Suture choice to reduce occurrence of surgical site infection, hernia, wound dehiscence and sinus/fistula: a network meta-analysis

BE Zucker¹, C Simillis¹, P Tekkis^{1,2,5}, C Kontovounisios^{1,2,3}

¹Department of Colorectal Surgery, Chelsea and Westminster Hospital, London, UK

²Department of Colorectal Surgery, Royal Marsden Hospital, London, UK

³Department of Surgery and Cancer, Imperial College, London, UK

ABSTRACT

BACKGROUND There are many options and little guiding evidence when choosing suture types with which to close the abdominal wall fascia. This network meta-analysis investigated the effect of suture materials on surgical site infection, hernia, wound dehiscence and sinus/fistula occurrence after abdominal surgery. The aim was to provide clarity on whether previous recommendations on suture choice could be followed with confidence.

METHODS AND METHODS In February 2017, the Cochrane Central Register of Controlled Trials, Medline, EMBASE and Science Citation Index Expanded were searched for randomised controlled trials investigating the effect of suture choice on these four complications in closing the abdomen. A reference search of identified trials was performed. Prisma guidelines and the Cochrane risk of bias tool were followed in the data extraction and synthesis. Two review authors screened titles and abstracts of trials identified. A random effect model was used for the surgical site infection network based on the deviance information criterion statistics.

RESULTS Thirty-one trials were included (11,533 participants). No suture material reached the predetermined 90% probability threshold for determination of 'best treatment' for any outcome. Pairwise comparisons largely showed no differences between suture types for all outcomes measured. However, nylon demonstrated a reduction in the occurrence of incisional hernias with respect to two commonly used absorbable sutures: polyglycolic acid (odds ratio, OR 1.91; 95% confidence interval, CI, 1.01–3.63) and polyglyconate (OR 2.18; 95% CI 1.17–4.07).

CONCLUSIONS No suture type can be considered the 'best treatment' for the prevention of surgical site infection, hernia, wound dehiscence and sinus/fistula occurrence.

KEYWORDS

Surgical site infection – Wound dehiscence – Abdominal wall closure – Suture choice

Accepted 13 August 2018

CORRESPONDENCE TO

Paris Tekkis, E: p.tekkis@imperial.ac.uk

Introduction

Complications of abdominal wall closure are common and include surgical site infection, wound dehiscence, incision site hernias and sinus formation.¹ Despite the frequency and severity of the sequelae of closing the abdominal wall, many aspects of the procedure reflect a surgeon's personal preference,² with little guiding evidence. This is particularly true of the choice of which sutures to use in abdominal wall closure. The premise that the wound will never regain the same strength as prior to surgery buoys the use of non-absorbable sutures. Despite this, the use of absorbable sutures (which are typically absorbed within 70–180 days)³ is sustained by reports that sutures do not help with wound healing after 6 weeks.⁴ Even within the groups of absorbable and non-

absorbable sutures, there are many options, with manufacturers often citing small differences between them as sufficient to guide choice.

Many factors that determine a patient's propensity to have complications following abdominal wall closure are patient related, such as obesity, age and diabetes, immunosuppression and smoking. However, the optimisation of surgical technique provides a significant opportunity to relieve patients and healthcare providers of the potentially significant sequelae of abdominal wall closure.⁵

The aim of this study was to perform a systematic review of the literature to identify the sutures used for closure of the abdominal wall and to carry out a network meta-analysis to compare the effectiveness of these sutures. Thirty-one studies (summarised in Table 1) were identified that were appropriate in their question and

Table 1

Author	Country	Incision	Condition	Suture type ^a and patients (n)			Surgical site infection (n)			Dehiscence (n)			Hernia (n)			Sinus/fistula (n)			
				Group	A	B	C	Group	A	B	C	Group	A	B	C	Group	A	B	C
Agrawal (2009)	India	Laparotomy	Peritonitis	3 (87)	2 (87)			31	30			20	21			10 (/76)	7/75	0	8
Pandey (2013)	India	Midline laparotomy	Var.	3 (100)	2 (100)					17	6								
Talpur (2011)	Pakistan	ns	ns	3 (136)	2 (138)			9	8	2	3	1	6					1	5
Irvin (1976)	UK	Median or paramedian laparotomy	ns	3 (52)	2 (57)	5 (52)		4	8	5	0	2	3	3		2	0	3	0
Seiler (2009)	Germany	Midline laparotomy	ns	3 (210)	1 (415)			26	72			28	37						
Wissing (1987)	Netherlands	Laparotomy	Var.	3 (379)	1 (370)	4 (377)		34	43	27	6	13	8	60	37	31	4	11	23
Hsiao (2000)	Taiwan	Laparotomy	Var.	3 (184)	1 (156)			9	5			7	3						
Leaper (1985)	UK?	Laparotomy	ns	4 (97)	1 (107)			9	18	0	1	0	1						
Israelsson (1994)	Sweden/Iceland	Midline laparotomy	Var.	4 (408)	1 (405)			35	38	3	2	50/318	49/325			1	1		
Singal (2016)	India	Midline laparotomy	Peritonitis	4 (30)	1 (30)			1	0	8	7	0	0			1	0		
Baracs (2011)	Hungary	Laparotomy	Colorectal	8 (188)	1 (197)			23	24										
Diener (2014)	Germany	Midline laparotomy	Var.	8 (587)	1 (598)			87	96	66	81								
Justinger (2013)	Germany?	Laparotomy	Var.	8 (485)	1 (371)			31	42										
Nakamura (2013)	Japan	Laparotomy	Colorectal	7 (206)	3 (204)			9	19										
Rasić (2011)	Croatia	Laparotomy	Colorectal	7 (91)	3 (94)			4	12	1	7	2	5						
Ruiz-Tovar (2017)	Spain	Laparotomy	Peritonitis	7 (51)	3 (50)			18	5										
Khan (2009)	Pakistan	Laparotomy	Var.	1 (50)	2 (50)			8	12	1	2	2	4			1	8		
Mohan (2015)	India	Laparotomy	Var.	1 (25)	2 (25)			3	4	0	1					1	3		
Krukowski (1987)		Midline laparotomy	Var.	1 (374)	2 (383)			13	27	1	1	1	3			0	1		
Cameron (1987)	UK	Midline laparotomy	ns	1 (143)	2 (141)			12	21	1	9	10	11			0	1		
Bloemen (2011)	Netherlands	Midline laparotomy	ns	1 (233)	2 (223)			18	14	18	9	58	45			5	3		
Berretta (2010)	Italy	Midline laparotomy	Gynae. cancer	1 (63)	2 (63)	9 (65)		1	3	1	4	8	5	4	6	7			
Brolin (1996)	USA	Laparotomy	Bariatric	1 (120)	9 (109)			0	0	0	2	11	20						
Cameron (1980)		Paramedian laparotomy	ns	2 (167)	5 (180)			13	19	1	1	7	8						
Osther (1995)	Denmark	Laparotomy	ns	5 (100)	6 (104)			16	7	7	6	11/70	7/67						
Carlson (1995)	USA	Midline laparotomy	Var.	4 (112)	6 (113)			4	2	3	0	4				1	0		

Sahlin (1993)	Sweden	Laparotomy	Var.	6 (345)	3 (339)	35	37	4	3	28	0	0
Leaper (1977)		Laparotomy	ns	4 (116)	5 (121)	10 (120)		1	1	0	5/96	8/100
Pollock (1979)	UK	Laparotomy	Var.	4 (99)	5 (99)	10 (96)	33	27	26	0	0	6/74
Ohira (2015)	Japan	Laparotomy	Gastric or colon cancer	12 (28)	1 (27)			2	0	3	3	11/83
Orr (2002)	USA	Laparotomy	ns	11 (104)	2 (97)	8	6	4	10	1	2	

gynaec., gynaecological; ns, not specified; var., various.
^a 1 = polydioxanone; 2 = polypropylene; 3 = polyglactin; 4 = nylon; 5 = polyglycolic acid; 6 = polyglyconate; 7 = triclosan-coated polyglactin; 8 = triclosan-coated polydioxanone; 9 = Ethibond®, 10 = steel; 11 = poly(L-lactide-co-glycolide); 12 = Polysorb®.

quality. These included studies investigating polyglactin,^{1,4,6–14} polydioxanone (PDS),^{5,15–27} polypropylene,^{28,29} nylon,^{30–32} polyglycolic acid (PGA),³³ polyglyconate, triclosan-coated polyglactin, triclosan-coated polydioxanone, Ethibond®, steel, poly(L-lactide-co-glycolide) (PLG) and Polysorb®.

Materials and methods

Search strategy

A comprehensive literature search was undertaken in MEDLINE, EMBASE, Science Citation Index Expanded and the Cochrane Central Register of Controlled Trials. All studies and citations identified were reviewed. A reference search of identified trials was also conducted. No restrictions were made based on language, publication year or publication status. The latest date for this search was February 2017. Details of the search strategy are provided in Table 2.

Inclusion and exclusion criteria

Only randomised controlled trials (RCTs) were considered for this network meta-analysis. Studies reporting on both elective and emergency abdominal surgeries were included. Studies discussing on both midline and non-midline incisions were included. Surgical specialty was not used to restrict trial inclusion. Surgeries of the inguinal area were not included.

Outcomes of interest

The various suture types used to close the abdomen were assessed for the following outcomes: sinus or fistula formation; occurrence of surgical site infection; wound dehiscence and incision site hernia.

Data collection

The titles and abstracts of the trials for inclusion were screened independently by two authors. One of the authors screened the full text of all trials identified for potential inclusion. The following data were extracted from each study: author, year of publication, language of publication, country, inclusion and exclusion criteria, sample size, participant characteristics, study design, including details of the surgical interventions, outcomes and risk of bias.

The senior author made all final decisions that arose as a result of discrepancy between author decisions. The Cochrane Collaboration's risk of bias tool was used to assess the included trials based on the following domains: allocation sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessors, incomplete outcome data and selective outcome reporting.³⁴ The presence of a vested interest bias in the studies was also assessed.

Statistical analysis

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses Group guidelines were used for the

Table 2 Detailed search strategy

Database	Search strategy
Cochrane Central Register of Controlled Trials	Abdominal wound closure
Medline (PubMed)	Abdominal wound closure AND ((randomized controlled trial [pt] OR controlled clinical trial [pt] OR randomized [tiab] OR placebo [tiab] OR drug therapy [sh] OR randomly [tiab] OR trial [tiab] OR groups [tiab]) NOT (animals [mh] NOT humans [mh]))
EMBASE (Ovid SP)	1 (Abdominal wound closure).af 2 (exp crossover-procedure/ or exp double-blind procedure/ or exp randomized controlled trial/ or exp single-blind procedure/).af 3 (random* OR factorial* OR crossover* OR cross over* OR cross-over* OR placebo* OR double* adj blind* OR single* adj blind* OR assign* OR allocat* OR volunteer*).af 4 2 OR 3 5 1 AND 4
Science Citation Index Expanded	1 TS=(abdominal wall closure) 2 TS=(random* OR rct* OR crossover OR masked OR blind* OR placebo* OR meta-analysis OR systematic review* OR meta-analys*) 3 1 AND 2

literature review and meta-analysis. Stata/IC 11 was used to devise a network plot of all the treatments assessed for that specific outcome. Any treatment not connected to the other treatments through the network plot were excluded from the analysis of that outcome. A Bayesian network meta-analysis was conducted using the Markov chain Monte Carlo method in WinBUGS 1.4 (MRC Biostatistics Unit, Cambridge, and Imperial College School of Medicine).

Between-study heterogeneity was assessed using deviance information criterion (DIC) and the residual deviance, in accordance with guidance from the National Institute for Health and Care Excellence Decision Support Unit documents.⁵⁵ Three different models were run for each outcome: fixed-effect, random-effects and random-effects inconsistency. Model fit was determined by the DIC, a measure that penalises complexity. Lower DICs were therefore used to determine model choice, as they indicated better-fitting models.⁵⁵ The random effects model, which assumes variation between studies owing to heterogeneity and generates a wider confidence interval, was used if it resulted in a better model fit as indicated by a DIC lower than that of a fixed effect model by at least 355. In other cases, the fixed effect model (a simpler model) was used. In addition, the consistency and inconsistency models were compared using the DIC and, if the inconsistency model resulted in a better model fit than the consistency model, the results of the network meta-analysis were interpreted with caution.⁵⁶

The probability of ranking of a treatment for each outcome of interest was calculated. A threshold of 90% probability was considered by the authors to be sufficient to confidently report that treatment as 'best' for that outcome.⁵⁷

Results

Eligible studies

A total of 1263 references were identified through electronic searches of the Cochrane Central Register of Controlled Trials (353), Medline (576), EMBASE (18) and Science Citation Index Expanded (316); 363 duplicates between databases were excluded. Title and abstract screening resulted in a further 838 irrelevant references being excluded. The remaining 62 articles were assessed for eligibility and 31 met the inclusion criteria (Fig 1).^{1,4-33} A total of 11,533 participants were included in the analysis. The risk of bias in the included trials is summarised in Figure 2.

Suture types compared

The following suture types were identified for abdominal wall closure: polyglactin, PDS, polypropylene, nylon, PGA, polyglyconate, triclosan-coated polyglactin, triclosan-coated polydioxanone, Ethibond, steel, PLG and Polysorb.

The results of all pairwise comparisons of the various suture types for the outcomes of interest are shown in Table 3. The surgical treatments with the highest probability of ranking from best to worst (first to twelfth) for the outcomes of interest are summarised in Table 4. Figure 3 shows an example of a network plot; similar plots were created for all outcomes of interest.

Surgical site infection

A total of 28 trials provided data on 10,921 participants and 11 suture types for the network meta-analysis on surgical site infection. The random effects model was preferred, based on the DIC statistics. No suture type reached the predetermined threshold of 90% probability of being the best treatment. Pairwise comparison revealed no differences in the occurrence of SSI as a result of suture material used.

Wound dehiscence

A total of 25 trials provided data on 8816 participants and all 12 suture types for the network meta-analysis on wound dehiscence. The fixed effects model was preferred. No

suture type reached the predetermined threshold of 90% probability of being the best treatment. Pairwise comparison revealed that triclosan-coated polyglactin sutures to be significantly more effective than Polysorb sutures in preventing abdominal wound dehiscence.

Hernia formation

A total of 24 trials provided data on 7658 participants and 11 suture types for the network meta-analysis on hernia formation. The fixed effects model was preferred. No suture type reached the predetermined threshold of 90% probability of being the best treatment. Pairwise comparison showed that PDS sutures were more effective than Polyglactin and Ethibond sutures at preventing hernia occurrence post-operatively. Furthermore, nylon sutures proved more effective than polyglycolic acid, polyglyconate and Ethibond sutures at preventing hernia formation postoperatively.

Sinus/fistula formation

A total of 15 trials provided data on 5815 participants and 7 suture types for the network meta-analysis on sinus/fistula formation. The fixed effects model was preferred. No suture type reached the predetermined threshold of 90% probability of being the best treatment. Pairwise comparison revealed that PDS sutures proved more effective than nylon sutures and polyglactin sutures proved more effective than PDS, polypropylene, nylon and steel sutures at preventing sinus/fistula formation.

Discussion

This network meta-analysis allowed simultaneous comparison of multiple suture types used to close the abdominal wall. This is an important benefit over traditional meta-analyses where only two suture types can be compared directly. Suture types have previously been compared with one another in head-to-head comparisons, with similar outcomes. Network meta-analyses, however, enable comparisons of interventions that have, as of yet, not been compared head to head. The inclusion of indirect

Table 3a Results of pairwise comparisons: surgical site infection.											
	PDS	Polypropylene	Polyglactin	Nylon	Polyglycolic acid	Polyglyconate	Triclosan-coated polyglactin	Triclosan-coated PDS	Ethibond	Steel	PLG
PDS	-	OR 1.22 CI 0.75-1.98	OR 0.92 CI 0.54-1.56	OR 0.87 CI 0.49-1.56	OR 1.11 CI 0.52-2.37	OR 0.6 CI 0.24-1.47	OR 0.79 CI 0.31-2.03	OR 0.9 CI 0.48-1.68	OR 0.34 CI 0.02-6.42	OR 0.84 CI 0.27-2.65	OR 1.57 CI 0.33-7.54
Polypropylene	-	-	OR 0.75 CI 0.37-1.55	OR 0.72 CI 0.34-1.53	OR 0.91 CI 0.37-2.25	OR 0.49; CI 0.18-1.37	OR 0.65 CI 0.22-1.88	OR 0.74 CI 0.33-1.63	OR 0.28 CI 0.01-5.49	OR 0.69 CI 0.2-2.41	OR 1.29 CI 0.25-6.67
Polyglactin	-	-	-	OR 0.95 CI 0.43-2.09	OR 1.21 CI 0.48-3.06	OR 0.65; CI 0.23-1.86	OR 0.86 CI 0.29-2.55	OR 0.98 CI 0.43-2.22	OR 0.37 CI 0.02-7.35	OR 0.92 CI 0.26-3.25	OR 1.71 CI 0.33-8.98
Nylon	-	-	-	-	OR 1.27 CI 0.49-3.3	OR 0.68; CI 0.23-2	OR 0.9 CI 0.3-2.74	OR 1.02 CI 0.44-2.41	OR 0.39 CI 0.02-7.77	OR 0.96 CI 0.27-3.48	OR 1.79 CI 0.34-9.57
Polyglycolic acid	-	-	-	-	-	OR 0.54; CI 0.17-1.75	OR 0.71 CI 0.21-2.39	OR 0.81 CI 0.3-2.16	OR 0.31 CI 0.01-6.36	OR 0.76 CI 0.19-3	OR 1.41 CI 0.25-8.07
Polyglyconate	-	-	-	-	-	-	OR 1.32 CI 0.36-4.88	OR 1.5 CI 0.5-4.5	OR 0.57 CI 0.03-12.3	OR 1.41 CI 0.33-6.06	OR 2.62 CI 0.43-16.05
Triclosan-coated polyglactin	-	-	-	-	-	-	-	OR 1.13 CI 0.36-3.52	OR 0.43 CI 0.02-9.42	OR 1.06 CI 0.24-4.71	OR 1.98 CI 0.32-12.41
Triclosan-coated PDS	-	-	-	-	-	-	-	-	OR 0.38 CI 0.02-7.66	OR 0.94 CI 0.25-3.48	OR 1.75 CI 0.32-9.51
Ethibond	-	-	-	-	-	-	-	-	-	OR 2.46 CI 0.11-57.56	OR 4.59 CI 0.16-128.08
Steel	-	-	-	-	-	-	-	-	-	-	OR 1.86 CI 0.27-13.05
CI, 95% confidence interval; OR, odds ratio; PDS, polydioxanone; PLG, poly(L-lactide-co-glycolide).											

Table 3b Results of pairwise comparisons: sinus formation (significant results shaded).

	PDS	Polypropylene	Nylon	Polyglactin	Polyglycolic acid	Polyglyconate	Steel
PDS	–	OR 2.67 CI 1.15–6.22	OR 2.13 CI 1.07–4.24	OR 0.27 CI 0.1–0.76	OR 0.07 CI 0–5.8	OR 0.08 CI 0–11.65	OR 7.02 CI 0.98–50.14
Polypropylene	–	–	OR 0.8 CI 0.27–2.37	OR 0.1 CI 0.03–0.38	OR 0.03 CI 0–2.35	OR 0.03 CI 0–4.68	OR 2.63 CI 0.31–22.34
Nylon	–	–	–	OR 0.13 CI 0.04–0.44	OR 0.03 CI 0–2.87	OR 0.04 CI 0–5.74	OR 3.3 CI 0.41–26.5
Polyglactin	–	–	–	–	OR 0.25 CI 0–24.22	OR 0.31 CI 0–48.08	OR 26.05 CI 2.83–240.06
Polyglycolic acid	–	–	–	–	–	OR 1.21 CI 0–934.7	OR 102.82 CI 0.8–13226.68
Polyglyconate	–	–	–	–	–	–	OR 84.86 CI 0.41–17401.89

CI, 95% confidence interval; OR, odds ratio; PDS, polydioxanone.

comparisons across trials may increase the power with respect to simple direct comparisons, such as in standard pairwise meta-analyses.³⁸ A network meta-analysis may also yield more reliable and definitive results, allowing visualisation and interpretation of a wider picture of the available evidence and enabling calculation of treatment rankings with probabilities.^{39,40}

Only RCTs reporting on closure of the abdominal wall were considered for this network meta-analysis. Only RCTs were selected to minimise the level of bias of included studies. Despite having to exclude important studies because of non-randomisation, conducting analysis comparing studies of different designs would be inappropriate. The authors acknowledge that a limitation of the methodology of network meta-analyses is the fact that the strength of the results is determined by the amount of evidence that a treatment carries and the number of comparisons available between treatments. Substantial discrepancies in the strength of the comparisons may affect the reliability of the network and result in inappropriate inferences. Further sources of limitations to the present network meta-analysis include both inter- and intra-RCT heterogeneity. Examples of inter-RCT heterogeneity include differences in operating technique (mass vs layered closure), suturing technique (interrupted vs continuous) and operation type. Individual RCTs included various procedures and degrees of contamination which may increase the heterogeneity of the results. Moreover, many of the studies had inclusion criteria that enabled the inclusion of a patient group with significant heterogeneity.

The rate of postoperative surgical site infection remains high at 3–20%, making it the most important early postoperative complication of midline laparotomy (incisional hernia is reported at 15% after open abdominal surgery, wound dehiscence at 0.5–3.4% and wound sinus at between 0–3.5%).^{3,27,41,42} Reports that fewer colony forming units of bacteria are required to produce surgical site infection in the presence of suture material date back to 1957.⁴³ It is as a result of this understanding that triclosan-coated sutures were developed, with the expectation that

asepsis may reduce the number of colony forming units able to grow. This has been a finding that has been substantiated by a number of individual RCTs.^{12,22} However, our meta-analysis found no significant differences between any sutures used for closing the abdominal wall on the occurrence of surgical site infection, including triclosan-coated sutures. This result has been supported by other meta-analyses, showing that even accounting for other factors such as suturing and closure technique does not have an effect on wound infection rates.⁴⁴ However, triclosan-coated sutures performed better than Polysorb sutures for the prevention of wound dehiscence. As subclinical infections are a risk factor for wound dehiscence, it is possible that it is through preventing these infections that triclosan-coated sutures may have an effect in preventing wound dehiscence.

Previous reports have led to debate as to whether incisional site hernia is most effectively avoided using nonabsorbable sutures or those that are absorbable.^{45,46} The use of nonabsorbable sutures is supported by the argument that absorbable sutures may leave the wound unsupported before it has sufficiently regained its intrinsic strength.⁴⁶ This meta-analysis seems, in contrast to other meta-analyses,⁴⁴ to support this point of view as use of nylon, a non-absorbable suture monofilament, demonstrated a reduction in the occurrence of incisional hernias with respect to two commonly used absorbable sutures: polyglycolic acid and polyglyconate.

The results of the pairwise analysis, similarly to RCTs, indicate that the suture materials are not equivalent in reducing the occurrence of the measured outcomes. However, the network meta-analysis suggests that there is insufficient evidence to recommend any individual suture material as the 'best choice' for reducing any of the outcomes measured. This is particularly pertinent considering the potential impact that recommendation of the 'best' suture may have. Surgical site infections, for example, cause significant patient morbidity as well as substantial health-care costs, with the National Institute for Health and Care

Table 3c Results of pairwise comparisons: hernia formation (significant results shaded).										
	PDS	Polypropylene	Polyglactin	Nylon	Polyglycolic acid	Ethibond	Steel	PLG	Polysorb	Triclosan-coated polyglactin
PDS	-	OR 1.1 CI 0.8–1.53	OR 1.6 CI 1.2–2.13	OR 0.77 CI 0.57–1.04	OR 1.47 CI 0.84–2.58	OR 1.68 CI 0.98–2.89	OR 1.92 CI 1.03–3.57	OR 0.99 CI 0.45–2.18	OR 0.38 CI 0.02–7.56	OR 0.96 CI 0.16–5.92
Polypropylene	-	-	OR 1.45 CI 0.94–2.23	OR 0.7 CI 0.45–1.09	OR 1.33 CI 0.7–2.55	OR 1.52 CI 0.81–2.86	OR 1.74 CI 0.86–3.51	OR 0.9 CI 0.38–2.11	OR 0.34 CI 0.02–6.97	OR 0.87 CI 0.14–5.52
Polyglactin	-	-	-	OR 0.48 CI 0.32–0.73	OR 0.92 CI 0.49–1.73	OR 1.05 CI 0.57–1.94	OR 1.2 CI 0.61–2.39	OR 0.62 CI 0.27–1.44	OR 0.24 CI 0.01–4.8	OR 0.6 CI 0.1–3.79
Nylon	-	-	-	-	OR 1.91 CI 1.01–3.63	OR 2.18 CI 1.17–4.07	OR 2.5 CI 1.25–4.99	OR 1.29 CI 0.56–3.01	OR 0.49 CI 0.02–9.99	OR 1.25 CI 0.2–7.9
Polyglycolic acid	-	-	-	-	-	OR 1.14 CI 0.52–2.49	OR 1.31 CI 0.57–3.02	OR 0.68 CI 0.26–1.78	OR 0.26 CI 0.01–5.42	OR 0.65 CI 0.1–4.38
Polyglyconate	-	-	-	-	-	-	OR 1.15 CI 0.5–2.61	OR 0.59 CI 0.23–1.54	OR 0.22 CI 0.01–4.73	OR 0.57 CI 0.09–3.82
Ethibond	-	-	-	-	-	-	-	OR 0.52 CI 0.19–1.41	OR 0.2 CI 0.01–4.19	OR 0.5 CI 0.07–3.41
Steel	-	-	-	-	-	-	-	-	OR 0.38 CI 0.02–8.42	OR 0.96 CI 0.13–7
PLG	-	-	-	-	-	-	-	-	-	OR 1.44 CI 0.04–49.15
Polysorb	-	-	-	-	-	-	-	-	-	OR 0.56 CI 0.04–7.66

CI, 95% confidence interval; OR, odds ratio; PDS, polydioxanone; PLG, poly(L-lactide-co-glycolide).

Table 3d Results of pairwise comparisons: dehiscence (significant results shaded).												
	PDS	Polypropylene	Polyglactin	Nylon	Polyglycolic acid	Polyglyconate	Ethibond	Steel	Triclosan-coated polyglactin	Triclosan-coated PDS	PLG	Polysorb
PDS	-	OR 1.05 CI 0.65-1.71	OR 0.7 CI 0.38-1.28	OR 0.98 CI 0.54-1.8	OR 1.06 CI 0.37-3.08	OR 0.68 CI 0.23-2.03	OR 1.08 CI 0.4-2.92	OR 0.33 CI 0.02-5.55	OR 0.06 CI 0-0.89	OR 0.81 CI 0.57-1.14	OR 0.34 CI 0.09-1.3	OR 15.35 CI 0.15-1539.11
Polypropylene	-	-	OR 0.66 CI 0.31-1.43	OR 0.93 CI 0.43-2.02	OR 1.01 CI 0.31-3.25	OR 0.64 CI 0.19-2.14	OR 1.02 CI 0.34-3.09	OR 0.32 CI 0.02-5.49	OR 0.06 CI 0-0.88	OR 0.77 CI 0.42-1.39	OR 0.32 CI 0.08-1.35	OR 14.57 CI 0.14-1497.85
Polyglactin	-	-	-	OR 1.41 CI 0.6-3.3	OR 1.52 CI 0.45-5.18	OR 0.97 CI 0.28-3.4	OR 1.54 CI 0.48-4.94	OR 0.48 CI 0.03-8.48	OR 0.08 CI 0.01-1.36	OR 1.16 CI 0.58-2.32	OR 0.48 CI 0.11-2.12	OR 21.97 CI 0.21-2292.01
Nylon	-	-	-	-	OR 1.08 CI 0.32-3.68	OR 0.69 CI 0.2-2.42	OR 1.09 CI 0.34-3.51	OR 0.34 CI 0.02-6.03	OR 0.06 CI 0-0.97	OR 0.82 CI 0.41-1.65	OR 0.34 CI 0.08-1.51	OR 15.63 CI 0.15-1629.86
Polyglycolic acid	-	-	-	-	-	OR 0.64 CI 0.14-2.94	OR 1.01 CI 0.24-4.35	OR 0.31 CI 0.02-6.35	OR 0.05 CI 0-1.03	OR 0.76 CI 0.25-2.33	OR 0.32 CI 0.06-1.78	OR 14.43 CI 0.13-1633.85
Polyglyconate	-	-	-	-	-	-	OR 1.58 CI 0.36-6.97	OR 0.49 CI 0.02-10.05	OR 0.09 CI 0-1.62	OR 1.19 CI 0.38-3.76	OR 0.5 CI 0.09-2.84	OR 22.6 CI 0.2-2577.18
Ethibond	-	-	-	-	-	-	-	OR 0.31 CI 0.02-6.13	OR 0.05 CI 0-0.99	OR 0.75 CI 0.26-2.16	OR 0.31 CI 0.06-1.69	OR 14.27 CI 0.13-1592.61
Steel	-	-	-	-	-	-	-	-	OR 0.17 CI 0-8.73	OR 2.41 CI 0.14-40.87	OR 1.01 CI 0.04-22.8	OR 45.83 CI 0.21-10112
Triclosan-coated polyglactin	-	-	-	-	-	-	-	-	-	OR 13.88 CI 0.88-217.57	OR 5.82 CI 0.28-122.29	OR 263.75 CI 1.24-55887.29
Triclosan-coated PDS	-	-	-	-	-	-	-	-	-	-	OR 0.42 CI 0.1-1.69	OR 19.01 CI 0.19-1931.41
PLG	-	-	-	-	-	-	-	-	-	-	-	OR 45.33 CI 0.37-5515.86
CI, 95% confidence interval; OR, odds ratio; PDS, polydioxanone; PLG, poly(L-lactide-co-glycolide).												

CI, 95% confidence interval; OR, odds ratio; PDS, polydioxanone; PLG, poly(L-lactide-co-glycolide).

Table 4a Probability for ranking sutures: 1–11 for surgical site infection.

Material	1	2	3	4	5	6	7	8	9	10	11
PDS	0.001317	0.01035	0.03325	0.07628	0.1249	0.1722	0.1977	0.1817	0.1264	0.05968	0.0162
Polypropylene	0.0003333	0.002217	0.008933	0.01998	0.03743	0.06413	0.1055	0.1675	0.2377	0.2623	0.09403
Polyglactin	0.003817	0.02778	0.08273	0.15	0.1769	0.1745	0.1456	0.1142	0.07575	0.03842	0.01028
Nylon	0.0155	0.06575	0.1281	0.162	0.1606	0.1416	0.1173	0.09038	0.06512	0.0394	0.01428
Polyglycolic acid	0.003767	0.01973	0.04817	0.07047	0.08727	0.0969	0.1072	0.1285	0.1613	0.1726	0.1041
Polyglyconate	0.194	0.311	0.1829	0.1033	0.06267	0.04367	0.0342	0.02695	0.0207	0.01432	0.006333
Triclosan-coated polyglactin	0.08052	0.1671	0.1618	0.1215	0.09265	0.07332	0.06802	0.06323	0.06032	0.06695	0.04453
Triclosan-coated PDS	0.03358	0.0949	0.1255	0.1235	0.1162	0.108	0.09848	0.09133	0.08595	0.07695	0.04552
Ethibond	0.5439	0.08432	0.04958	0.03432	0.02505	0.02343	0.02238	0.02565	0.03108	0.0591	0.1012
Steel	0.08725	0.1568	0.1287	0.09628	0.07918	0.06707	0.06527	0.067	0.07593	0.09487	0.08165
PLG	0.03607	0.06007	0.05025	0.04232	0.03715	0.03515	0.03835	0.04358	0.05982	0.1154	0.4818

PDS, polydioxanone; PLG, poly(L-lactide-co-glycolide).

Table 4b Probability for ranking sutures: 1–8 for sinus formation.

Material	1	2	3	4	5	6	7
PDS	0.0001167	0.01018	0.1724	0.7822	0.03335	0.001783	0.00001667
Polypropylene	0	0.00001667	0.001483	0.03363	0.3073	0.499	0.1585
Nylon	0	0.00003333	0.002217	0.06115	0.5671	0.3404	0.02908
Polyglactin	0.1002	0.4264	0.4706	0.002817	0.00005	0	0
Polyglycolic acid	0.4635	0.2974	0.184	0.04095	0.009933	0.003933	0.0002167
Polyglyconate	0.4362	0.2657	0.1663	0.05972	0.02493	0.0284	0.01868
Steel	0.00001667	0.0002333	0.002983	0.01953	0.05735	0.1264	0.7935

PDS, polydioxanone.

Table 4c Probability for ranking sutures: 1–11 for hernia formation.

Material	1	2	3	4	5	6	7	8	9	10	11
PDS	0.0009667	0.0188	0.1034	0.2613	0.322	0.2054	0.07175	0.01487	0.0016	0.00003333	0
Polypropylene	0.001283	0.01237	0.0505	0.133	0.2394	0.2737	0.1876	0.07463	0.02172	0.005283	0.0006
Polyglactin	0	0	0.0001	0.001217	0.00885	0.04587	0.1337	0.2502	0.2997	0.2029	0.0575
Nylon	0.0559	0.2452	0.381	0.2346	0.06775	0.01262	0.002767	0.0003167	0	0	0
Polyglycolic acid	0.0002667	0.0023	0.01073	0.02823	0.05692	0.1088	0.1852	0.2143	0.1715	0.1467	0.07507
Polyglyconate	0.0001167	0.0009167	0.0036	0.01162	0.02695	0.05673	0.1059	0.1668	0.2203	0.2376	0.1695
Ethibond	0.0002333	0.001233	0.003867	0.009383	0.01885	0.04103	0.0742	0.107	0.1403	0.233	0.3709
Steel	0.03363	0.1072	0.1577	0.1577	0.1335	0.1316	0.1176	0.06775	0.04477	0.03238	0.0162
PLG	0.4742	0.1634	0.0627	0.03803	0.03025	0.02785	0.02722	0.02305	0.02392	0.03595	0.09343
Polysorb	0.1329	0.1806	0.1207	0.067	0.05238	0.05383	0.05563	0.04925	0.04838	0.07145	0.168
Triclosan-coated polyglactin	0.3005	0.2681	0.1058	0.05798	0.04323	0.04267	0.03843	0.03175	0.02785	0.03477	0.0489

PDS, polydioxanone; PLG, poly(L-lactide-co-glycolide).

Table 4d Probability for ranking sutures: 1–12 for dehiscence.

Material	1	2	3	4	5	6	7	8	9	10	11	12
PDS	0.00003333	0.00005	0.002333	0.01475	0.04865	0.1062	0.1681	0.2143	0.2181	0.1601	0.06328	0.004133
Polypropylene	0	0.00003333	0.002517	0.01475	0.04413	0.08713	0.1368	0.1794	0.2006	0.2013	0.1219	0.0115
Polyglactin	0.0001833	0.02227	0.1268	0.2382	0.2314	0.1669	0.1012	0.0585	0.03328	0.01587	0.005	0.0004167
Nylon	0.0001333	0.00355	0.01935	0.05117	0.08828	0.1237	0.1448	0.1492	0.1525	0.1458	0.1086	0.01292
Polyglycolic acid	0.0001833	0.007617	0.03348	0.07345	0.09282	0.09323	0.08512	0.08178	0.1008	0.1581	0.2331	0.04027
Polyglyconate	0.005	0.07273	0.1845	0.2021	0.1311	0.0894	0.06737	0.06303	0.06563	0.06853	0.04402	0.006567
Ethibond	0.001183	0.01788	0.05312	0.0805	0.07623	0.07722	0.07517	0.07982	0.0966	0.133	0.2649	0.04438
Steel	0.1559	0.2834	0.162	0.0679	0.0447	0.03308	0.02797	0.02813	0.03315	0.04793	0.09203	0.02378
Triclosan-coated polyglactin	0.7643	0.1777	0.03883	0.008867	0.003867	0.002	0.00145	0.0009833	0.0008333	0.0005833	0.0005667	0.00001667
Triclosan-coated PDS	0.0003	0.01222	0.0699	0.1449	0.1795	0.1825	0.1625	0.1191	0.0738	0.03922	0.01522	0.0009667
PLG	0.07122	0.394	0.2935	0.08995	0.04965	0.0299	0.02072	0.016	0.01317	0.01127	0.009167	0.001467
Polysorb	0.001483	0.008583	0.0137	0.01348	0.009717	0.008717	0.00885	0.0098	0.01158	0.01832	0.04218	0.8536

PDS, polydioxanone; PLG, poly(L-lactide-co-glycolide).

Figure 3 An example network plot for surgical site infection. Similar plots were created for wound dehiscence, hernia formation and sinus formation. The size of the circle indicates the number of studies present that involved that suture material, while the line thickness indicates how many studies compared those two suture material directly.

Excellence estimating that each surgical site infection costs between £2,100 and £10,500.⁴⁷ The knowledge that the presence of sutures increases the likelihood of infection in a wound provides a clear opportunity to develop interventions to prevent this. Recent studies have investigated the use of sutureless closing of the abdomen;⁴⁸ however, this has yet to be proved to reduce post-surgical complications with regard to sutured closing of the abdomen in an RCT.

However, other interventions such as the use of different aseptics or antibiotics must be developed to reduce the occurrence of this preventable source of morbidity.

References

1. Talpur AA, Awan MS, Surhio AR. Closure of elective abdominal incisions with monofilament, non-absorbable suture material versus polyfilament absorbable suture material. *J Ayub Med Coll Abbottabad* 2011; **23**: 51–54.

2. Ceydeli A, Rucinski J, Wise L. Finding the best abdominal closure: an evidence-based review of the literature. *Curr Surg* 2005; **62**(2): 220–225.
3. Albertsmeier M, Seiler CM, Fischer L *et al.* Evaluation of the safety and efficacy of MonoMax® suture material for abdominal wall closure after primary midline laparotomy: a controlled prospective multicentre trial: ISSAAC (NCT005725079). *Langenbeck's Arch Surg* 2012; **397**: 363–371.
4. Agrawal V, Sharma N, Joshi MK, Minocha VR. Role of suture material and technique of closure in wound outcome following laparotomy for peritonitis. *Trop Gastroenterol* 2009; **30**: 237–240.
5. Berretta R, Rolla M, Patrelli TS *et al.* Randomised prospective study of abdominal wall closure in patients with gynaecological cancer. *Aust N Z J Obstet Gynaecol* 2010; **50**: 391–396.
6. Irvin TT, Koffman CG, Duthie HL. Layer closure of laparotomy wounds with absorbable and non-absorbable suture materials. *Br J Surg* 1976; **63**: 793–796.
7. Pandey S, Singh M, Singh K, Sandhu S. A prospective randomized study comparing non-absorbable polypropylene (Prolene®) and delayed absorbable polyglactin 910 (Vicryl®) suture material in mass closure of vertical laparotomy wounds. *Indian J Surg* 2013; **75**: 306–310.
8. Seiler CM, Bruckner T, Diener MK *et al.* Interrupted or continuous slowly absorbable sutures for closure of primary elective midline abdominal incisions: a multicenter randomized trial (INSECT: ISRCTN24023541). *Ann Surg* 2009; **249**: 576–582.
9. Wissing J, van Vroonhoven TJ, Schattenkerk ME *et al.* Fascia closure after midline laparotomy: results of a randomized trial. *Br J Surg* 1987; **74**: 738–741.
10. Hsiao WC, Young KC, Wang ST, Lin PW. Incisional hernia after laparotomy: prospective randomized comparison between early-absorbable and late-absorbable suture materials. *World J Surg* 2000; **24**: 747–752.
11. Sahlin S, Ahlberg J, Granström L, Ljungström KG. Monofilament versus multifilament absorbable sutures for abdominal closure. *Br J Surg* 1993; **80**: 322–324.
12. Nakamura T, Kashimura N, Noji T *et al.* Triclosan-coated sutures reduce the incidence of wound infections and the costs after colorectal surgery: a randomized controlled trial. *Surgery* 2013; **153**: 576–583.
13. Rasić Z, Schwarz D, Adam VN *et al.* Efficacy of antimicrobial triclosan-coated polyglactin 910 (Vicryl® Plus) suture for closure of the abdominal wall after colorectal surgery. *Coll Antropol* 2011; **35**: 439–443.
14. Ruiz-Tovar J, Alonso N, Morales V, Llaveró C. Association between triclosan-coated sutures for abdominal wall closure and incisional surgical site infection after open surgery in patients presenting with fecal peritonitis: a randomized clinical trial. *Surg Infect (Larchmt)* 2015; **16**: 588–594.
15. Khan NA, Almas D, Shehzad K *et al.* Comparison between delayed absorbable polydioxanone and non-absorbable (Prolene) suture material in abdominal wound closure Pakistan. *Pakistan Armed Forces Med J* 2009; **59**(1). www.pafmj.org/showdetails.php?id=232&t=o (cited August 2018)
16. Mohan SVS, Shushil Kumar BV *et al.* Comparison between delayed-absorbable polydioxanone (PDS) and non-absorbable (polypropylene) suture material in abdominal wound closure. *IOSR J Dent Med Sci* 2015; **14**: 2,279–2,861.
17. Krukowski ZH, Cusick EL, Engeset J, Matheson NA. Polydioxanone or polypropylene for closure of midline abdominal incisions: a prospective comparative clinical trial. *Br J Surg* 1987; **74**: 828–830.
18. Cameron AEP, Parker CJ, Field ES *et al.* A randomised comparison of polydioxanone (PDS) and polypropylene (Prolene®) for abdominal wound closure. *Ann R Coll Surg Engl* 1987; **69**: 113–115.
19. Bloemen A, Van Dooren P, Huizinga BF, Hoofwijk AGM. Randomized clinical trial comparing polypropylene or polydioxanone for midline abdominal wall closure. *Br J Surg* 2011; **98**: 633–639.
20. Brolin RE. Prospective, randomized evaluation of midline fascial closure in gastric bariatric operations. *Am J Surg* 1996; **172**: 328–331.
21. Ohira G, Kawahira H, Miyauchi H *et al.* Synthetic polyglycomer short-term absorbable sutures vs. polydioxanone long-term absorbable sutures for preventing incisional hernia and wound dehiscence after abdominal wall closure: a comparative randomized study of patients treated for gastric or colon. *Surg Today* 2015; **45**: 841–845.
22. Justinger C, Slotta JE, Ningel S *et al.* Surgical-site infection after abdominal wall closure with triclosan-impregnated polydioxanone sutures: results of a randomized clinical pathway facilitated trial (NCT00998907). *Surgery* 2013; **154**: 589–595.
23. Diener MK, Knebel P, Kieser M *et al.* Effectiveness of triclosan-coated PDS Plus versus uncoated PDS II sutures for prevention of surgical site infection after abdominal wall closure: the randomised controlled PROUD trial. *Lancet* 2014; **384**: 142–152.
24. Baracs J, Huszár O, Sajjadi SG, Horváth ÖP. Surgical site infections after abdominal closure in colorectal surgery using triclosan-coated absorbable suture (PDS Plus) vs. uncoated sutures (PDS II): a randomized multicenter study. *Surg Infect (Larchmt)* 2011; **12**: 483–489.
25. Leaper DJ, Allan A, May RE *et al.* Abdominal wound closure: a controlled trial of polyamide (nylon) and polydioxanone suture (PDS). *Ann R Coll Surg Engl* 1985; **67**: 273–275.
26. Israelsson LA, Jonsson T. Closure of midline laparotomy incisions with polydioxanone and nylon: the importance of suture technique. *Br J Surg* 1994; **81**: 1,606–1,608.
27. Singal R, Kumar M, Kaushik N, Dhar S. A comparative study of polydioxanone and nylon for abdominal wall closure with interrupted figure of eight in peritonitis cases. *J Curr Surg* 2016; **6**(3–4): 65–72.
28. Cameron AEP, Gray RCF, Talbot RW, Wyatt AP. Abdominal wound closure: a trial of Prolene and Dexon. *Br J Surg* 1980; **67**: 487–488.
29. Orr JW Jr, Montz FJ, Barter J *et al.* Continuous abdominal fascial closure: a randomized controlled trial of poly(L-lactide/glycolide). *Gynecol Oncol* 2003; **90**: 342–347.
30. Carlson MA, Condon RE. Polyglyconate (Maxon) versus nylon suture in midline abdominal incision closure: a prospective randomized trial. *Am Surg* 1995; **61**: 980–983.
31. Leaper DJ, Pollock AV, Evans M. Abdominal wound closure: a trial of nylon, polyglycolic acid and steel sutures. *Br J Surg* 1977; **64**: 603–606.
32. Pollock AV, Greenali MJ, Mary F, Ba E. Single-layer mass closure of major laparotomies by continuous suturing. *J R Soc Med* 1979; **72**: 1–5.
33. Ooster PJ, Gjøde P, Mortensen BB *et al.* Randomized comparison of polyglycolic acid and polyglyconate sutures for abdominal fascial closure after laparotomy in patients with suspected impaired wound healing. *Br J Surg* 1995; **82**: 1,080–1,082.
34. Cochrane Collaboration. Cochrane Methods Bias. Risk of Bias Tool. <https://methods.cochrane.org/bias/risk-bias-tool> (cited August 2018).
35. Dias S, Welton NJ, Sutton AJ, Ades AE. *NICE DSU Technical Support Document 2: A Generalised Linear Modelling Framework for Pairwise and Network Meta-analysis of Randomised Controlled Trials*. Sheffield: National Institute for Health and Care Excellence Decision Support Unit; 2011 (updated 2016).
36. Dias S, Welton NJ, Sutton AJ *et al.* *NICE DSU Technical Support Document 4: Inconsistency in Networks of Evidence Based on Randomised Controlled Trials*. Sheffield: National Institute for Health and Care Excellence Decision Support Unit; 2011 (updated 2014).
37. Dias S, Welton NJ, Sutton AJ, Ades AE. *NICE DSU Technical Support Document 1: Introduction to Evidence Synthesis for Decision Making*. Sheffield: National Institute for Health and Care Excellence Decision Support Unit; 2011 (updated 2012).
38. Mills EJ, Thorlund K, Ioannidis JP. Demystifying trial networks and network meta-analysis. *BMJ* 2013; **346**: f2914.
39. Jansen JP, Naci H. Is network meta-analysis as valid as standard pairwise meta-analysis? It all depends on the distribution of effect modifiers. *BMC Med* 2013; **11**: 159.
40. Mills EJ, Ioannidis JP, Thorlund K *et al.* How to use an article reporting a multiple treatment comparison meta-analysis. *JAMA* 2012; **308**: 1,246–1,253.
41. Andersen LPH, Klein M, Gögenur I, Rosenberg J. Long-term recurrence and complication rates after incisional hernia repair with the open onlay technique. *BMC Surg* 2009; **9**: 6.
42. Shanmugam VK, Fernandez S, Evans KK *et al.* Postoperative wound dehiscence: predictors and associations. *Wound Repair Regen* 2015; **23**(2): 184–190.
43. Elek SD, Conen PE. The virulence of *Staphylococcus pyogenes* for man: a study of the problem of wound infection. *Br J Exp Pathol* 1957; **38**: 573–579.
44. Diener MK, Voss S, Jensen K *et al.* Elective midline laparotomy closure: the INLINE systematic review and meta-analysis. *Ann Surg* 2010; **251**(5): 843–856.
45. Dobrin PB. Suture selection for hernia repair. In: Bendavid R, Abrahamson J, Arregui ME *et al.* (eds) *Abdominal Wall Hernias*. New York, NY: Springer; 2001. pp 237–245.
46. Patel SV, Paskar DD, Nelson RL *et al.* Closure methods for laparotomy incisions for preventing incisional hernias and other wound complications. *Cochrane Database Syst Rev* 2017; **11**: CD005661.
47. National Institute for Health and Care Excellence. *NICE Support for Commissioning for Surgical Site Infection*. Manchester: NICE; 2013.
48. Bruzoni M, Jaramillo JD, Dunlap JL *et al.* Sutureless vs sutured gastroschisis closure: a prospective randomized controlled trial. *J Am Coll Surg* 2017; **224** (6): 1,091–1,096.e1.