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Comparison of Interrupted Versus Continuous Closure in Abdominal Wound Repair: A Meta-analysis of 23 Trials

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OBJECTIVE: There is a lack of consensus among surgeons over interrupted versus continuous methods of abdominal wound closure. The objective of this study was to perform a meta-analysis to estimate the pooled odds ratio (OR) for dehiscence and incisional hernia in the interrupted technique of laparotomy wound closure as compared to the continuous technique.

METHODS: All randomized, controlled trials comparing continuous and interrupted methods of laparotomy wound closure, with burst abdomen and/or incisional hernia as the outcomes, were included in the meta-analysis. MEDLINE, Clinical Evidence and the Cochrane Library were searched. Burst abdomen and incisional hernia were the two primary outcomes.

RESULTS: Twenty-three studies were identified, with a total of 10,900 patients. The interrupted method of closure was associated with significantly less dehiscence as compared with the continuous method (OR, 0.576; $p = 0.014$; relative risk reduction, 39.8%; number needed to treat, 143). The interrupted technique was also found to be better in the *nonabsorbable suture*, *vertical incision* and *mass closure* subgroups. However, no difference in the hernia risk was found between the two methods.

CONCLUSION: Interrupted laparotomy wound closure reduces the odds of dehiscence by half compared with continuous wound closure. [*Asian J Surg* 2008;31(3):104–14]

Key Words: abdomen, meta-analysis, operative surgical procedures, surgical wound dehiscence, suture techniques

Introduction

The quest for the best closure technique for abdominal incisions continues. The surgeon's endeavour is to eliminate consequences of wound failure: wound dehiscence in the acute form, and incisional hernia as the late manifestation.

To achieve this goal, several modifications in opening the abdomen and closing the wound have been tried. There are many studies in the literature comparing various methods of wound closure, with conflicting results. Three meta-analyses of these studies have been performed, which have been successful in resolving many of the issues. However, there is still no consensus over continuous versus interrupted methods of wound closure, with one of the meta-analyses favouring the interrupted method,[1] another favouring the continuous method,[2]

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and the third not finding any significant difference between the two.[3]

The continuous method of closure has some advantages, namely quick closure with a smaller number of knots, thereby lessening the chances of sinus formation. Because some of the trials have not shown any difference in the complication rates between the two methods, many abdominal surgeons have come to believe in the superiority of continuous closure.

However, an in-depth review of the literature and our own personal data demonstrated an advantage of interrupted closure in reducing the risk of abdominal dehiscence.[4]

It was because of this state of controversy that we embarked upon a meta-analysis of the prevailing surgical experience. Our aim was to estimate the pooled odds ratio (OR) for dehiscence and incisional hernia using the interrupted method as compared with the continuous technique of laparotomy wound closure.

Methods

Literature search

The databases of MEDLINE (year 1966 onwards), Clinical Evidence and the Cochrane Library were searched on the Internet using the key words "abdomen", "abdominal", "laparotomy", "randomized", "randomised", "controlled", "trial", "suture", "continuous", "interrupted" and "closure" in various combinations. The MEDLINE-generated links of two of the articles were also searched. The Internet search was conducted from August 2003 to November 2003.

A manual search was carried out from the bibliographies of the identified papers and from important textbooks on general, gastrointestinal and emergency surgery. Finally, important unpublished data were also sought (in raw form) from known sources.

Inclusion criteria

All randomized and controlled trials comparing continuous and interrupted methods of laparotomy wound closure, with burst abdomen and/or incisional hernia as the outcomes, were included.

Exclusion criteria

Articles printed in a language other than English were not included.

Quality of trials

The quality of the articles was subjectively assessed by two reviewers (AS and HG) according to the following criteria: (1) method of randomization given or not; (2) blinding in allocation of groups; (3) blinding in evaluation; and (4) number of patients lost to follow-up or excluded from outcome reporting. We did not calculate any quality score and did not exclude any study from the meta-analysis on this basis (Table 1).

Data extraction

The data were extracted by two reviewers (AS and HG) independently. Each article was divided into two parts: (1) materials and methods, and (2) results, and the two parts were separately photocopied. The data were collected separately for these two parts to guard against reviewer bias.

Definitions of the outcome events were accepted as reported. Any discrepancies were sorted out by discussion and consensus. The respective authors of the published trials were also contacted by mail if any further information was required.

Meta-analysis

Burst abdomen and incisional hernia were the two primary outcomes. Continuous and interrupted techniques were compared for each of the two outcomes separately. Because the trials included different suture materials and incision techniques, the data were also analysed under the following six subgroups: absorbable sutures, nonabsorbable sutures, layered closure, mass closure, vertical incision and transverse incision (i.e. the subgroup of studies using absorbable sutures only in both the study arms, subgroup using nonabsorbable sutures only, and so on). For sensitivity analysis, we performed a separate analysis of those studies that had used blinding for randomization, followed by an analysis of those that had used blinding for evaluation also. The subgroup analysis for patients having peritonitis was not carried out because most authors had not reported the outcome for the patients with peritonitis in each study arm separately.

The OR was used as the summary statistic with significance levels at $p = 0.05$.

Absolute risk reduction (ARR, risk difference) was calculated as follows: ARR = risk in the control group – risk in the treated group.

Table 1. Characteristics of the studies included

No.	Citation, yr, country	Journal	Comments	Randomization	Blinding		Follow-up	Arm (C/I)	Suture	M/L	V/T	*n*
					r	e						
1	Srivastava et al, 2004, India	Ind J Surg	≥18 yr, emergency+elective	Sealed envelopes	Y	Y	4 wk	C	Prolene no. 1	M	V	110
								I; X	Prolene no. 1	M	V	100
2	Mishra, 2002, India	Thesis	≥11 yr, emergency+elective	Sealed envelopes	Y	Y	4 wk	C	Prolene no. 1	M	V	52
								I; X	Prolene no. 1	M	V	53
3	Gislason et al, 1995, Norway	Eur J Surg		Not mentioned	Y	Y	1 yr (for hernia)	C	Maxon+Vicryl	M	Both	402
								I	Vicryl	M	V	169
										L	T	28
4	Fagniez et al, 1985, France	Arch Surg	Multicentric, midline, elective+emergency	Sealed corner of form	Y	N	1 mo	C	Dexon+Vicryl	M	V	1,563
								I	-do-	M	V	1,572
5	Cleveland et al, 1988, USA	Am Surg	Gastric restrictive procedures; 2 studies, study 1 included here	Cards drawn in op. room	Y	N	?	C	Vicryl #1	M	V	62
								I	-do-	M	V	82
6	Larsen et al, 1989, Denmark	Acta Chir Scand		Sealed envelopes	Y	N	14–59 mo (median, 41 mo)	C	Surgilon 2-0	L	Both	75
								C	Dexon 2-0	L	Both	87
								I	Dexon 2-0	L	Both	76
7	Wissing et al, 1987, Netherlands	Br J Surg	Multicentric (4 centres)	Sealed envelopes	Y	N	At 1 yr, 77%	C	Vicryl+PDS	M	V	749
								C	Nylon no. 1	M	V	377
								I	Vicryl no. 2	M	V	365
8	Orr et al, 1990, USA	Am J Obstet Gynecol	Gynaecological procedures	Computer-generated random table	Y	N	At 1 mo & 6 mo	C	Maxon no. 1	M	T	72
											V	129
								I	-do-	M	T	76
								I; SJ			V	125
9	Stone et al, 1983, USA	South Med J	Emergency operations for abdominal trauma	Randomly assigned hosp. no.	N	N	?	C	Prolene no. 1/2	M	Both	178
								I	-do-	M	Both	161
10	Trimbos et al, 1992, Netherlands	Arch Surg	Multicentric (2 centres); all gynaecological procedures	On table?	Y	Y	2 wk & 1 yr	C	Maxon no. 0	M	V	168
								I	Vicryl no. 1	M	V	172
11	Irvin et al, 1977, UK	Br Med J	Used interrupted polyester retention sutures in continuous group	Cards drawn in op. room	Y	N	6 mo	C	Prolene	L	V	100
								I; SJ	Stainless steel	M	V	100
12	Askew et al, 1983, Australia	Aust N Z J Surg		By date	N	N	6 wk, 100%; total 6 mo	C	Nylon 0	L	Both	62
								I	Dexon 1	M	Both	42

13	Sahlin et al, 1993, Sweden	Br J Surg	Elective + emergency	Sealed envelopes before closure	Y	Y	At 1 yr, 69%	C	Maxon no. 0	M	V	187
											T	155
								I	Vicryl no. 0	M	V	187
											T	148
14	Colombo et al, 1997, Italy	Obstet Gynecol	All gynaecological cancers	Computer-generated random no.; in OT	Y	Y	6 mo–3 yr	C	Maxon no. 1	M	V	316
								I; SJ	Dexon no. 1	M	V	316
15	Goligher et al, 1975, UK	Br J Surg	Elective, all paramedian; used reinforcing int. sutures in continuous group	Sealed envelopes before closure	Y	N	Till 6 mo	C	C. catgut no. 1	L	V	107
								C	-do-	L	V	107
								I; SJ	Stainless steel	M	V	110
16	Richards et al, 1983, USA	Ann Surg	Incision, 5 cm	Sealed envelopes before closure	Y	N	85% at 12 mo	C	Prolene 0	M	V	244
										L	T	39
								I; SJ	Dexon 0	M	V	229
											T	50
17	Mc Neill et al, 1986, USA	Arch Surg	Gastric restrictive surgery	By hospital no.	N	N	1 yr min.	C	Dexon no. 2	M	V	51
								I; near-far	Stainless steel	M	V	54
18	Lewis & Wiegand, 1989, Canada	CJS	> 10 cm incisions	By year of birth on table	Y	N	1, 3, 6, 12, 24 & 60 mo	C	Prolene no. 1	M	V	95
								I; SJ	Dexon no. 1	M	V	105
19	Leaper et al, 1977, UK	Br J Surg		Sealed envelopes	Y	N	At 6 mo	C	C. catgut + Nylon	L	Both	116
								I; SJ	Stainless steel	M	Both	120
								I; SJ	Dexon no. 1	M	Both	121
20	Shukla et al, 1981, India	Ind J Surg	Emergency + elective	?	N	N	6–15 mo	C	C. catgut	L	Both	100
								I; SJ	Nylon	M	Both	100
21	Brolin et al, 1996, USA	Am J Surg	Gastric restrictive surgery	In OT: last digit of hospital no.	N	N	Mean, 29.4 mo	C	PDS no. 1	M	V	120
								I; SJ	Ethibond no. 1	M	V	109
22	Mishra, Nepal	Personal comm.	Emergency + elective gynaecological procedures	Sealed envelopes	Y	N	4 wk	C	Prolene 1, 2, 3	M	Both	80
								I	Prolene 1, 2	M	Both	80
								I; X	-do-	M	Both	80
23	Agrawal et al, Nepal	Personal comm.	Vertical midline; emergency surgical cases	Sealed envelopes	Y	N	4 wk for burst; 1 yr for hernia	C	Prolene no. 1	M	V	45
								I	Prolene no. 1	M	V	34
								I	Prolene no. 1	M	V	41

r = randomization; e = evaluation; I = interrupted sutures; C = continuous sutures; SJ = Smead- Jones technique; X = X sutures; M = mass closure; L = layered closure; V = vertical incision; T = transverse incision; *n* = number of patients.

Relative risk reduction (RRR) was calculated as: RRR = [1 – (Risk in treated group/Risk in control group)] × 100.

Number needed to treat (NNT = 1/ARR) was also calculated.

A funnel plot was drawn for assessing the publication bias. The meta-analysis was done using the Mantel-Haenszel method. The χ^2 test was used as the test for heterogeneity. The random effects model was used for heterogeneous data and the fixed effects model for trials with insignificant heterogeneity.

All analyses were conducted using Comprehensive Meta-Analysis version 1.0.23 (Biostat, Englewood, NJ, USA).

Results

Characteristics of the studies

More than 1,800 search items were screened for retrieval, and 30 studies were found to be potentially appropriate for the meta-analysis. Out of these, seven studies were found not to meet the inclusion criteria and were excluded for the following reasons: groups formed on an alternate case basis (two studies), nonrandomized trial (one study), historical controls (two studies), data on dehiscence and wound infections pooled (one study), and both interrupted and continuous sutures used in the same patient for the two layers of abdomen in one of the study arms (one study). Twenty-three randomized controlled trials comparing continuous and interrupted methods of abdominal wound closure were included, out of which 20 were peer reviewed publications.[4–23] There was one thesis dissertation by Dr S. Mishra from King George's Medical College, Lucknow, India. This study compared continuous with interrupted mass closure (employing the double "X" technique of the author[4]) in 105 patients undergoing elective and emergency midline laparotomies.[24]

We also included two studies that have not yet been published. Both of these randomized controlled trials were designed by the author (AS) and utilized the double X interrupted technique.[4] The first study was by Professor C.S. Agrawal and coworkers, from the B.P. Koirala Institute of Health Sciences, Dharan, Nepal. In this randomized controlled trial, continuous mass closure, far and near Smead Jones interrupted suturing and interrupted double X suture techniques were compared using no. 1 polypropylene (PROLENE, Ethicon, Johnson & Johnson Ltd., India) in 120 patients undergoing emergency vertical midline laparotomy. The second randomized controlled trial was by Dr S. Mishra, from the B.P. Koirala Institute of Health Sciences, Dharan, Nepal. The study compared continuous mass closure, figure of eight far and near Smead Jones interrupted suturing and interrupted X suture with polypropylene (PROLENE, Ethicon, Johnson & Johnson Ltd.) in 240 patients undergoing emergency as well as elective laparotomy for gynaecological procedures.

Out of the 23 studies, three trials included gastric restrictive procedures only.[7,19,23] Three published trials[10,11,16] and one unpublished trial (Mishra, Nepal) included gynaecological operations for malignant as well as benign conditions. There were three multicentre trials, of which two involved emergency and elective general surgical procedures and the third study involved gynaecological operations. Blinding for randomization was not done in five studies.[11,15,19,22,23] Blinding for evaluation was done in six studies.[4,5,12,14,16,24] The follow-up period ranged from 4 weeks for dehiscence and up to 5 years for hernia (Table 1).

Publication bias

The funnel plot was nearly symmetrical and of an inverted "V" shape, indicating low publication bias (Figures 1 and 2).

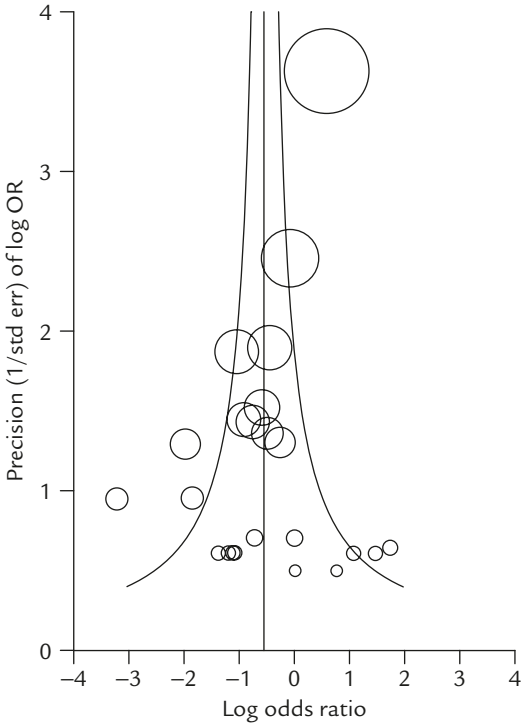

Figure 1. Funnel plot of the data with dehiscence as the outcome measure. The circles represent studies, the size of the circle being proportional to the study size.

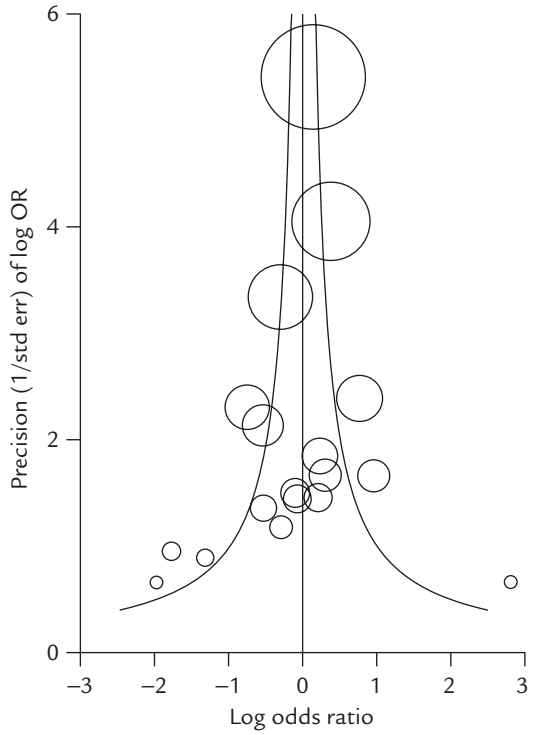

Figure 2. Funnel plot of the data with hernia as the outcome measure.

Heterogeneity of trial outcomes

The data were found to be heterogeneous overall with dehiscence as the outcome measure (χ^2 test of heterogeneity, $p = 0.046$). However, when the risk of dehiscence was evaluated in various subgroups, namely vertical incision, transverse incision, mass closure, layered closure, absorbable sutures and nonabsorbable sutures, it was found to be homogeneous within all the subgroups ($p > 0.05$, χ^2 test; Table 2). The trials were not heterogeneous as far as the incisional hernia risk was concerned (χ^2 test of heterogeneity, $p = 0.09$).

Risk of dehiscence

The point estimates and 95% confidence interval (CI) of the OR, respective *p* values, RRR, ARR and NNT of the majority of the studies favoured interrupted sutures for preventing dehiscence. The pooled OR combining all the studies was 0.576 ($p = 0.014$), in favour of interrupted sutures (Figure 3). There was an RRR of 39.8% and the NNT was 143, i.e. 143 patients needed to be treated by the interrupted method to prevent one extra burst (Table 2). The interrupted technique was also found to be significantly better in the nonabsorbable suture and vertical incision subgroups, with an OR of 0.342 ($p = 0.000$) and 0.569 ($p = 0.006$), respectively (Figure 4 for vertical incision). The OR was 0.757 for the mass closure subgroup, with a near significant *p* value of 0.059 (Figure 5). The two arms were, however, not significantly different in the absorbable suture subgroup (OR, 1.13; 95% CI, 0.777–1.663; $p = 0.51$). Because the delayed absorbable sutures (PDS and Maxon) would behave in a manner similar to nonabsorbable sutures as far as wound dehiscence is concerned (as also pointed out by Van't Riet et al in their meta-analysis), the data for the absorbable and nonabsorbable subgroups were reanalysed, with the PDS and Maxon sutures included in the nonabsorbable subgroup. The results, however, did not change (Table 2).

Risk of incisional hernia

The two techniques were not found to be significantly different (Figure 6). Subgroup analysis also did not show any statistical difference between the two techniques (Table 2).

In the transverse incision subgroup, there were only three studies comparing dehiscence risk, with only one event, and only two studies comparing hernia risk, with 13 events. The results in this subgroup did not show any significant difference between the two arms. There was only one study with layered closure in both the arms.

For sensitivity analysis, the analysis of studies that had included blinding for randomization and those that had included blinding for evaluation gave similar results except for slight changes in the effect size and variance.

Discussion

Of the various ways of evaluating evidence from multiple studies, meta-analysis is based on quantitative methods.[25] Important issues regarding meta-analysis are that the individual studies may differ considerably from each other, and some studies may be of poor quality.[26] Two important factors determining the quality of a study are randomization and peer-reviewed full-length publication. In our study, only properly randomized studies were included in the meta-analysis. For instance, studies with distribution of patients on an alternate case basis were excluded.[27] Twenty articles were full-length peer-reviewed papers and one was a thesis dissertation. For the remaining two trials, raw data were acquired for analysis. The results obtained from the analysis of only blinded studies were also found to be similar to the overall results obtained by

Table 2. Summary of the meta-analysis results in all the subgroups

	Articles, *n*	*N* Total	Treated*	Control*	χ^2 test $p^\dagger$	Effect (OR)	95% CI		$p^\ddagger$	ARR	RR	RRR	NNT
							Lower	Upper					
Dehiscence													
All articles	23	10,900	85/4,984	147/5,916	0.046	0.576	0.372	0.892	0.014	0.01	0.602	39.8	143
All articles with blinding for randomization	18	9,931	76/4,520	127/5,411	0.085	0.702	0.524	0.939	0.017	0.01	0.713	28.7	143
All articles with blinding for evaluation also	6	2,536	15/1,162	39/1,374	0.970	0.446	0.243	0.818	0.009	0.02	0.476	52.4	67
Vertical incision	15	5,165	36/2,164	83/3,001	0.871	0.569	0.381	0.850	0.006	0.01	0.591	40.9	83
Nonabsorbable sutures only	6	1,205	23/645	49/560	0.275	0.342	0.203	0.577	0.000	0.06	0.382	61.8	18
Absorbable sutures only	9	7,179	51/3,305	58/3,874	0.589	1.137	0.777	1.663	0.510	0.00	1.134	–13.4	–500
Absorbable sutures excluding delayed absorbable	3	3,442	37/1,730	22/1,712	0.489	1.644	0.976	2.768	0.062	–0.01	1.630	–63	–125
Nonabsorbable including delayed absorbable	8	1,836	25/955	49/881	0.238	0.396	0.241	0.650	0.000	0.04	0.432	56.8	29
Mass closure	17	9,437	79/4,300	120/5,137	0.067	0.757	0.567	1.011	0.059	0.01	0.766	23.4	167
All excluding Fagniez et al	22	7,765	48/3,412	126/4,353	0.520	0.467	0.335	0.652	0.000	0.02	0.486	51.4	63
Absorbable sutures excluding Fagniez et al	8	4,044	14/1,733	37/2,311	0.988	0.686	0.383	1.229	0.205	0.01	0.691	30.9	200
Mass closure excluding Fagniez et al	16	6,302	42/2,728	99/3,574	0.591	0.515	0.358	0.742	0.000	0.01	0.536	46.4	71
Transverse incision	3	540	1/274	0/266	0.921	1.49	0.192	11.578	0.703	0.00	1.483	–48.3	–333
Hernia													
All articles	18	5,976	210/2,592	293/3,384	0.099	1.059	0.871	1.288	0.566	0.00	1.052	–5.2	–250
All articles with blinding for randomization	14	5,448	181/2,337	274/3,111	0.223	1.001	0.813	1.233	0.990	0.00	1.001	–0.1	–
All articles with blinding for evaluation also	4	2,029	80/931	93/1,098	0.080	0.988	0.718	1.360	0.942	0.00	0.989	1.1	1000
Vertical incision	13	4,241	178/1,799	245/2,442	0.211	1.118	0.901	1.386	0.310	–0.01	1.102	–10.2	–111
Nonabsorbable	2	311	17/171	15/140	0.365	0.753	0.354	1.601	0.461	0.03	0.786	21.4	40
Absorbable	8	3,575	138/1,573	201/2,002	0.405	0.972	0.768	1.229	0.810	0.00	0.975	2.5	500
Mass closure	10	3,804	177/1,639	233/2,165	0.304	1.174	0.943	1.460	0.151	–0.02	1.149	–14.9	–67
Transverse incision	2	451	6/224	7/227	0.977	0.897	0.307	2.622	0.843	0.00	0.901	9.9	333

*Expressed as "number of events/number of patients"; †*p* value in the χ^2 test for heterogeneity; ‡*p* value for the OR. OR = odds ratio; CI = confidence interval; ARR = absolute risk reduction; RR = relative risk; RRR = relative risk reduction; NNT = numbers needed to treat.

Citation	*n* total	Treated	Control	Effect	Lower	Upper	*p* value
Agrawal et al (per. comm.)	120	9/75	8/45	.631	.224	1.774	.380
Askew et al, 1983	96	1/40	0/56	4.291	.170	108.080	.337
Brolin et al, 1996	229	2/109	0/120	5.605	.266	118.046	.213
Cleveland et al, 1988	144	0/82	1/62	.248	.010	6.204	.360
Colombo et al, 1997	614	0/306	1/308	.334	.014	8.241	.482
Fagniez et al, 1985	3,135	37/1,572	21/1,563	1.770	1.031	3.038	.036
Gislason et al, 1995	583	3/192	11/391	.548	.151	1.989	.354
Goligher et al, 1975	319	1/108	12/211	.155	.020	1.208	.042
Irvin et al, 1977	191	1/96	1/95	.989	.061	16.052	.994
Larsen et al, 1989	238	0/76	0/162	2.124	.042	108.064	.701
Leaper et al, 1977	357	1/241	1/116	.479	.030	7.729	.596
Lewis et al, 1989	196	0/103	1/93	.298	.012	7.403	.433
McNeill et al, 1986	105	1/54	0/51	2.888	.115	72.523	.500
Mishra et al (per. comm.)	240	1/160	11/80	.039	.005	.312	.000
Mishra et al, 2002	105	6/53	14/52	.347	.122	.988	.042
Orr et al, 1990	402	0/201	0/201	1.000	.020	50.642	1.000
Richards et al, 1982	562	3/279	5/283	.604	.143	2.553	.489
Sahlin et al, 1993	684	3/339	4/345	.761	.169	3.427	.721
Shukla et al, 1981	200	2/100	13/100	.137	.030	.622	.003
Srivastava et al, 2004	210	3/100	8/110	.394	.102	1.530	.165
Stone et al, 1983	339	3/161	7/178	.464	.118	1.825	.261
Trimbos et al, 1992	340	0/172	1/168	.324	.013	8.002	.468
Wissing et al, 1987	1,491	8/365	27/1,126	.912	.411	2.026	.821
Combined (23)	**10,900**	**85/4,984**	**147/5,916**	**.576**	**.372**	**.892**	**.014**

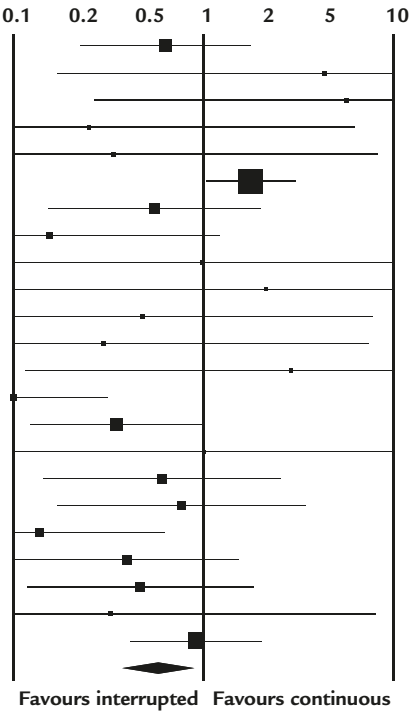

Figure 3. Dehiscence risk: meta-analysis of all articles. The data are represented as "number of dehiscence/number of patients in the arm" in the treated (interrupted) and control (continuous) arms. The "effect" is the odds ratio (OR); "upper" and "lower" are 95% confidence interval (CI) limits. Forrest plot is given on the right hand side. The square dots in the plot represent studies and the lines depict 95% CI. The size of each dot is proportional to the study size. The diamond at the end represents the pooled OR, its length depicting the 95% CI.

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Colombo et al, 1997	614	0/306	1/308	.334	.014	8.241	.482
Goligher et al, 1975	319	1/108	12/211	.155	.020	1.208	.042
Irvin et al, 1977	191	1/96	1/95	.989	.061	16.052	.994
Lewis et al, 1989	196	0/103	1/93	.298	.012	7.403	.433
McNeill et al, 1986	105	1/54	0/51	2.888	.115	72.523	.500
Mishra et al, 2002	105	6/53	14/52	.347	.122	.988	.042
Orr et al, 1990	254	0/125	0/129	1.032	.020	52.404	.988
Richards et al, 1982	473	2/229	5/244	.421	.081	2.193	.290
Sahlin et al, 1993	374	3/187	4/187	.746	.165	3.380	.703
Srivastava et al, 2004	210	3/100	8/110	.394	.102	1.530	.165
Trimbos et al, 1992	340	0/172	1/168	.324	.013	8.002	.468
Wissing et al, 1987	1,491	8/365	27/1,126	.912	.411	2.026	.821
Combined (15)	**5,165**	**36/2,164**	**83/3,001**	**.569**	**.381**	**.850**	**.006**

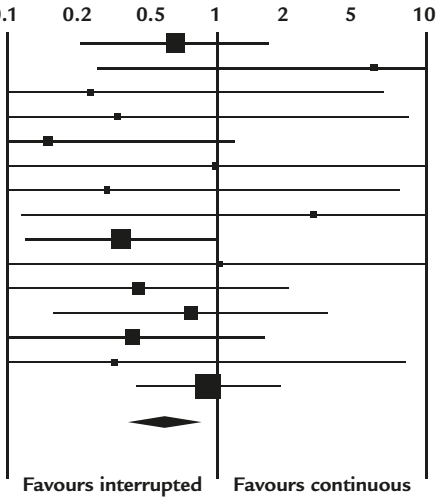

Figure 4. Dehiscence risk: meta-analysis of articles using vertical incision in both the arms. (See the legend of Figure 3 for details.)

including all the studies. Potential sources of error include confounding variables such as patient factors (age, sex, comorbid conditions), surgery-related factors (elective *vs.* emergency, contamination) and postoperative factors (coughing, straining). These factors were found to be similar or "matched" between different study arms in each of the studies. The data for analysis were also found to be statistically homogeneous in all the subgroups.

The results in the transverse and layered subgroups cannot be commented on, because of the small number of studies. Out of the remaining four subgroups, vertical and nonabsorbable groups showed a definite advantage

Citation	*n* total	Treated	Control	Effect	Lower	Upper	*p* value
Agrawal et al (per. comm.)	120	9/75	8/45	.631	.224	1.774	.380
Brolin et al, 1996	229	2/109	0/120	5.605	.266	118.046	.213
Cleveland et al, 1988	144	0/82	1/62	.248	.010	6.204	.360
Colombo et al, 1997	614	0/306	1/308	.334	.014	8.241	.482
Fagniez et al, 1985	3,135	37/1,572	21/1,563	1.770	1.031	3.038	.036
Gislason et al, 1995	560	3/169	11/391	.624	.172	2.267	.470
Lewis et al, 1989	196	0/103	1/93	.298	.012	7.403	.433
McNeill et al, 1986	105	1/54	0/51	2.888	.115	72.523	.500
Mishra et al (per. comm.)	240	1/160	11/80	.039	.005	.312	.000
Mishra et al, 2002	105	6/53	14/52	.347	.122	.988	.042
Orr et al, 1990	402	0/201	0/201	1.000	.020	50.642	1.000
Richards et al, 1982	523	3/279	5/244	.520	.123	2.197	.365
Sahlin et al, 1993	684	3/339	4/345	.761	.169	3.427	.721
Srivastava et al, 2004	210	3/100	8/110	.394	.102	1.530	.165
Stone et al, 1983	339	3/161	7/178	.464	.118	1.825	.261
Trimbos et al, 1992	340	0/172	1/168	.324	.013	8.002	.468
Wissing et al, 1987	1,491	8/365	27/1,126	.912	.411	2.026	.821
Combined (17)	**9,437**	**79/4,300**	**120/5,137**	**.757**	**.567**	**1.011**	**.059**

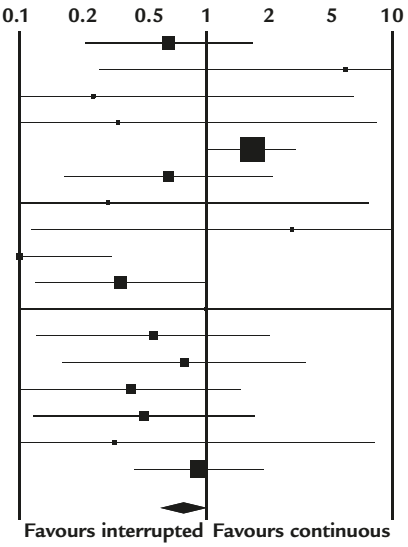

Figure 5. Dehiscence risk: meta-analysis of articles using mass closure in both the arms. (See the legend of Figure 3 for details.)

Citation	*n* total	Treated	Control	Effect	Lower	Upper	*p* value
Agrawal et al (per. comm.)	120	12/75	11/45	.589	.235	1.475	.255
Askew et al, 1983	80	4/30	0/50	17.151	.889	330.755	.013
Brolin et al, 1996	148	20/73	11/75	2.196	.966	4.989	.057
Cleveland et al, 1988	144	5/82	4/62	.942	.242	3.662	.931
Colombo et al, 1997	614	45/306	32/308	1.487	.917	2.412	.106
Gislason et al, 1995	491	7/164	28/327	.476	.203	1.114	.081
Goligher et al, 1975	319	1/108	11/211	.170	.022	1.334	.057
Irvin et al, 1977	191	5/96	4/95	1.250	.325	4.805	.745
Larsen et al, 1989	212	2/73	5/139	.755	.143	3.990	.740
Leaper et al, 1977	294	13/198	5/96	1.279	.442	3.697	.649
Lewis et al, 1989	196	11/103	4/93	2.660	.817	8.665	.093
Mc Neill et al, 1986	100	5/52	5/48	.915	.248	3.380	.894
Orr et al, 1990	402	3/201	5/201	.594	.140	2.519	.475
Richards et al, 1982	385	1/184	4/201	.269	.030	2.430	.210
Sahlin et al, 1993	684	21/339	28/345	.748	.416	1.344	.330
Shukla et al, 1981	200	0/100	3/100	.139	.007	2.718	.130
Trimbos et al, 1992	240	7/122	5/118	1.376	.424	4.462	.594
Wissing et al, 1987	1,156	48/286	128/870	1.169	.814	1.680	.398
Combined (18)	**5,976**	**210/2,592**	**293/3,384**	**1.059**	**.871**	**1.288**	**.566**

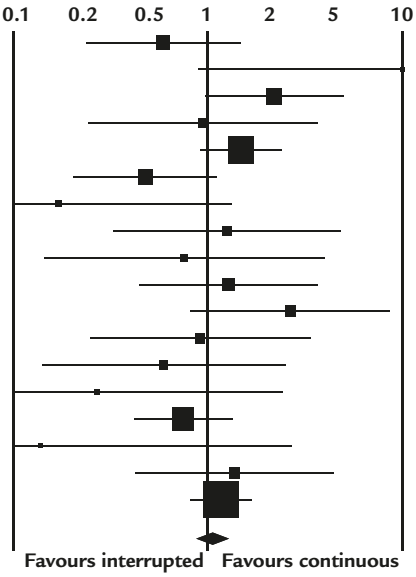

Figure 6. Hernia risk: meta-analysis of all articles. (See the legend of Figure 3 for details.)

of interrupted closure in reducing the dehiscence risk. The benefit of the interrupted technique also approached significance in the mass closure group. It may be noted that in none of the subgroups was the continuous arm found to be significantly better than the interrupted arm.

The major mechanism of wound rupture is the suture cutting through the fascia, though occasionally it may be due to suture break or slippage of the knot. A continuous suture places the integrity of the entire wound on a single strand and a cut-through at a single point can slacken the entire suturing. Rubinstein and Russell, using vector analysis of suture tension, showed that for a given force, perpendicular interrupted sutures have the least tension.[28] The figure-of-eight interrupted method deserves special mention. This technique was first developed by Smead in 1900 and popularized later by Jones et al.[29] An increased tension across the wound is distributed between the two loops in such a way that the wound remains well approximated without the suture cutting through. Our own vector analysis on an abdominal aponeurotic wall, with the help of biomedical engineers, revealed that the interrupted X suturing technique reduces the cut out force, whereas the continuous suture exerts a "hacksaw effect" at the tissue-suture interface and the to-and-fro movements of the suture strand within the tissues act like a Gigli saw, due to varying tension of different parts of the

abdominal wall on breathing and movement, gradually causing the suture to cut through the linea alba.[4] If this cut through occurs early in the postoperative period, it results in a burst, whereas if this same process takes place later, it results in an incisional hernia. The present meta-analysis supports this biomechanical explanation.

The lack of an advantage of the interrupted suture in the prevention of incisional hernia probably suggests that incisional hernia results from a multitude of factors and the suturing technique is only one of them. The stretching of the tissues with time, loss of tensile strength of the linea alba and changing dynamics of collagen metabolism with advancing age may play an important role in the pathogenesis of hernia.

The French multicentre trial carried out by Fagniez et al was the largest study included in our meta-analysis.[6] They found greater dehiscence risk in the interrupted group, though the difference was significant only in the "contaminated wounds" subgroup. However, the details of the interrupted suturing technique were not described. Hence, we have reanalysed the data after excluding the data of Fagniez et al. This resulted in further reduction of OR for dehiscence with narrower 95% CI. We feel that the specific technique of interrupted suturing is of crucial importance and either a figure-of-eight (Smead-Jones method[29] or double X method[4]) or double horizontal mattress of Professor Hughes' technique[30] should be employed to provide a secure repair. If a simple interrupted suture is inserted, it is likely to cut through like a cheese wire.

Three meta-analyses have previously been reported on this same issue.[1–3] However, they all included only a small number of studies comparing continuous and interrupted methods of suturing, ranging from six to eight. Van't Riet et al included only studies with at least 100 patients and a minimum follow-up of 1 year. Though a follow-up of 1 year would be desirable for calculating risk of hernia, a period of 4 weeks can be considered sufficient for assessing dehiscence. Wadstrom and Gerdin, in a clinical review, found that a majority of disruptions occurred between the 6th and 9th day after surgery.[31] Similar findings were reported in other trials. Moreover, in the meta-analysis by Hodgson et al, only three out of six studies had used similar suture material in the two comparison arms.[2] In the meta-analysis by Weiland et al, there were three such studies out of seven, while Van't Riet et al had included only one such study.[1,3] As a result, they could not perform same-group comparisons like continuous absorbable versus interrupted absorbable, and continuous nonabsorbable versus interrupted nonabsorbable. Our meta-analysis is the most comprehensive and up-to-date, including 23 trials.

Our meta-analysis has demonstrated a reduction in the odds of wound-closure burst to half, using the interrupted method of abdominal wall closure. Incisional hernias occur with the same frequency with both the interrupted technique of laparotomy wound closure and the continuous technique.

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