

Meta-analysis of randomized clinical trials comparing open and laparoscopic inguinal hernia repair

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Background: The aim was to conduct a meta-analysis of the randomized evidence to determine the relative merits of laparoscopic (LIHR) and open (OIHR) inguinal hernia repair.

Methods: A search of the Medline, Embase, Science Citation Index, Current Contents and PubMed databases identified all randomized clinical trials that compared OIHR and LIHR and were published in the English language between January 1990 and the end of October 2000. The meta-analysis was prepared in accordance with the Quality of Reporting of Meta-analyses (QUOROM) statement. The six outcome variables analysed were operating time, time to discharge from hospital, return to normal activity and return to work, postoperative complications and recurrence rate. Random effects meta-analyses were performed using odds ratios and weighted mean differences.

Results: Twenty-nine trials were considered suitable for meta-analysis. Some 3017 hernias were repaired laparoscopically and 2972 hernias were repaired using an open method in 5588 patients. For four of the six outcomes the summary point estimates favoured LIHR over OIHR; there was a significant reduction of 38 per cent in the relative odds of postoperative complications (odds ratio 0.62 (95 per cent confidence interval (c.i.) 0.46 to 0.84); $P = 0.002$), 4.73 (95 per cent c.i. 3.51 to 5.96) days in time to return to normal activity ($P < 0.001$), 6.96 (95 per cent c.i. 5.34 to 8.58) days in time to return to work ($P < 0.001$) and 3.43 (95 per cent c.i. 0.35 to 6.50) h in time to discharge from hospital ($P = 0.029$). There was a significant increase of 15.20 (95 per cent c.i. 7.78 to 22.63) min in the mean operating time for LIHR ($P < 0.001$). The relative odds of short-term recurrence were increased by 50 per cent for LIHR compared with OIHR, although this result was not statistically significant (odds ratio 1.51 (95 per cent c.i. 0.81 to 2.79); $P = 0.194$).

Conclusion: LIHR was associated with earlier discharge from hospital, quicker return to normal activity and work, and significantly fewer postoperative complications than OIHR. However, the operating time was significantly longer and there was a trend towards an increase in the relative odds of recurrence after laparoscopic repair.

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Introduction

Laparoscopic inguinal hernia repair (LIHR) was introduced following the success of laparoscopic cholecystectomy on the premise that there would be less postoperative discomfort and pain, recovery time would be reduced, repair of a recurrent hernia would be easier because the repair is performed in virgin tissue, concurrent treatment of bilateral hernias, simultaneous diagnostic laparoscopy and high ligation of the hernia sac would be feasible, and

cosmesis would be improved^{1–5}. Furthermore, because LIHR places the prosthesis in the preperitoneal space in a 'tension-free' manner^{6,7}, the recurrence rate may be lower than that after conventional open inguinal hernia repair (OIHR). Shortcomings of the laparoscopic approach, however, include a risk of major complications related specifically to the laparoscopic approach, such as bowel perforation or major vascular injury, the potential for adhesion formation and complications when the

peritoneum is breached and prosthetic material exposed, a more complex and difficult technique, the requirement for general anaesthesia, greater cost⁸, and potential difficulties with subsequent prostate, bladder and lower limb peripheral vascular surgery^{9,10}. In contrast, OIHR can be performed under local anaesthesia on an outpatient at minimum cost with negligible risk to intra-abdominal structures^{11–13}.

The earliest LIHR techniques were associated with two serious problems. The first was an unacceptably high recurrence rate approaching 20 per cent^{14,15}. This resulted from a non-scientific type of repair involving simple placement of large plugs or sheets of prosthetic material in the most obvious hernia defect while failing to reinforce the entire weakened inguinal floor and cover all the potential hernia sites adequately. This problem was addressed by placing a large, flat prosthesis to support the entire inguinal floor, which led to a dramatic drop in the recurrence rate in contemporary LIHR series. The second problem was the increased incidence of sensory nerve injury resulting from indiscriminate placement of staples^{16–19}. However, increased familiarity with the posterior abdominal wall anatomy⁹ and the introduction of new types of tacking device and stapleless repair have virtually eliminated injury to the sensory nerves during LIHR²⁰. Now that these technical problems have been resolved and the operative procedure has been standardized, the potential benefits of LIHR compared with OIHR may be better assessed.

The present appraisal was based on a meta-analysis of pooled data from 29 randomized clinical trials that compared laparoscopic and open methods of inguinal hernia repair. This meta-analysis was prepared in accordance with the Quality of Reporting of Meta-analyses (QUOROM) statement²¹.

Patients and methods

Randomized clinical trials of any size that compared LIHR with any type of OIHR, and were published in full in peer-reviewed journals in the English language between January 1990 and the end of October 2000, were included. Unpublished studies and abstracts presented at national and international meetings were excluded. Published studies that reported three or fewer outcome variables or that contained insufficient information^{22–24} were also excluded, but only after an effort had been made to obtain unpublished or missing data from the original authors. Duplicate publications were also excluded²⁵.

Trials were identified by conducting a comprehensive search of Medline, Embase, Science Citation Index,

Current Contents and PubMed databases, using medical subject headings 'hernia', 'inguinal', 'comparative study', 'prospective studies', 'randomized controlled trials', 'random allocation' and 'clinical trial'. Manual search of the bibliographies of relevant papers was also carried out to identify trials for possible inclusion.

Data extraction and critical appraisal were carried out by three authors, who also contacted the original authors of some of the trials for clarification of data and to obtain unpublished, missing or additional information on various outcome measures. The response to this was extremely good. Six outcome variables were considered most suitable for analysis: operating time, time to discharge from hospital, return to normal activity and return to work, postoperative complications and hernia recurrence rate. Other outcome measures, such as postoperative pain, analgesia requirements and hospital costs, were excluded owing to variations in reporting methodology and the inability to devise uniform objective analysis of these outcomes. The quality of the randomized clinical trials was assessed using Jadad's scoring system²⁶.

Statistical analysis

Meta-analyses were performed using odds ratios (ORs) for binary and weighted mean differences (WMDs) for continuous outcome measures²⁷. Random effects models were used to combine the data and statistical heterogeneity was assessed using the χ^2 test. To assess whether heterogeneity was explained by study-level co-variables (year of study, length of follow-up and size of study) a random effects meta-regression model was used²⁸.

Subgroup analyses were performed by comparing the results of the two methods of LIHR (transabdominal preperitoneal (TAPP) and totally extraperitoneal (TEP)) and OIHR (tension free and tension creating) separately²⁷. A sensitivity analysis was carried out to assess the impact of study quality on the results, by excluding poor-quality studies (Jadad score 1)²¹. All estimates were obtained using 'meta'²⁹ and 'metareg'³⁰ macros in Stata[®] version 6 (Stata Corporation, College Station, Texas, USA) and plots were obtained by means of S-PLUS 2000[™] (MathSoft, Cambridge, Massachusetts, USA).

Results

A total of 29 randomized prospective clinical trials that included 5989 hernia repairs (LIHR 3017, OIHR 2972) in 5588 patients (LIHR 2783, OIHR 2805) were considered suitable for meta-analysis (*Table 1*). Open inguinal herniorrhaphy was performed using a variety of tension-creating (Bassini, McVay, Shouldice, Maloney darn) and

Table 1 Details of all prospective randomized trials that compared laparoscopic and open inguinal hernia repair published in the English language literature

Reference	Quality*	Type of repair		No. of patients		Follow-up (months)
		Laparoscopic	Open	Laparoscopic	Open	
TAPP <i>versus</i> OIHR						
31	0	TAPP	Shouldice or darn	42 (57)	44 (44)	8 (median)
32	2	TAPP	Lichtenstein†	48 (52)	52 (58)	10 (median)
33	3	TAPP	Darn	75 (83)	75 (84)	7 (mean)
34	2	TAPP	Bassini, McVay, Shouldice, Lichtenstein†, patch and/or plug	43 (43)	49 (49)	14 (median)
35	3	TAPP	Maloney darn	58 (58)	66 (66)	1.5
36	2	TAPP	Shouldice	28 (28)	34 (34)	3
37	2	TAPP	Shouldice	44 (56)	43 (52)	6.7 (mean)
38	2	TAPP	Lichtenstein†	20 (20)	18 (18)	10 (median)
39	3	TAPP	Shouldice	110 (122)	89 (89)	12
40	2	TAPP	OPP mesh†	24 (33)	25 (29)	18 (median)
41	3	TAPP	OPP mesh†	42 (56)	37 (52)	34 (mean)
42	3	TAPP	Bassini	88 (114)	87 (103)	24 (mean)
43	3	TAPP	Lichtenstein†	18 (20)	20 (20)	17 (median)
44	2	TAPP	Lichtenstein†	52 (77)	56 (72)	28 (median)
45	2	TAPP	Modified Bassini	60 (64)	60 (63)	32 (mean)
46	3	TAPP	Lichtenstein†	200 (223)	200 (224)	3
47	2	TAPP	Shouldice	80 (80)	80 (80)	25 (mean)
48	2	TAPP	OPP mesh†	207 (207)	199 (199)	12 (maximum)
49	3	TAPP	Shouldice	138 (138)	130 (130)	12 (median)
50	3	TAPP or TEP	Conventional anterior (various techniques)	468 (494)	460 (487)	12
51	2	TAPP	Lichtenstein†	52 (52)	52 (52)	1
52	1	TAPP	Shouldice	54 (54)	48 (48)	72 (minimum)
TEP <i>versus</i> OIHR						
53	2	TEP	Shouldice or darn	32 (39)	72 (74)	7.3 (median)
54	3	TEP	Lichtenstein† or OPP mesh†	60 (67)	60 (64)	—
55	1	TEP	Stoppa†	51 (72)	49 (73)	20 (mean)
56	3	TEP	Conventional anterior (various techniques)	487 (487)	507 (507)	20 (median)
57	3	TEP	Lichtenstein†	22 (22)	23 (23)	10 (median)
58	3	TEP	Mesh-plug†	150 (169)	142 (146)	17 (median)
IPOM <i>versus</i> OIHR						
59, 60	2	IPOM	Bassini or McVay	30 (30)	28 (32)	41 (mean)
Total				2783 (3017)	2805 (2972)	

Values in parentheses are numbers of hernias. *Jadad score (maximum 5). †Tension-free repair. TAPP, transabdominal preperitoneal; OIHR, open inguinal hernia repair; OPP, open preperitoneal; TEP, totally extraperitoneal; IPOM, intraperitoneal onlay mesh.

tension-free (Stoppa, Lichtenstein, Gilbert and Rutkow, Robbins) techniques. TAPP repair was the most common laparoscopic technique (22 studies) followed by TEP repair (six) and intraperitoneal onlay mesh repair (one).

In general, the quality of the studies was poor on critical appraisal (mean quality score 2 of 5). This was because the method of randomization was not defined in a number of studies, it was not possible to blind study participants and investigators for these procedures, and a description of withdrawals and drop-outs was not always provided. This has been observed in other reviews and meta-analyses of surgical trials^{61–63}.

The pooled data (OR and WMD) for the six outcomes are summarized in *Table 2* and *Figs 1–6*. As statistically significant heterogeneity was evident for the majority of outcome measures, random effects models were used to combine the data²⁷. For two outcomes (recurrence and operating time) the summary point estimate favoured OIHR over LIHR. For duration of operation there was a statistically significant increase of 15.20 (95 per cent confidence interval (c.i.) 7.78 to 22.63) min for LIHR compared with OIHR ($P < 0.001$) (*Fig. 1*). The relative odds of short-term recurrence was increased by 50 per cent after LIHR compared with OIHR, although this result was not statistically significant (OR 1.51 (95 per cent c.i. 0.81

Duration of operation

Reference	LIHR		OIHR	
	<i>n</i>	Operating time (min)	<i>n</i>	Operating time (min)
TEP				
53	39	87.5(31.3)	74	50.0(32.3)
55	72	60.0(14.0)	73	61.0(12.0)
57	22	67.5(12.0)	23	53.0(9.0)
58	169	31.5(18.8)	146	30.5(15.0)
56	487	45.0(3.8)	507	40.0(6.3)
54	67	58.0(5.8)	64	45.0(4.3)
Subtotal	856		887	
TAPP				
40	33	65.5(13.4)	29	55.5(8.3)
34	43	86.7(30.2)	49	79.8(58.7)
41	56	79.0(32.0)	52	56.0(16.0)
42	114	82.0(28.0)	103	45.0(15.0)
38	20	71.5(4.3)	18	45.0(16.8)
43	18	62.0(19.8)	20	65.0(13.3)
48	207	65.0(25.0)	199	38.0(14.0)
49	138	77.0(30.4)	130	45.0(13.5)
39	122	72.0(30.0)	89	62.0(25.0)
35	58	72.0(2.0)	66	32.0(1.0)
52	54	65.0(26.3)	48	47.5(20.0)
31	57	35.0(8.8)	44	30.5(13.8)
50	494	58.4(22.5)	487	43.4(15.9)
44	77	66.6(21.9)	72	48.2(22.9)
51	52	49.6(5.4)	52	33.9(6.2)
36	28	46.0(9.2)	34	38.4(9.7)
33	83	50.0(8.25)	84	35.0(2.5)
45	64	95.0(28.0)	63	67.0(27.0)
37	56	87.0(26.3)	52	59.0(13.8)
46	223	46.6(20.0)	224	46.8(15.7)
47	80	61.0(12.0)	80	47.0(17.0)
Subtotal	2077		1995	
IPOM				
59, 60	30	63.2(20.0)	32	80.9(26.3)
Subtotal	30		32	
Pooled (random effects)	2963		2914	

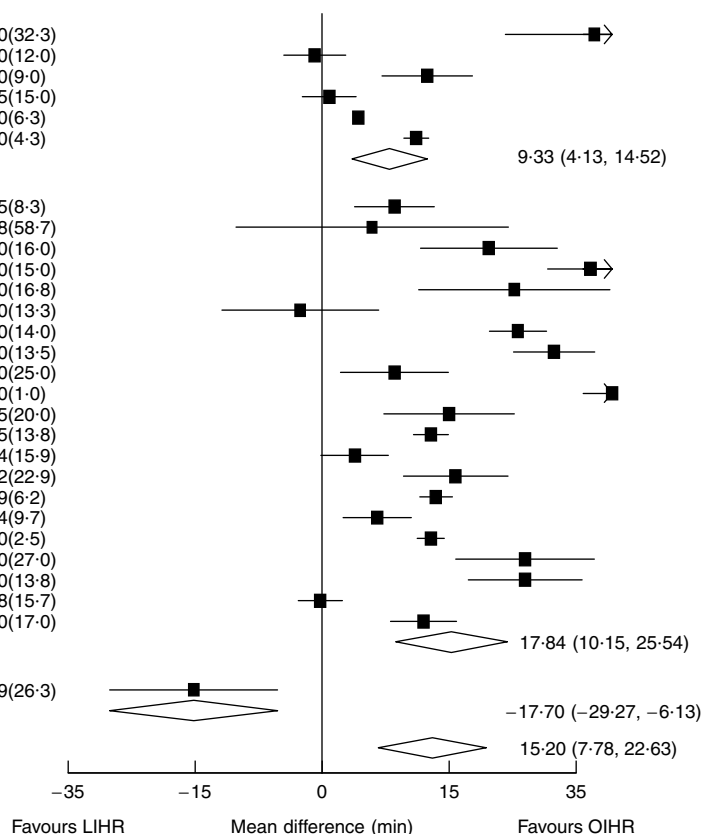


Fig. 1 Pooled estimates of duration of operation. Values in left panel are mean(s.d.). Squares indicate point estimates of treatment effect (weighted mean difference), with the size of square representing the weight attributed to each study. Ninety-five per cent confidence intervals are indicated by horizontal bars. The summary weighted mean difference from the pooled studies with 95 per cent confidence intervals is represented by a diamond. Values to the left of the vertical line at zero favour laparoscopic inguinal hernia repair (LIHR). Point estimates are significant at the $P < 0.050$ level if their confidence intervals exclude the vertical line at zero. OIHR, open inguinal hernia repair; TEP, totally extraperitoneal repair; TAPP, transabdominal preperitoneal repair; IPOM, intraperitoneal onlay mesh repair

Table 2 Summary of pooled data comparing laparoscopic and open hernia repair

	Pooled OR or WMD	<i>P</i>	Test for heterogeneity	
			χ^2	<i>P</i>
Complication rate	0.62 (0.46, 0.84)*	0.002	0.43	< 0.001
Hernia recurrence rate	1.51 (0.81, 2.79)*	0.194	0.88	0.001
Duration of operation (min)	15.20 (7.78, 22.63)†	< 0.001	387.26	< 0.001
Duration of hospital stay (h)	-3.43 (-6.50, -0.35)†	0.029	52.51	< 0.001
Return to normal activity (days)	-4.73 (-5.96, -3.51)†	< 0.001	6.04	< 0.001
Return to work (days)	-6.96 (-8.58, -5.34)†	< 0.001	9.97	< 0.001

Values in parentheses are 95 per cent confidence intervals. *OR, odds ratio; †WMD, weighted mean difference.

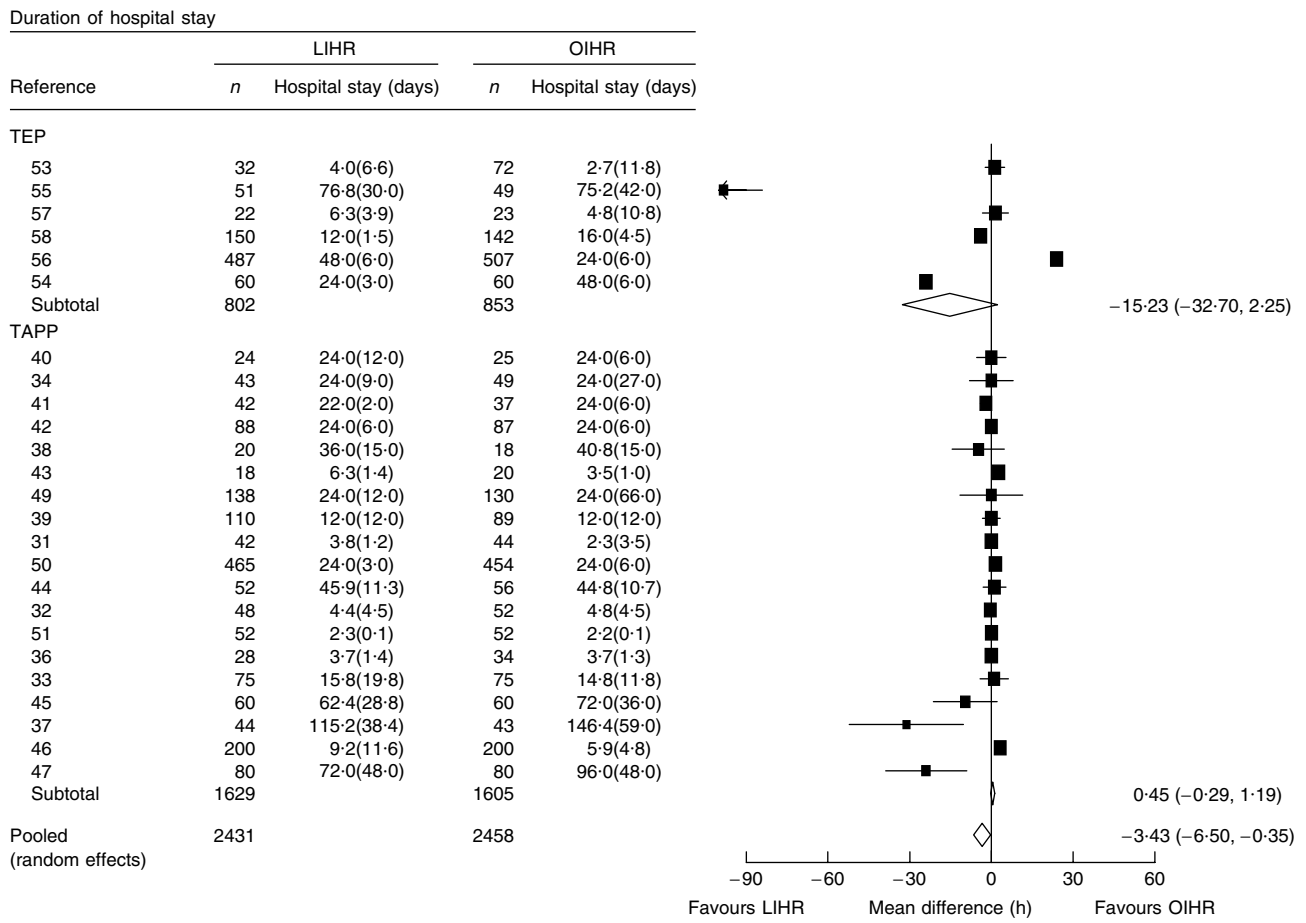


Fig. 2 Pooled estimates of hospital stay. Values in left panel are mean(s.d.). Squares indicate point estimates of treatment effect (weighted mean difference), with the size of square representing the weight attributed to each study. Ninety-five per cent confidence intervals are indicated by horizontal bars. The summary weighted mean difference from the pooled studies with 95 per cent confidence intervals is represented by a diamond. Values to the left of the vertical line at zero favour laparoscopic inguinal hernia repair (LIHR). Point estimates are significant at the $P < 0.050$ level if their confidence intervals exclude the vertical line at zero. OIHR, open inguinal hernia repair; TEP, totally extraperitoneal repair; TAPP, transabdominal preperitoneal repair

to 2.79); $P = 0.194$) (Fig. 6). For the remaining outcomes, the summary point estimates favoured LIHR over OIHR. There was a statistically significant reduction of 38 per cent in the relative odds of complications (OR 0.62 (95 per cent c.i. 0.46 to 0.84); $P = 0.002$) after laparoscopic repair (Fig. 5). There was a mean reduction in hospital stay of 3.43 (95 per cent c.i. 0.35 to 6.50) h ($P = 0.029$) after LIHR compared with OIHR (Fig. 2), in time to return to normal activities of 4.73 (95 per cent c.i. 3.51 to 5.96) days ($P < 0.001$) (Fig. 3), and in time to return to work of 6.96 (95 per cent c.i. 5.34 to 8.58) days ($P < 0.001$) (Fig. 4). Not every study reported data on each outcome.

The meta-regression analysis indicated that the only statistically significant association between a study level

co-variate and outcome occurred with length of follow-up and return to normal activities. The meta-regression equation produced was return to normal activity (mean difference) = -2.24 (s.e. 1.44) $-0.16 \times$ length of follow-up (s.e. 0.07, $P = 0.032$), indicating that the mean difference increased linearly with length of follow-up by approximately 1 day for every 6 days of follow-up. Even after explaining a proportion of the between-study variability in this way, residual heterogeneity remained (between-study variance estimated as 10.84).

The results of subgroup analyses that compared the results for the two laparoscopic procedures (TAPP and TEP) separately are shown in Table 3. For all outcomes except hospital discharge the direction of effect was

Return to normal activity

Reference	LIHR		OIHR	
	<i>n</i>	Time (days)	<i>n</i>	Time (days)
TEP				
53	32	34.5(42.0)	72	32.0(31.4)
55	51	4.5(1.7)	49	11.3(4.6)
57	22	14.0(8.0)	23	20.0(10.0)
58	150	8.0(2.0)	142	15.0(2.5)
56	487	6.0(1.5)	507	10.0(2.5)
Subtotal	742		793	
TAPP				
40	24	7.0(14.8)	25	5.0(7.3)
34	43	9.6(7.6)	49	10.9(7.4)
41	42	21.0(15.5)	37	29.0(13.4)
42	88	14.0(10.1)	87	22.0(11.2)
43	18	14.0(7.5)	20	21.0(14.8)
49	138	13.0(13.8)	130	18.0(13.0)
39	110	10.0(8.0)	89	23.0(21.0)
35	58	22.0(24.3)	66	28.0(25.5)
31	42	29.5(21.3)	44	30.0(15.0)
50	273	10.0(3.5)	263	14.0(5.3)
32	48	15.0(3.8)	52	14.0(5.8)
51	52	45.5(7.0)	52	42.7(8.8)
36	28	10.1(1.4)	34	11.9(1.3)
33	73	3.0(6.3)	72	7.0(6.8)
45	35	28.0(10.8)	32	35.0(9.0)
37	44	23.5(14.1)	43	41.8(28.2)
46	197	2.9(1.8)	199	4.0(2.3)
47	80	3.0(2.0)	80	11.0(4.0)
Subtotal	1393		1374	
IPOM				
59, 60	30	7.5(3.8)	28	18.5(6.8)
Subtotal	30		28	
Pooled (random effects)	2165		2195	

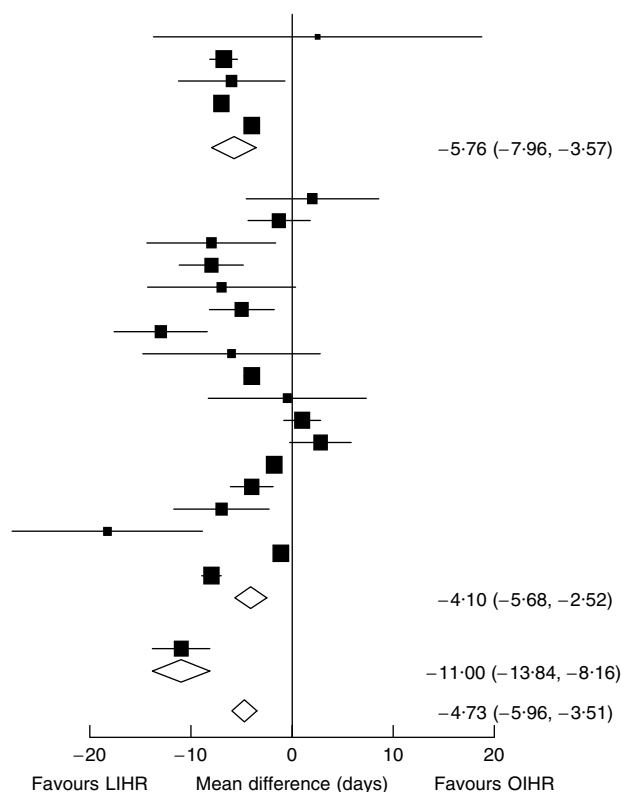


Fig. 3 Pooled estimates of time to return to normal activity. Values in left panel are mean(s.d.). Squares indicate point estimates of treatment effect (weighted mean difference), with the size of square representing the weight attributed to each study. Ninety-five per cent confidence intervals are indicated by horizontal bars. The summary weighted mean difference from the pooled studies with 95 per cent confidence intervals is represented by a diamond. Values to the left of the vertical line at zero favour laparoscopic inguinal hernia repair (LIHR). Point estimates are significant at the $P < 0.050$ level if their confidence intervals exclude the vertical line at zero. OIHR, open inguinal hernia repair; TEP, totally extraperitoneal repair; TAPP, transabdominal preperitoneal repair; IPOM, intraperitoneal only mesh repair

Table 3 Subgroup analysis comparing laparoscopic transabdominal preperitoneal and totally extraperitoneal repair with open hernia repair

	TAPP versus OIHR				TEP versus OIHR			
	Pooled OR or WMD	<i>P</i>	Test for heterogeneity		Pooled OR or WMD	<i>P</i>	Test for heterogeneity	
			χ^2	<i>P</i>			χ^2	<i>P</i>
Complication rate	0.70 (0.49, 1.00)*	0.048	0.46	< 0.001	0.39 (0.20, 0.75)*	0.005	0.46	0.003
Hernia recurrence rate	1.58 (0.73, 3.42)*	0.241	1.12	0.008	0.77 (0.27, 2.19)*	0.628	0.37	0.190
Duration of operation (min)	17.84 (10.15, 25.54)†	< 0.001	309.17	< 0.001	9.33 (4.13, 14.52)†	< 0.001	35.23	< 0.001
Duration of hospital stay (h)	0.45 (-0.29, 1.19)†	0.231	1.08	< 0.001	-15.23 (-32.70, 2.25)†	0.088	467.09	< 0.001
Return to normal activity (days)	-4.10 (-5.68, -2.52)†	< 0.001	7.79	< 0.001	-5.76 (-7.96, -3.57)†	< 0.001	4.14	< 0.001
Return to work (days)	-6.93 (-10.04, -3.83)†	< 0.001	37.77	< 0.001	-7.42 (-8.72, -6.12)†	< 0.001	1.00	< 0.001

Values in parentheses are 95 per cent confidence intervals. TAPP, transabdominal preperitoneal; OIHR, open inguinal hernia repair; TEP, totally extraperitoneal; *OR, odds ratio; †WMD, weighted mean difference.

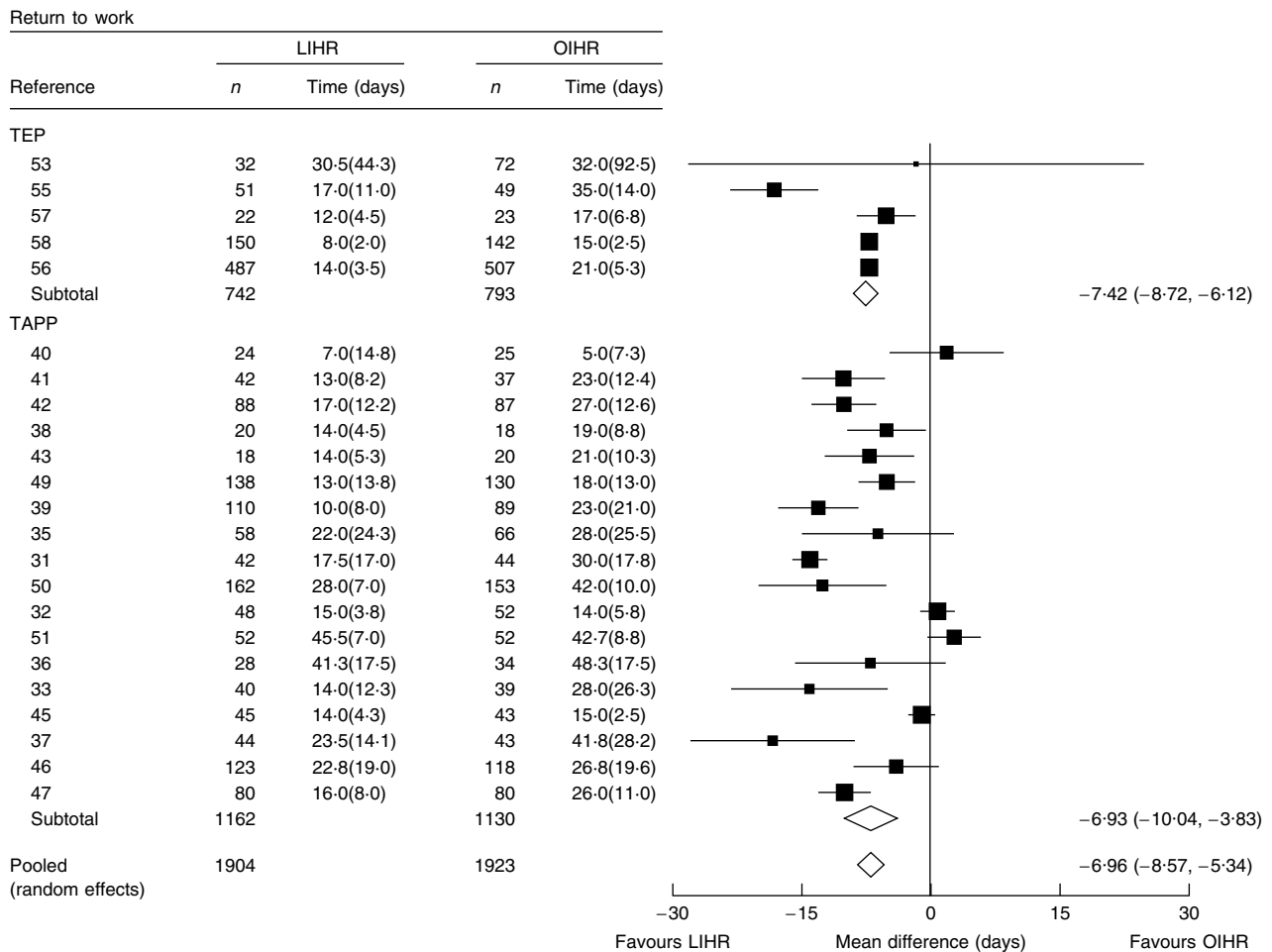


Fig. 4 Pooled estimates of time to return to work. Values in left panel are mean(s.d.). Squares indicate point estimates of treatment effect (weighted mean difference), with the size of square representing the weight attributed to each study. Ninety-five per cent confidence intervals are indicated by horizontal bars. The summary weighted mean difference from the pooled studies with 95 per cent confidence intervals is represented by a diamond. Values to the left of the vertical line at zero favour laparoscopic inguinal hernia repair (LIHR). Point estimates are significant at the $P < 0.050$ level if their confidence intervals exclude the vertical line at zero. OIHR, open inguinal hernia repair; TEP, totally extraperitoneal repair; TAPP, transabdominal preperitoneal repair

Table 4 Subgroup analysis comparing laparoscopic inguinal hernia repair with tension-free and tension-creating open hernia repair

	LIHR versus tension free				LIHR versus tension creating			
	Pooled OR or WMD	<i>P</i>	Test for heterogeneity		Pooled OR or WMD	<i>P</i>	Test for heterogeneity	
			χ^2	<i>P</i>			χ^2	<i>P</i>
Complication rate	0.55 (0.32, 0.95)*	0.033	0.81	< 0.001	0.68 (0.47, 0.97)*	0.035	0.26	< 0.001
Hernia recurrence rate	2.14 (1.07, 4.28)*	0.032	0.00	0.595	1.23 (0.54, 2.79)*	0.628	1.12	0.002
Duration of operation (min)	14.25 (4.19, 24.32)†	0.006	359.17	< 0.001	16.26 (10.32, 22.19)†	< 0.001	111.47	< 0.001
Duration of hospital stay (h)	-5.32 (-8.57, -2.06)†	0.001	30.77	< 0.001	-1.34 (-8.26, 5.57)†	0.703	132.60	< 0.001
Return to normal activity (days)	-3.40 (-5.98, -0.81)†	< 0.001	14.73	< 0.001	-5.82 (-7.29, -4.36)†	< 0.001	4.32	< 0.001
Return to work (days)	-5.50 (-8.61, -2.38)†	0.001	24.07	< 0.001	-9.07 (-11.98, -6.16)†	< 0.001	17.12	< 0.001

Values in parentheses are 95 per cent confidence intervals. LIHR, laparoscopic inguinal hernia repair; *OR, odds ratio; †WMD, weighted mean difference.

Postoperative complications

Reference	LIHR	OIHR
TEP		
53	4 of 32	7 of 72
55	2 of 51	11 of 49
57	16 of 22	18 of 23
58	20 of 150	33 of 142
56	54 of 487	99 of 507
54	15 of 60	46 of 60
Subtotal	111 of 802	214 of 853
TAPP		
40	5 of 24	2 of 25
34	10 of 43	6 of 49
41	28 of 42	23 of 37
42	40 of 88	81 of 87
38	4 of 20	15 of 18
43	5 of 18	8 of 20
48	62 of 207	48 of 199
49	13 of 138	15 of 130
39	8 of 110	9 of 89
35	6 of 58	1 of 66
52	4 of 54	4 of 48
31	17 of 42	21 of 44
50	108 of 361	155 of 356
44	14 of 52	15 of 56
32	6 of 48	9 of 52
51	14 of 52	13 of 52
36	7 of 28	6 of 34
33	6 of 75	16 of 75
45	24 of 60	30 of 60
37	6 of 44	9 of 43
46	164 of 200	191 of 200
47	15 of 80	13 of 80
Subtotal	586 of 1844	690 of 1820
IPOM		
59, 60	5 of 30	5 of 28
Subtotal	5 of 30	5 of 28
Total	682 of 2676	909 of 2701

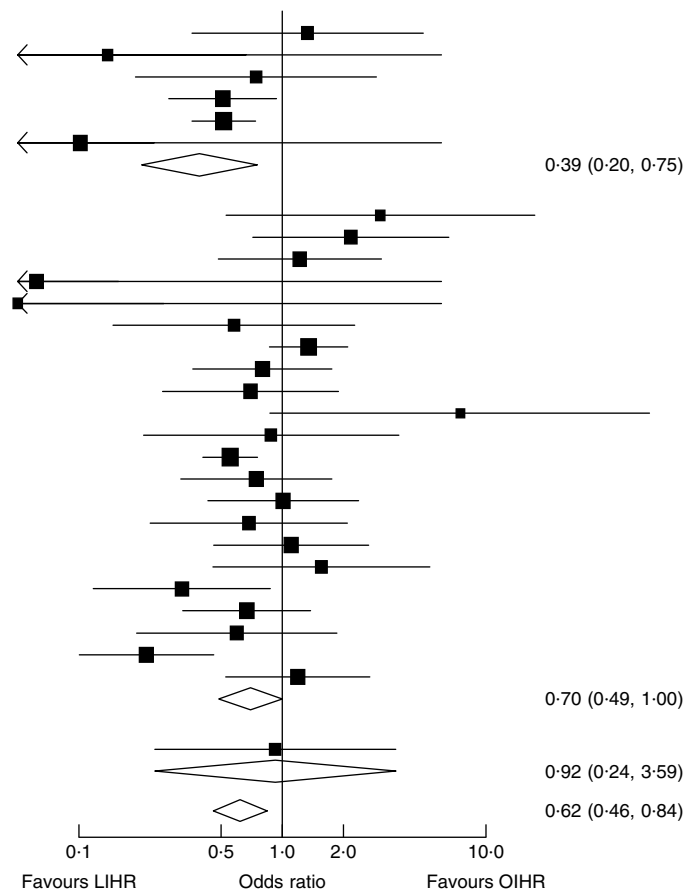


Fig. 5 Pooled estimates of postoperative complications. Squares indicate point estimates of treatment effect (odds ratio), with the size of square representing the weight attributed to each study. Ninety-five per cent confidence intervals are indicated by horizontal bars. The summary odds ratio from the pooled studies with 95 per cent confidence intervals is represented by a diamond. Values to the left of the vertical line at 1.0 favour laparoscopic inguinal hernia repair (LIHR). Point estimates are significant at the $P < 0.050$ level if their confidence intervals exclude the vertical line at 1.0. OIHR, open inguinal hernia repair; TEP, totally extraperitoneal repair; TAPP, transabdominal preperitoneal repair; IPOM, intraperitoneal onlay mesh repair

consistent across both laparoscopic subgroups. The effect in certain subgroups, however, became statistically non-significant, probably owing to the reduced power in these subgroup analyses compared with the overall pooled result. Similarly, the results of subgroup analyses for each type of open hernia repair (tension free and tension creating) showed the direction of effect to be consistent across both subgroups, although the effect in certain subgroups again became non-significant (*Table 4*). In the sensitivity analysis, limiting the investigation to higher-quality studies only (Jadad score 2 or 3) did not change the inference at the 5 per cent level for any of the outcomes.

Discussion

LIHR has stirred a tremendous amount of controversy since its introduction^{8,9}. Its proponents continue to argue that the procedure is superior to OIHR because it is associated with less postoperative pain, an earlier return to work and unrestricted physical activity, and a better cosmetic result. The opponents, however, argue that there is a higher incidence of major intraoperative and postoperative complications owing to the invasive nature of the procedure, especially when the TAPP route is used, an increased incidence of hernia recurrence and substantially greater

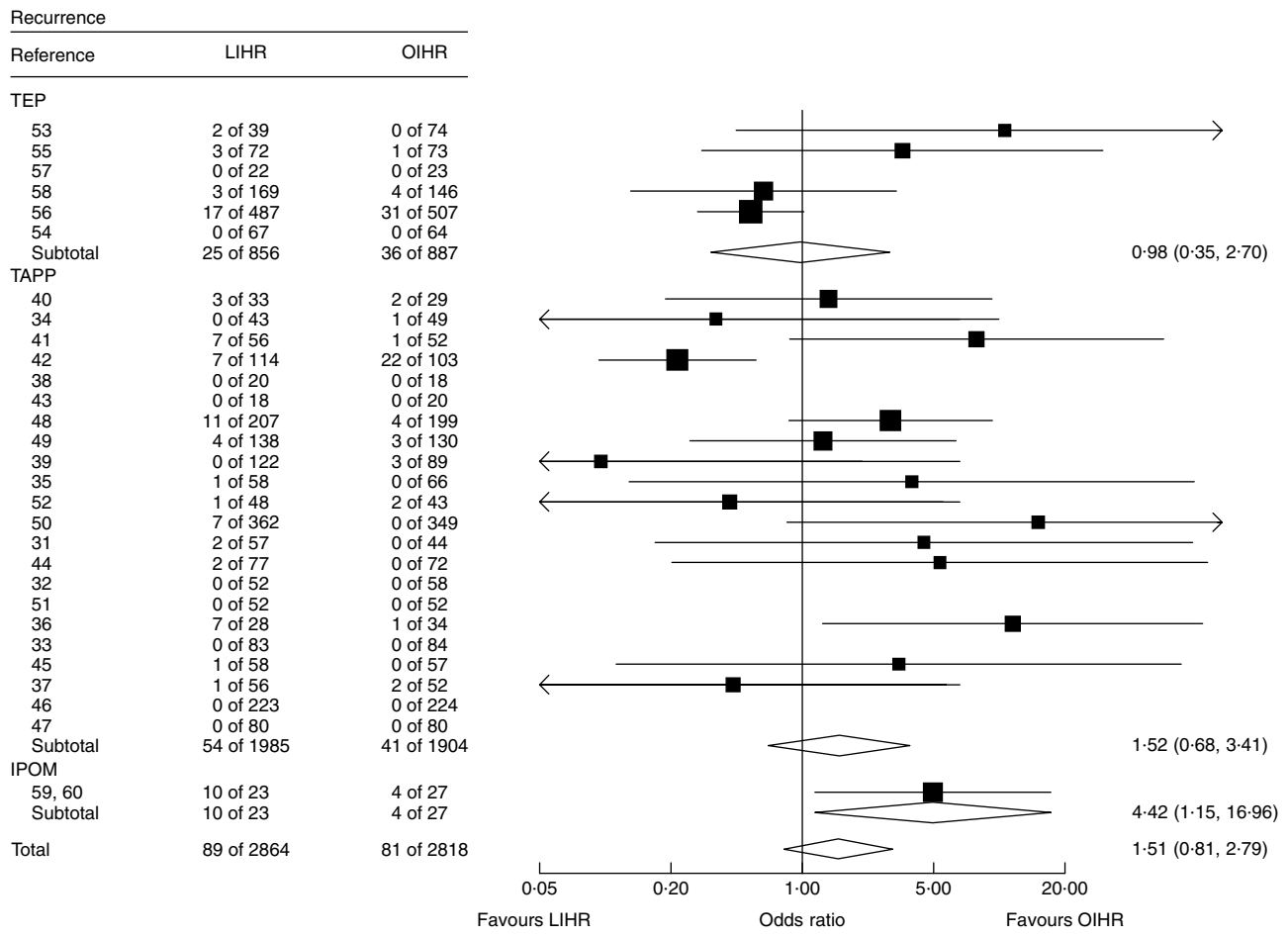


Fig. 6 Pooled estimates of recurrence. Squares indicate point estimates of treatment effect (odds ratio), with the size of square representing the weight attributed to each study. Ninety-five per cent confidence intervals are indicated by horizontal bars. The summary odds ratio from the pooled studies with 95 per cent confidence intervals is represented by a diamond. Values to the left of the vertical line at 1.00 favour laparoscopic inguinal hernia repair (LIHR). Point estimates are significant at the $P < 0.050$ level if their confidence intervals exclude the vertical line at 1.00. OIHR, open inguinal hernia repair; TEP, totally extraperitoneal repair; TAPP, transabdominal preperitoneal repair; IPOM, intraperitoneal onlay mesh repair

costs⁹. Furthermore, long-term results are unknown⁹. This controversy has encouraged a number of investigators to initiate randomized clinical trials in an attempt to address some of these issues. With two exceptions^{50,56}, these comparative trials have recruited a limited number of patients (Table 1). The published results for various outcome measures have been contradictory, further intensifying the debate. To clarify some of these issues, a meta-analysis was undertaken, concentrating on six treatment variables of great importance in inguinal hernia repair that could be analysed objectively. In the past, meta-analyses⁶⁴ and a systematic review⁶⁵ on this subject have been published. Their findings are compared with those of this meta-analysis and the significant differences are highlighted.

Of the 28 trials that reported the duration of operation, 19 revealed statistically significantly longer operations for LIHR than for OIHR (Fig. 1). Pooling these trials revealed an overall significantly longer operating time for LIHR (Table 1). Subgroup analysis continued to show this trend for TAPP and TEP against both tension-free and tension-creating open repairs (Tables 3 and 4). This has important implications for both patients and healthcare providers. Longer operations expose patients to a protracted anaesthesia, which may increase the morbidity and even mortality rates. Longer operating and anaesthesia times also increase the direct cost of the procedure. The longer operating time for LIHR may in part reflect an early learning curve, as this is a relatively new

procedure. Furthermore, the operating time for LIHR also includes the time for setting up laparoscopic equipment. With experience, however, the operating time for LIHR is approaching that for OIHR^{23,46}. The previous two meta-analyses^{64,65} have also shown a significantly longer operating time for LIHR, but there was no subgroup analysis for TAPP and TEP.

The majority of trials showed a trend towards earlier discharge from hospital after LIHR (Fig. 2). Pooling these trials resulted in overall significantly earlier discharge from hospital for LIHR compared with OIHR (Table 2). In sensitivity analysis, the extreme finding of Champault *et al.*⁵⁵ was found to be highly influential; when it was removed from the analysis the effect was dramatically reduced and no longer statistically significant (WMD - 1.14 (95 per cent c.i. - 4.21 to 1.92) h; $P = 0.464$). Subgroup analysis continued to show this trend although in some cases it was no longer significant at the 5 per cent level (Tables 3 and 4). These conclusions are different from those drawn by the EU Hernia Trialists Collaboration (EUHTC) meta-analysis⁶⁵, which showed no difference in postoperative length of stay between the two groups. These contradictory findings may be explained by the fact that 25 trials were analysed for this variable in the present analysis as opposed to 20 by the EU group, and the inclusion of these additional data might have had a bearing on the overall results.

Patients returned to normal activity much sooner after LIHR (Fig. 3). This finding was universal among the reported trials and was confirmed by the present analysis. Subgroup analysis showed significantly earlier return to normal activity after either TAPP or TEP repair compared with OIHR (Table 3). Furthermore when LIHR was compared with tension-free and tension-creating OIHR, this effect remained in favour of LIHR (Table 4). An earlier return to normal activity after LIHR may be possible owing to the absence of a groin incision and dissection of the groin musculature, or the tension-free nature of the repair. It might also be affected by different postoperative instructions for LIHR and OIHR, a differential perception of the two types of hernia repair acquired through health professionals and the lay media by the patient (patient bias), or even inherent physician bias, rather than any true biological response to the type of hernia repair. The previous two meta-analyses^{64,65} have similarly shown that LIHR leads to an early return to usual activity. However, neither of these analyses differentiated between return to full activity and return to work. The present analysis considered these variables separately, providing data that are likely to be important for employers and worker's disability compensation.

Patients returned to work more quickly after LIHR (Fig. 4). This finding was also universal among the reported trials, and was confirmed by the present analysis of all pooled data and the subgroup analysis (Tables 3 and 4).

Only three studies^{32,34,35} evaluated quality of life objectively after LIHR. Payne *et al.*³² used a panel of exercises devised to test the muscles of the lower abdomen, arms and upper legs most affected by inguinal hernia repair. They noted a significant correlation between straight leg raise (SLR) exercises at 1 week and return to physically demanding jobs. Comparison of the two hernia operations by this criterion favoured LIHR. They also noted that patients who had bilateral laparoscopic repair regained the baseline for SLR by 1 week. In contrast, after bilateral OIHR patients regained normal SLR only after 4 weeks. Barkun *et al.*³⁴ used the Nottingham Health Profile Questionnaire to show that the improvement in quality of life was significantly greater after LIHR than OIHR at 1 month only. Lawrence *et al.*³⁵ reported a significant improvement in social function and energy, and significantly less pain at 10 days and 6 weeks after LIHR than OIHR. They failed, however, to show any significant improvement in the time to resumption of normal activity after LIHR. As 26 other trials failed to measure quality of life objectively, it is possible that physician and patient bias may have determined the earlier return to a normal lifestyle after LIHR.

It has been estimated that hernia repair causes the loss of 10 million working days each year, at a cost that has not been defined precisely, but is obviously enormous^{8,66}. An early return to productive activity is therefore important for society in general. As the contribution of employers to their employees' healthcare benefits continues to increase, earlier return to work should be an incentive to the use of LIHR. This meta-analysis noted a mean reduction of 7 days in sick leave after LIHR. The issue of postoperative quality of life after LIHR remains controversial because of poor-quality data and, until these issues have been studied objectively, it will be difficult to convince healthcare providers to reimburse for laparoscopic hernia repair.

Gilbert and Graham⁶⁷ reported a complication rate of 29 per cent after 867 LIHRs by a group of surgeons who specialized in the procedure. They reported rates of blood transfusion, bladder injury, urinary tract infection, need for immediate reoperation, bowel obstruction, myocardial infarction, transient leg pain, persistent leg pain and hydrocele formation that were ten times greater than those after OIHR. MacFadyen *et al.*⁶⁸ similarly reported a high incidence of complications after 841 LIHRs performed by a group of dedicated laparoscopic surgeons. However, the present analysis failed to show a higher incidence of either

minor or major complications after laparoscopic hernia repair (Fig. 5). On the contrary, the overall number of complications after laparoscopic repair was less than that after open repair. This discrepancy may be explained by the small numbers of patients in individual series, experienced and senior surgeons performing LIHR compared with OIHR, and the reporting of only significant complications after LIHR.

Of the 29 trials analysed, 19 demonstrated an increase in complication rates after OIHR and in eight^{33,38,42,46,50,54–56} this difference was statistically significant. The other ten studies showed an increased incidence of perioperative morbidity with LIHR but in only one was this difference significant³⁵. In the present meta-analysis a significant reduction in the complication rate was demonstrated after LIHR compared with OIHR. Subgroup analysis also showed that both TAPP and TEP repairs were associated with significantly fewer complications than open repair (Table 3). Furthermore, this effect was still apparent when LIHR was compared with tension-creating and tension-free repairs (Table 4). It is estimated that the cost of repairing 500 000–700 000 inguinal hernias per annum in North America is approximately \$3 billion (direct and indirect costs)^{8,66}. Reducing the number of complications should produce significant savings with an equal or better health outcome.

The early observations of a higher risk of complications after LIHR no longer appear valid. As the laparoscopic procedure is still evolving, further modifications of the operative technique may reduce complication rates even further. The risks of trocar-site hernia (at 10- or 12-mm ports) and neuralgia have been virtually eliminated by the closure of all trocar sites, avoiding staples for repair, and judicious staple placement or use of a tacking device if the mesh is fixed^{8,69}. The use of the open trocar placement technique for TAPP repair, or the use of TEP repair, has virtually eliminated the incidence of hollow viscus and vascular injury.

In the present analysis there was a trend towards an increase in the odds of short-term hernia recurrence following LIHR of 50 per cent compared with OIHR (Table 2 and Fig. 6) but this difference was not significant. Subgroup analysis supported this trend towards an increased recurrence rate after LIHR although it was statistically significant only for laparoscopic repair *versus* tension-free open repair (Tables 3 and 4). The two previous meta-analyses^{64,56} similarly showed non-significantly higher rates of recurrence after LIHR. Recurrences during the first 12–18 months after surgery are usually due to technical error^{69,70}. Lowham *et al.*⁷¹ in their review of causes of recurrence after LIHR found that surgeons

with experience of more than 50 laparoscopic repairs had a recurrence rate of less than 1 per cent. This learning curve is similar to that for tension-free OIHR^{72,73}. Half of all recurrences after open hernia repair occur after 5 years and 75 per cent within 10 years after surgery^{74,75}, so longer-term follow-up after LIHR remains essential for a meaningful comparison with OIHR.

The present meta-analysis included a total of 5989 inguinal hernia repairs in 5588 patients, the largest body of information so far available for the comparison of LIHR and OIHR in the English language literature. Laparoscopic repair was associated with significantly fewer postoperative complications, earlier hospital discharge and faster return to normal activity and work, but at the expense of a longer operating time. Although there was no significant difference in short-term recurrence rates there was a trend towards an increase in the relative odds of recurrence after laparoscopic repair. Some of the more controversial issues surrounding laparoscopic repair, such as postoperative pain and cost, have been difficult to analyse because of the varied reporting methodologies. It is likely that the minor complications of LIHR were under-reported because of a preoccupation with major complications, which continue to attract attention despite their low incidence. Moreover, the long-term recurrence rate is unknown after LIHR. These data are awaited eagerly as they will have a major impact on whether or not LIHR is adopted as the procedure of choice for inguinal hernia. Nonetheless, it may be concluded that LIHR is a safe and effective alternative to OIHR that enables a faster convalescence and return to productive activity. The increased short-term recurrence rate is of concern and must be addressed in further large randomized trials now that the learning phase of this technique has been passed.

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