, being used in 28.7 % of patients (554/1932). With respect to alternative tissue adhesives, 18.2 % of patients underwent closure with LB (352/1932), while 4.0 % of patients had skin closure with LS (77/1932). Sutured approach to skin closure methods consisted of ID in 25.1 % (485/1932), transcutaneous (TC) in 20.2 % (390/1932) and subcutaneous in 3.5 % (68/1932) of patients. APT closure was utilised for wound closure in 9.6 % (186/1932) of patients. Finally, 3.3 % (63/1932) of patients underwent closure with STP.

13 studies out of 19 studies reported on number port sites, totalling to 3435 port site wounds.

3.5. Complications

Overall, eighteen of nineteen RCTs included reported on complication rates.[10,11,20,24–38] Chen et al.'s study[27] was excluded from reported complications and analysis due to a discrepancy in the format in which complications were reported. Wound complications were reported by 16.5 % (252/1525) of patients (Supplementary Table 1), and complications were reported in 12.3 % (376/3046) of port sites (Table 2).

Table 1
surgical procedure data per patient across individual studies. *N; number, N/R; not reported, u/k; unknown, avg; average, pt; patient.*

Author	N	General surgical	Gynaecological	Urological	VATS	Operative setting	Port site data	Avg. port site length (per site)
Buchweitz[1]	77	–	77	–	–	Elective		6.2 mm (mean)
Buchweitz[2]	52	–	52	–	–	Elective	Per pt: 1x10mm 2 or 3 × 5mm	N/R
Chen	–	–	–	–	–	Elective	All 5 mm	N/R
Dowson	154	154	–	–	–	Elective	N/R	7.73 mm (mean)
Fluellen	N/R	–	–	–	–	N/R	N/R	N/R
Jan	N/R	–	–	–	–	Elective	N/R	5 mm (median)
Jallali	25	25	–	–	–	N/R	Per pt: 3 × 5mm 1x10mm	N/R
Kent	N/R	–	–	–	–	Elective/emergency	N/R	8.45 mm (mean)
Luckraz	60	–	–	–	60	N/R	N/R	N/R
Maartense	140	140	–	–	–	Elective	All 5 or 10 mm	N/R
Matin	92	18	16	58	–	Elective	N/R	11.82 mm (mean)
Park	138	–	138	–	–	Elective	All 15–20 mm	N/R
Ramjit	138	138	–	–	–	Elective	N/R	27.2 mm (mean total per pt)
Rosen	54	–	54	–	–	Elective	Per pt: 1 × 5mm 1x10mm 1x umbilical incision	N/R
Romero	49	49	–	–	–	Emergency	Per pt: 1x10mm 2 × 5mm	N/R
Safta	70	70	–	–	–	Elective	N/R	25 mm (mean)
Sebesta	59	–	–	59	–	N/R	N/R	11.62 mm (mean)
Sharma	100	100	–	–	–	Elective	All 10 mm	N/R
Singh	90	90	–	–	–	Elective	252 ports <10 mm 149 ports 10–12 mm	N/R
Total	1298	784	337	117	60	Elective		

Table 2
Surgical complication data for all methods of wound closure per patient and per site.

Method of closure	Total (patient,site)	Complications (per patient, per site)	Infection (per patient, per site)	Dehiscence (per patient, per site)	Erythema (per patient, per site)	Pain (per patient, per site)
OCA	554, 1116	104/485, 96/901	28/489, 14/901	13/441, 14/901	0/50, N/R	6/74, 2/72
LB	352, 796	79/210, 141/796	25/271, 20/618	18/271, 15/618	6/61, 29/178	N/R, 6/178
LS	77, 77	1/56, 1/56	N/R, N/R	1/56, 1/56	0/56, 0/56	N/R, N/R
ID	485, 801	38/335, 83/659	12/340, 4/456	6/290, 2/456	3/52, 32/219	4/52, 10/219
TC	390, 337	19/188, 19/297	19/297	3/187, 0/243	16/216, 21/117	10/102, 1/52
SC	68, 68	0/68, 0/68	0/68, 0/68	0/68, 0/68	N/R, N/R	N/R, N/R
APT	185, 269	7/120, 36/269	4/120, 4/234	1/78, 13/234	1/23, N/R	1/48, 1/98
STP	63, N/R	4/63, N/R	2/63, N/R	2/63, N/R	N/R, N/R	N/R, N/R
Total	2174 (19 studies), 3464 (13 studies).	252/1525 (18 studies), 376/3046 (11 studies).	80/1499 (13 studies), 45/2464 (7 studies).	45/1513 (13 studies), 45/2576 (9 studies).	26/458 (5 studies), 82/570 (3 studies).	21/276 (4 studies), 20/619 (3 studies).

N; number, N/R; not reported, OCA; octylcyanoacrylate. ID; subcuticular, TC; transcutaneous, LB; Liquiband, APT, adhesive paper tape, LS; Leukosan, SC; subcutaneous, STP; staples.

Wound complications were reported in 21.4 % (104/485), 37.6 % (79/210), 1.8 % (1/56), 11.3 % (38/335), 10.1 % (19/188), 0 % (0/68), 5.8 % (7/120) and 6.3 % (4/63) of patients who underwent closure with OCA, LB, LS, ID, TC, SC, APT and STP, respectively. Complications were reported in 10.7 % (96/901), 18.3 % (141/796), 1.8 % (1/56), 12.6 % (83/659), 6.4 % (19/297), 0.0 % (0/68) and 13.4 % (36/269) of sites closed by OCA, LB, LS, ID, TC, SC and APT respectively (not reported for STP). At NMA, there was no significant difference between closure methods when compared across patients or site (Fig. 1A1 and 1A2).

3.6. Infection

Wound infection rates were reported for fourteen of the nineteen included clinical trials.[10,11,20,24,26,27,29,31–38] Overall postoperative wound infection rates were 5.3 % per patient (80/1499) and 1.8 % per site (45/2464). For OCA, LB, ID, TC, SC, APT and STP complication rates were 5.7 % (28/489), 9.2 % (25/271), 3.5 % (12/340), 4.7 % (9/190), 0 % (0/68), 3.3 % (4/120) and 6.3 % (4/63) per patient respectively. When compared across site they were 1.6 % (14/901), 3.2 % (20/618), 0.9 % (4/456), 1.6 % (3/187), 0 % (0/68) and 1.7 % (4/234) respectively for OCA, LB, ID, TC, SC and APT. When frequency of complication rates were integrated into Network-Meta Analysis, there was no significant difference between closure methods across patients or across sites. Individual study results are available in Table 2 and forest plots for these studies are available in Fig. 1 (Fig. 1B1 and 1B2).

3.7. Dehiscence

Thirteen studies reported on wound dehiscence.[10,11,20,24–26,29,31,32,34,35,37,38] Dehiscence was reported in 3.0 % (45/1513) of patients and 1.7 % (45/2576) of laparoscopic port sites. Dehiscence rates per patient and per port site were 3.0 % (13/441) and 1.6 % (14/901), 6.6 % (18/271) and 2.4 % (15/618), 1.8 % (1/56) and 1.8 % (1/56), 2.1 % (6/290) and 0.4 % (2/456), 1.6 % (4/246) and 0 % (0/243), 0 % (0/68) and 0 % (0/68), and 1.3 % (1/78) and 5.6 % (13/234) for OCA, LB, LS, ID, TC, SC, and APT closure methods respectively. Dehiscence rate per patient only was reported for STP closure and was 3.22 % (2/63). At NMA, there was no statistically significant difference when comparing wound dehiscence rates across patients or sites. Individual study results are available in Table 2 and forest plots for these studies are available in Fig. 1 (Fig. 1C1 and 1C2).

3.8. Pain

Port site pain rates were reported by four out of nineteen studies.[26,30,35,37] Overall pain rates were 7.6 % (21/276) in patients and 3.2 % (20/619) in port sites. Pain rates were 8.1 % (6/74) and 2.8 % (2/72), 7.7 % (4/52) and 4.6 % (10/219), 9.8 % (10/102) and 1.9 % (1/52), and 2.1 % (1/48) and 1.0 % (1/98) per patient and per site for OCA, ID, TC and APT wound closure methods respectively. Pain rates were reported per site only for LB (3.4 % (6/178)). Pain rates were not reported for LS, SC and STP. At NMA there was no significant difference between closure methods in terms of pain.

3.9. Patient satisfaction - wound cosmesis

Wound cosmesis was assessed using HWES (9 studies)[11,24,25,27–31,33,38] and VAS (9 studies).[24,25,27–31,33,38] One study utilised the Stony Brook Scar Evaluation Scale.[23]

3.10. Visual Analogue Scale

Follow-up timepoints for assessment of cosmetic outcome varied between studies, and as most follow-up via VAS in the included RCTs was greater than 1 month postoperatively, our study divided VAS cosmesis into two follow-up timepoint categories: follow-up 1–3 months and follow-up at or beyond 3 months postoperatively. For clarity, if VAS was performed at 90 days, this data was included in the latter (at or beyond 3 months postoperatively). As previously outlined, VAS was standardised as a 10-point scale, with 0 representing the best possible cosmetic outcome and 10 representing the worst; as subjectively identified by patients themselves. 9 studies included VAS as a gauge of laparoscopic scar cosmesis and data via the Stony Brook Scar Evaluation was also standardised and included. At NMA, 1 study[35] was excluded due to utilisation of combined closure methods for site closure, and data on cosmesis by Stony Brook Scar Evaluation Scale was also excluded at NMA.

Three studies[10,29,34] reported cosmetic outcomes through VAS at 1–3 months postoperatively, in which 206 patients had VAS recorded across 3 closure methods. Two studies were integrated at NMA,[10,34] which showed no statistically significant difference between closure methods for cosmesis at this follow-up timepoint. Data on cosmesis by VAS, study data summaries and forest plots are available in Supplementary Table 2

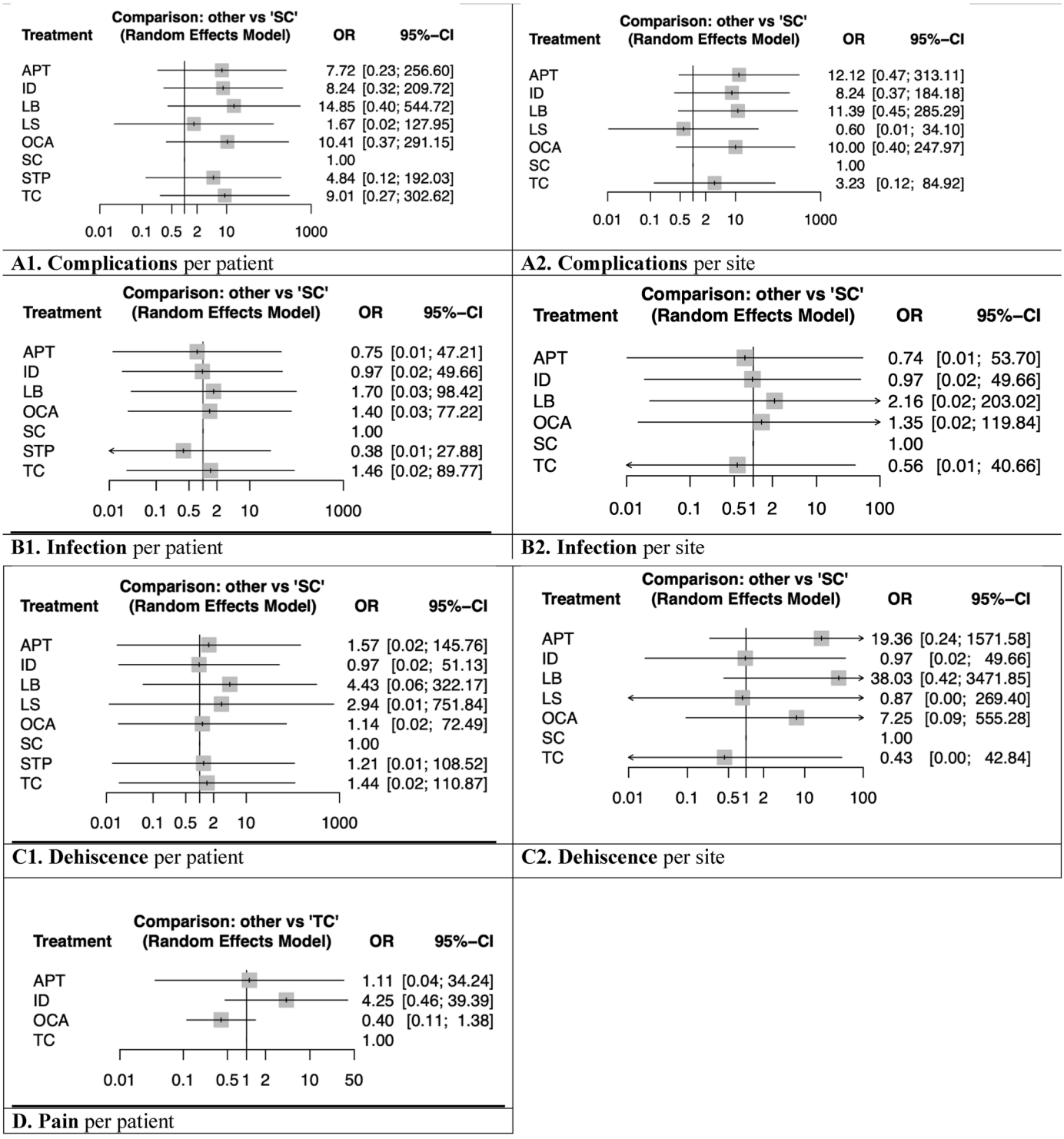

Fig. 1. Forest Plots comparing complication rates across closure methods (A1) overall complications per patient; (A2) overall complications per site; (B1) infection per patient; (B2) infection per site; (C1) dehiscence per patient; (C2) dehiscence per site; (D) pain per site.

and Supplementary Fig. 2.

At 3 months or thereafter, 639 patients had VAS recorded across seven studies.[10,23,25,26,33,35,38] Mean VAS was 2.25, 3.8, 1.85, 2.9, 1 and 1.85 for OCA, LS, ID, TC, SC and STP respectively. After exclusion, 549 patients were included with data eligible for analysis at NMA. Individual comparison of closure methods showed TC conferred an inferior cosmetic outcome to ID and to APT in Buchweitz et al. and Singh et al.'s study respectively. There was no statistically significant difference between closure methods at NMA, although TC trended towards significance in terms of inferiority (MD = −0.71, 95 % CI = −1.41; 0.00).

3.11. Hollander Wound Evaluation Scale (HWES)

Nine RCTs reported wound cosmesis via HWES.[24,25,27–31,33,38] HWES was divided into 2 categories; values reported at 2 weeks and 2 months follow-up and those reported between 3 and 4 months follow-up. For standardisation only studies that reported HWES as a percentage point

of those with optimal HWES (i.e. 6 out of 6 on a 6 point scale) were included in the data shown (8 out of 9 studies) and all were deemed eligible for inclusion at NMA.

Four studies reported cosmesis by HWES at a follow-up point between 2 weeks and 2 months.[24,27,29,30] A total of 594 patients had HWES reported for their port site wounds which were closed by either LB, OCA, ID and TC. 90.91 % (540/594) reported to have optimal wound cosmesis by this grading system. Wounds closed by LB had the highest optimal cosmesis rate at 98.9 % (176/178). When comparing closure methods individually there was no difference between closure method, however at NMA, LB was shown to be the most favourable closure method compare individual comparison of closure methods ID was shown to be associated with reduced patient satisfaction compared to LB.

Four studies reported cosmesis as a percentage of those who had wounds graded as optimal via HWES at 3–4 months follow-up.[25,31,33,38] 1619 patients had their wounds graded by HWES at 3–4 months postoperatively, with 90.18 % (1460/1619) being adjudged to have wounds with optimal cosmesis. When subdivided based on closure method, optimal wound closure was adjudged for (559/583), (507/520), (55/56), (122/157), (125/164) and (92/139) of patients with wound closure with OCA, LB, LS, ID, TC and APT respectively. At NMA, LS showed a statistically favourable cosmesis compared to other methods. Data on cosmestic outcomes as graded by HWES and study data summaries and forest plots denoting cosmetic outcomes are available in Supplementary Table 3 and Supplementary Fig. 2 (Supplementary Fig. 2A and 2B) respectively.

4. Discussion

Given the surgical paradigm trend towards MIS, the current body of literature offers a relative paucity of definitive guidance for optimal mode of closure of surgical sites after MIS. To the knowledge of the authors, this study is the first of its kind to incorporate four distinct closure methods, namely sutures, tissue glue, adhesive paper tape and stapled closure, for integration and analysis via NMA. Additionally, this study draws data from RCTs alone which facilitates for more meaningful observations to be drawn with a lower associated risk of the biases inherently present in observational studies. In addition, the trials included span centres across 5 different continents, integrating a vast array of treatment settings and clinical practices into our study and allowing for a holistic review of port site closure in the modern day management paradigm.

Prior to making deductions based on these data, it must be borne in mind that factors dictating elected means of wound closure in MIS include surgical setting vis a vis elective versus emergency setting, patient factors, and co-morbidities, with sparse evidence to support any suggested modality. In this study, no significant difference was observed between closure methods in terms of overall complications, infection, dehiscence or post-operative pain. In terms of wound dehiscence, tissue adhesives and APT seemingly trended towards a poorer outcome, though failing to present statistical significance, with higher risk of dehiscence per site at NMA according to our analysis for LB, OCA and APT. Dehiscence rates per patient demonstrated less of an overall discrepancy compared to dehiscence per site however a similar trend emerged for LB at NMA, whereby this method of closure had the highest risk of dehiscence compared to alternatives included in the analysis (OR = 4.43). These results support the authors *a priori* deduction, given the increased propensity rates for wound dehiscence development following use of tissue adhesives in previous literature,[3] results which are in keeping with the data presented in this study. Notably, the three studies with mean wound length >10 mm were responsible for 12 of the 45 overall episodes of dehiscence per patient,[20,24,34] all of which directly compared ID and OCA. These are important nuances which should be considered and translated in contemporary surgical practice following MIS.

Cosmesis was assessed at a number of follow-up timepoints by two separate validated and standardised clinical scales.[14,15] While there was no cosmetic difference between closure methods at 1–3 months postoperatively VAS, scar cosmesis in the early postoperative period was adjudged subjectively by recipients to be favourable for LB compared to other methods (HWES, 2 weeks to 2 months), albeit the data pertaining to cosmesis by HWES for LB was drawn from a sole study,[31] thus limiting its robustness. At a later postoperative timepoint (3 months follow-up and thereafter), LS was deciphered to confer a superior long-term outcome by HWES. It is noteworthy that findings were drawn on the adhesive from a study[25] that received funding from a company that is a producer of LS (BSN (Hamburg, Germany)). Nevertheless, excluding LS, there was no significant difference between closure methods at this timepoint. Interestingly, sutures performed poorly in our analysis of wound cosmesis. ID appeared to be inferior to its counterparts by HWES at greater than 3 months postoperatively. This contradicts current evidence which suggests that ID is superior to alternative methods in terms of cosmetic outcomes for patients.[39] Additionally, and surprisingly, it contradicts recent findings from a multicentre RCT performed by the current authors which identified ID as a superior mode for laparoscopic port site closure when utilising cosmesis as a primary outcome.[11]

This study is not without limitations. Firstly, while the inclusion of data on port site closure methods used in isolation allowed for direct comparisons in this review, combined closure techniques are often employed in contemporary surgical practice. Secondly, while it is interesting that adhesive was identified to have optimal cosmetic outcomes relative to counterparts at both early and late postoperative timepoints by HWES, it is noteworthy that results integrated into NMA are drawn from a sole study in the case of both LB and LS.[25,31] Thirdly, standardising data collated from multiple studies is a challenge inherently present for almost any systematic review, particularly for frequency of complications in this case. This challenge was confounded by discrepancy in wound complication definitions, such as wound infection and various pain scales and time intervals, lending itself to unavoidable inter-study discrepancies. Additionally, while eighteen out of nineteen included studies scored at least three points out of a maximum of five on risk of bias assessment, lack of blinding or incomplete masking was evident in some included studies. Finally, our study integrated data on multiple forms of MIS, including one study[32] which detailed VATS wound sites, which are inherently different to the MIS port sites used in abdominal and pelvic surgery. Notwithstanding such egregious issues, the scales employed for cosmesis analysis in our review provide reliability in standardisation across studies and it may be true that observations drawn in this setting are more well-founded than those without standardisation.

In conclusion, our study found no significant difference between closure methods in terms of complications at NMA and superior cosmesis with adhesives. Consequently, our study validates the use of tissue adhesives for primary closure of port sites after MIS with caveats of high risk subjects such as those with elevated BMI and emergency operative setting to be considered when choosing the method of closure following MIS.

CRediT authorship contribution statement

E.P. Kerin: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **M.G. Davey:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **L. Bouz Mkabaah:** Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **N.E. Donlon:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

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Conflicts of interest to disclose

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2025.116542.

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