REVIEW ARTICLE

Royal Australasian College of Surgeons

Robotic inguinal hernia repair: systematic review and meta-analysis

Amjad Qabbani,* Omar M. Aboumarzouk ,*†‡ Tamer ElBakry,* Abdulla Al-Ansari* and Mohamed S. Elakkad*

*Surgical Department, Hamad Medical Corporation, Doha, Qatar
†School of Medicine, Dentistry and Nursing, The University of Glasgow, Glasgow, UK and
‡College of Medicine, Qatar University College of Medicine, Doha, Qatar

Key words
hernia repair, herniorrhaphy, inguinal hernia repair, robot.

Correspondence

A. Qabbani MD; **O. M. Aboumarzouk** MBChB, MSc, PhD, MRCS, FRCS (Urol); **T. ElBakry** MD; **A. Al-Ansari** MD; **M. S. Elakkad** MD.

Accepted for publication 20 November 2020.

doi: 10.1111/ans.16505

[Correction added on 27 Januar 2021, after first online publication: copyright line updated.]

Abstract

Background: We aimed to conduct a systematic review and meta-analysis of RHR's efficiency and safety, in addition to comparison between open and laparoscopic techniques.
Methods: A literature review was conducted from 2000 to 2020 including studies reporting on their centre's outcomes for robotic hernial repairs. A meta-analysis was conducted. For continuous data, Mantel–Haenszel chi-squares test was used and inverse variance was used for dichotomous data.
Results: In total, 19 studies were included. A total of 8987 patients were treated for hernia repairs, 4248 underwent open repairs, 2521 had robotic repairs and 1495 had laparoscopic repair. Cumulative analysis of robotic series: The overall average operative time was 90.8 min (range 25–180.7 min). The overall conversation rate was 0.63% (10/1596). The overall complication rate was 10.1% (248/2466). The overall recurrence rate was 1.2% (14/1218). Readmission rate was 1.6% (28/1750). Comparative meta-analysis outcomes include robotic versus open and robotic versus laparoscopic. Robotic versus open: The robotic group had significantly longer operative times and less readmission rates. There was no difference between the two groups regarding complications, post-operative pain occurrence and hernia recurrence rates. Robotic versus laparoscopic: The robotic group had significantly longer operative times and less complications. There was no difference regarding post-operative pain occurrence, hernia recurrence rates or readmission rates.
Conclusion: Robotic hernia repair is a safe and efficient technique with minimal complications and a short learning curve; however, it remains inferior to the standard open technique. It does, however, have a role in minimally invasive technique centres. A multicentre randomized control trial is required comparing robotic, open and laparoscopic techniques.

Introduction

With a lifetime risk of nearly 25% in men and 3% in women, more than 20 million groin hernial repairs are carried out worldwide.[1,2] Traditionally, hernial repair is carried out with the open techniques with a low morbidity rate; however, with the advent of minimally invasive surgery, the procedure has been carried out utilizing laparoscopy.[3,4] Laparoscopy has the advantage of shorter recovery periods than the traditional open Lichtenstein procedure.[5] Laparoscopy allowed the development of new techniques, such as the transabdominal preperitoneal repair and the extraperitoneal repair, which maintain low recurrence rates and complications rates of the traditional open repair allowing for less post-operative pain and a quicker recovery period, in addition to allowing for detection of bilateral hernia in its early stages leading to concurrent repair.[4,6]

However, with the advent of the robotic system, given an increased manoeuvrability, improved vision with 10 times magnification, three-dimensional views, enhanced endo-wrist dexterity and a shorter learning curve, robotic hernia repair is becoming more popular and being utilized by skilled surgeons.[3,4,6,7] Worldwide, there has been an exponential increase in the use of the robot through the surgical specialties, with nearly a 175% increase over a 5-year period and 625% increase in the USA alone.[8,9]

Although the first to utilize the robotic system to repair inguinal hernias were urologists, during robotic prostatectomy procedure, general surgeons have quickly taken this advanced technique to their armament.[10,11] The first robotic series published was described in 2015 in France; however since then, the number of centres have risen significantly reporting their outcomes.[12] Furthermore, there have been a number of studies that have looked at various aspects of the robotic technique, in addition to four review articles.[3,4,6,13] However, these have only included less than half of the current published literature describing robotic hernial repairs, in addition to missing out published literature on the subject matter. Ergo, a more methodical approach, is required to ensure all published material is included into a systematic review and meta-analysis.

To this end, we aimed to carry out a thorough up-to-date systematic review and meta-analysis of the literature looking at the efficacy and safety of robotic inguinal hernia repair as well as comparing robotic to open and laparoscopic repairs.

Methods

The systematic review was performed using Cochrane and PRISMA guidelines.[8,14,15] The search strategy included the following databases to identify relevant articles: the USA National Library of Medicine's life science database (MEDLINE) (2000–May 2020), EMBASE (2000–May 2020), Cochrane Central Register of Controlled Trials – CENTRAL (in the Cochrane Library – 2020), CINAHL (2000–May 2020), Clinicaltrials.gov, Google Scholar and individual journals.

Search terms used in conjunction with each other included: 'Inguinal', 'Hernia', 'Laparoscopic', 'Robotic', 'Robot', 'Robotic Assisted', 'Hernia Repair' and 'Inguinal Hernia Repair'.

Medical Subject Headings (MeSH) phrases included:

- ('Robotic Surgical Procedures' (Mesh) AND 'Hernia, Abdominal' (Mesh))
- ('Robotic Surgical Procedures' (Mesh) AND 'Hernia, Inguinal' (Mesh))
- ('Robotic Surgical Procedures' (Mesh) AND 'Herniorrhaphy' (Mesh)).

Study selection

All languages were included if data were extractable, and also references of searched papers were evaluated for further studies for potential inclusion. Authors were contacted wherever the data were not available or not clear, to be able to adequately assess inclusion of their study. If data were not extractable, provided or clarified, the study was excluded.

Studies that had duplicate data in another study were excluded and only the largest of the two data sets were included. No assumptions were made regarding data; if it was unclear or not mentioned, the data were not included into the meta-analysis.

Reviewers (AQ, OMA and MSE) identified studies that appeared to fit the inclusion criteria for full review. The reviewers independently selected studies for inclusion. Disagreement between the authors in study inclusion was resolved by consensus of all authors.

Data extraction

Data of each included study were independently extracted by the authors (AQ and OMA) after which a senior author (MSE) extracted the data independently and cross checked each data extraction to ensure quality assurance of data across the board. Discrepancy of the data extraction was resolved by consensus by all extracting authors.

Only published studies on adult patients were included, describing the corresponding institutes experience in robotic inguinal hernia repair. Case series <10, case reports, editorials, surveys, animal studies, hernia repairs in conjunction, paediatric reports and single-site surgery (as this is still an evolving technique and majority of surgeons do not use single-site surgery) were excluded.

The following variables were extracted from each study: patient demographics, operative times, mesh used, mesh fixations, peritoneal closure, conversion rates, recurrence rates complications and follow-up. The data of each study were grouped into a meta-analysis in an intention-to-treat basis.

We intend to portray the efficacy and safety by analysing the operative parameters as well as outcomes (i.e. complications and recurrence rates). Furthermore, an analysis of comparison between open, laparoscopic and robotic procedures was carried out where data were available.

Statistical analysis and quality assessment

We used the Review manager (RevMan) v.5.2 programme (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) to conduct the analysis. For continuous data, a Mantel–Haenszel chi-squared test was used and expressed as the mean difference with 95% confidence interval (CI) and an inverse variance was used for dichotomous data and expressed as risk ratio with 95% CI. $P < 0.05$ was considered significant.[8] For rates, percentages of total were used using excel to calculate from tables.

Heterogeneity was analysed using a chi-squared test on N-1 degrees of freedom, with an alpha of 0.05 used for statistical significance and with the I^2 test. I^2 values of 25%, 50% and 75% correspond to low, medium and high levels of heterogeneity, respectively.[8] A fixed-effect model was used unless statistically significant high heterogeneity ($I^2 > 75\%$ was considered as significantly high heterogeneity) existed between studies. A random-effects model was employed if heterogeneity existed.[16,17]

An assessment of the methodological quality of the studies was conducted in line with the National Institutes of Health's Study Quality Assessment Tools.[18]

Results

Literature search

The literature search identified 820 studies, of which 257 were removed due to duplication and 521 were excluded due to non-relevance based on titles and abstracts (Fig. 1). Full manuscripts were evaluated in 42 studies, of which 21 studies were excluded due to not meeting inclusion criteria. The remaining 21 studies were included (Fig. 1).[5,12,13,19–36] However, three studies were from the same centres and data were used only once.[20,24,29] Furthermore, one study included two sets of robotic data; therefore, each data were used independently.[25] Therefore, in total, 19 studies were included (Fig. 1).

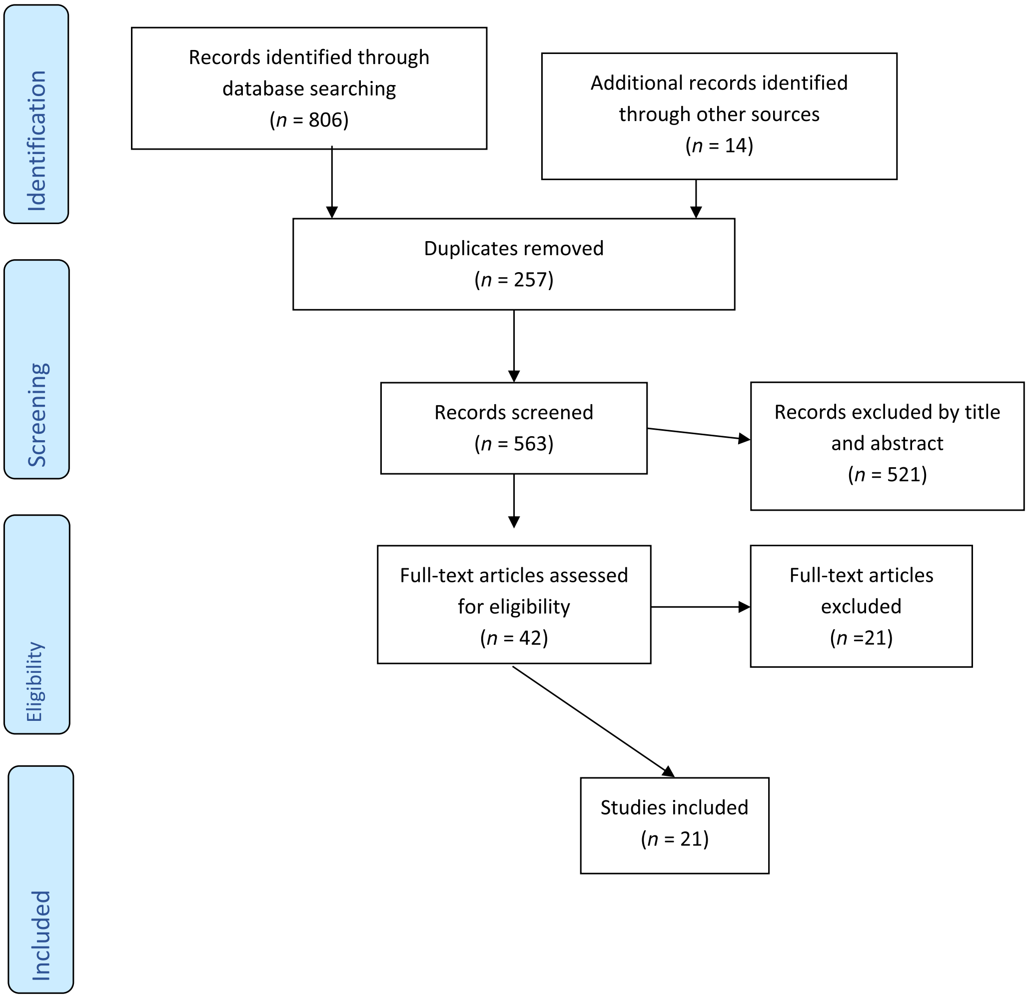


Fig 1. Flow chart for article selection process of the review.

Characteristics of the included studies

The trials span over a 5-year period from 2015 with the latest in 2020. All the studies except two were from the USA, one being the first published series from France and the other from Belgium.[12,32] Nearly all the studies were retrospective (15 studies), four were prospective, 17 were single centre and two were multicentre studies (Table 1). Five studies compared between robotic and open repairs and eight studies compared between robotic and laparoscopic hernial repairs (Table 1).

A total of 8987 patients were treated for hernia repairs, of whom 4248 underwent open repairs, 2521 had robotic repairs and 1495 had laparoscopic repair (Table 1). Ages ranged from 16 to 96.

Cumulative analysis of robotic series

In total, 2521 patients underwent robotic hernia repairs. The majority (92.3%, 2215/2400) were men. Age ranged from 16 to 96 with a mean age of 50.6 years. The mean body mass index (BMI) was 22.95, with a range of 16.4–40.4. There were 601 patients who underwent bilateral repairs, representing 38.8% of those that reported on laterality (601/1550).[12,13,21,23–25,27,28,30–32,35] Of the studies that mentioned the types of mesh used, the majority used the Progrip mesh (Medtronic, Minneapolis, USA) (61.5%, 8/13).[12,13,19,24,25,30–32] Fourteen studies mentioned the mesh fixation used, four studies did not fixate the mesh and relied on its self-gripping properties,[12,25,31,32] four studies also used sutures,[13,19,27,35] two studies used glue,[22,28] three studies used sutures and tacks[23,24,30] and one study used only tacks.[36]

Seventeen studies mentioned their overall complications rates,[5,12,13,19,21–25,27,28,30–35] 13 studies reported their hernial recurrence rates,[5,12,13,19,22–25,27,28,30,33,36] seven studies reported their readmission rates[5,21,24,30,31,34] and the follow-up period across the 19 studies ranged from 17 to 864 days with an average of 170 days.

Cumulative analysis of operative outcomes

Cumulative analysis of operative outcomes include the following:

- The overall average operative time across the board was 90.8 min (range 25–180.7 min). Six studies provided data regarding unilateral and bilateral repairs, comparison of which shows it takes more time to do a bilateral repair (Fig. 2).
- The overall conversation rate was 0.63% (10/1596).

Table 1 Patient demographics

Robotic cumulative	Study design	Robot system	Total patients	Age	Sex (male/total)	BMI	Bilateral
Engan (2015)[12]	Ret, single centre	Si	34	49.3 (16–80); mean	30/34	26.5 (19.8–40.4)	9/34
Arcerito (2016)[19]	Pros, single centre	Si	78	56 (25–96)	62/78	26 ± 5.4	NM
Escobar Dominguez (2016)[23]	Ret, single centre	Si or Xi	78	55.1 ± 15.1	71/78	27.6 ± 6.1	45/78
Oviedo (2016)[33]	Ret, single centre	Si	27	NM	NM	NM	NM
Waite (2016)[35]	Ret, single centre	Si	39	58.1 (21–80)	38/39	27.5 (23.02–35.87)	10/39
Edelman (2017)[22]	Ret, single centre	Si or Xi	154	57 (21–85)	138/154	24.3 (19–31.6)	NM
Higgins (2017)[26]	Ret, single centre	Si	12	NM	NM	NM	NM
Iraniha (2018)[28]	Pros, single centre	Si	82	52.8 (17–83)	NM	26.4 (16.4–35.6)	77/82
Kudsi (2017)[31]	Ret	Xi	118	58.8 ± 15.4	101/118	28.44 ± 5.02	35/118
Charles (2018)[5]	Ret	SI	69	52 (39–62); 52 ± 3.8	59/69	24.9 ± 4.6; 24.9 ± 0.9	NM
Gamagami (2018)[24]	Ret, multicentre	Si	444	55.8 ± 15.9	397/444	26.8 ± 4.7	69/444
Gonzalez-Hernandez (2018)[25]	Ret, single centre	Si	54	57.5 ± 14.1	51/54	27.6 ± 4.8	30/54
Gonzalez-Hernandez (2018)[25]	Ret, single centre	Si	50	50.6 ± 13.5	49/50	29.3 ± 4.7	23/50
Kosturakis (2018)[30]	Ret, single centre	Xi	100	57.2 ± 1.3	100/100	27.8 ± 4.8	59/100
Muysoms (2018)[32]	Pros, single centre	Xi	49	60.4 ± 16.5	48/49	25 ± 3.4	15/49
Tam (2019)[13]	Ret, single centre	Si or Xi	335	58.9 ± 14.1	311/335	26.9 ± 4.6	131/335
Huerta (2019)[27]	Ret, single centre	Xi	71	59.9 ± 12.5	71/71	27.5 ± 5.2	42/71
Pokala (2019)[34]	Ret, multicentre	Si or Xi	594	NM	566/594	NM	NM
Zayan (2019)[36]	Ret, single centre	NM	37	53.9 (49.1–58.6)	37/37	27.36 (25.29–29.39)	NM
Ebeling (2020)[21]	Pros, single centre	Xi	96	54.7 ± 15.9	86/96	NM	56/96
Robotic versus open							
Charles (2018)[5]	Ret	SI	69	52 (39–62); 52 ± 3.8	59	24.9 ± 4.6; 24.9 ± 0.9	NM
		Open	191	56 (48–67); 56 ± 3.1	175	25.1 (23.2–27.8); 25.1 ± 0.7	NM
Gamagami (2018)[24]	Ret, multicentre	Si	444	55.8 ± 15.9	397	26.8 ± 4.7	69
		Open	444	56.4 ± 16	401	27 ± 5	71
Kosturakis (2018)[30]	Ret, single centre	Xi	100	57.2 ± 1.3	100	27.8 ± 4.8	59
		Open	100	63.5 ± 1.1	99	26.2 ± 0.5	7
Huerta (2019)[27]	Ret, single centre	Xi	71	59.9 ± 12.5	71	27.5 ± 5.2	42
		Open	1100	61.3 ± 12.8	1097	26.6 ± 4.3	80
Pokala (2019)[34]	Ret, multicentre	Si or Xi	594	NM	566	NM	NM
		Open	2413	NM	2029	NM	NM
Robotic versus laparoscopic							
Waite (2016)[35]	Ret, single centre	Si	39	58.1 (21–80)	38	27.5 (23.02–35.87)	10
		Lap	24	57.5 (43–72)	24	27.6 (21.02–33.25)	6
Higgins (2017)[26]	Ret, single centre	Si	12	NM	NM	NM	NM
		Lap	274	NM	NM	NM	NM
Kudsi (2017)[31]	Ret	Xi	118	39	101	28.44 ± 5.02	35
		Lap	157	55.1 ± 14.8	149	27.01 ± 4.86	37
Charles (2018)[5]	Ret	SI	69	52 (39–62); 52 ± 3.8	59	24.9 ± 4.6; 24.9 ± 0.9	NM
		Lap	241	57 (45–67); 57 ± 5.5	214	25.8 (23.1–28.4); 25.8 ± 1.3	NM
Muysoms (2018)[32]	Pros, single centre	Xi	49	60.4 ± 16.5	48	25 ± 3.4	15
		Lap	63	59 ± 11.8	61	24 ± 3	41
Huerta (2019)[27]	Ret, single centre	Xi	71	59.9 ± 12.5	71	27.5 ± 5.2	42
		Lap	128	58.3 ± 12.4	128	26.3 ± 4.1	104
Pokala (2019)[34]	Ret, multicentre	Si or Xi	594	NM	566	NM	NM
		Lap	540	NM	434	NM	NM
Zayan (2019)[36]	Ret, single centre	NM	37	53.9 (49.1–58.6)	37	27.36 (25.29–29.39)	NM
		Lap	68	52.7 (49.2–56.1)	59	26.13 (25.14–27.11)	NM

BMI, body mass index; Lap, Laparoscopic; NM, not mentioned; Pros, Prostpective; Ret, Retrospective.

- The overall complication rate was 10.1% (248/2466).
- Post-operative pain was seen in 2.8% (70/2466).
- Urinary retention was seen in 2.8% (68/2466).
- Infection rate was 0.4% (9/2466).
- Seroma/haematoma rate was 3% (75/2466).
- The remaining 1% (26/2466) patients had other non-specific complications such as renal failure, myocardial infarctions, pulmonary, port site hernia or bowel-related issues.
- One patient died of unrelated health issues (0.0004, 1/2466).

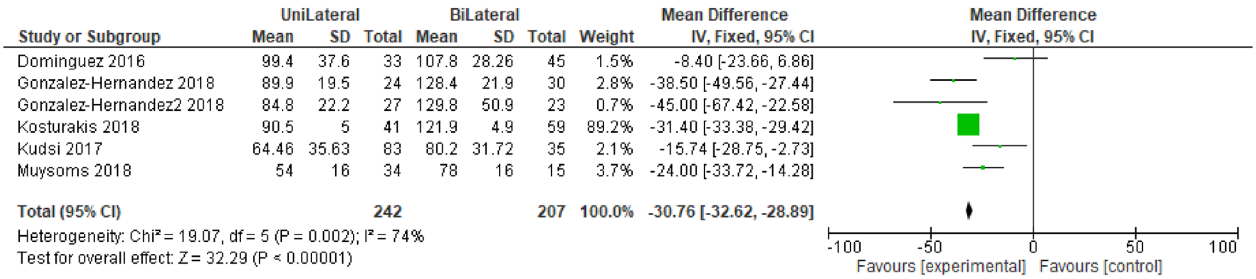


Fig 2. Comparison of unilateral to bilateral robotic operative times.

- The overall recurrence rate was 1.2% (14/1218).
- Readmission rate was 1.6% (28/1750).

Comparative meta-analysis outcomes

Robotic versus open

In total, five studies compared robotic repairs to open repairs.[5,24,27,30,34] There were 1278 robotic cases versus 4248 open cases (Table 1).

Patient demographics. There was a significantly younger group of patients in the robotic group (four studies: 2519 patients) ($P < 0.007$; MD −3.33, 95% CI −5.77, −0.89) (Fig. 3a).

Although more bilateral hernias were repaired in the robotic group (27.6% versus 9.6%), there was no statistical difference (three studies: 2256 patients) ($P = 0.09$; odds ratio (OR) 6.86, 95% CI 0.73, 64.53) (Fig. 3b).

There was no difference regarding BMI (four studies: 2519 patients) ($P = 0.47$; MD −0.08, 95% CI −0.29, −0.13) (Fig. 3c).

Operative outcomes. The robotic group had significantly longer operative times (four studies: 2519 patients) ($P < 0.00001$; MD −31.17, 95% CI 25.80, 36.54) (Fig. 3d).

There was no difference between the two groups regarding complications (6.7% versus 6.9%) (five studies: 5526 patients) ($P = 0.67$; OR 0.78, 95% CI 0.24, 2.48) (Fig. 3e).

There was no difference regarding post-operative pain occurrence (three studies: 2259 patients) ($P = 0.75$; OR 0.56, 95% CI 0.02, 19.07) (Fig. 3f).

There was no difference regarding hernia recurrence rates (3.3% versus 1.7%) (three studies: 1631 patients) ($P = 0.75$; OR 1.87, 95% CI 0.74, 4.70) (Fig. 3g).

There were significantly less readmissions rates in the robotic group (1.8% versus 3.7%) (four studies: 4355 patients) ($P = 0.0006$; OR 0.42, 95% CI 0.26, 0.69) (Fig. 3h).

Robotic versus laparoscopic

In total, eight studies compared robotic repairs to open repairs.[5,26,27,31,32,34–36] There were 989 robotic cases versus 1495 laparoscopic cases (Table 1).

Patient demographics. There was no difference regarding age between the groups (four studies: 896 patients) ($P = 0.93$; MD 0.22, 95% CI −4.91, 5.34) (Fig. 4a).

There were significantly less bilateral repairs in the robotic group (36.9% versus 50.5%) (four studies: 649 patients) ($P = 0.08$; OR 0.63, 95% CI 0.45, 0.89) (Fig. 4b).

There was no difference regarding BMI (four studies: 896 patients) ($P = 0.42$; MD 0.61, 95% CI −0.86, 2.07) (Fig. 4c).

Operative outcomes. The robotic group had significantly longer operative times (five studies: 1179 patients) ($P = 0.004$; MD 16.56, 95% CI 5.24, 27.87) (Fig. 4d).

There were significantly less complications in the robotic group (1.3% versus 3.6%) (four studies: 1829 patients) ($P = 0.005$; OR 0.39, 95% CI 0.2, 0.76) (Fig. 4e).

There was no difference regarding post-operative pain occurrence (three studies: 537 patients) ($P = 0.38$; OR 0.73, 95% CI 0.37, 1.46) (Fig. 4f).

There was no difference regarding hernia recurrence rates (1.4% versus 1.5%) (four studies: 889 patients) ($P = 0.78$; OR 0.85, 95% CI 0.27, 2.67) (Fig. 4g).

There was no difference regarding readmission between the groups (1.2% versus 2.2%) (three studies: 1706 patients) ($P = 0.15$; OR 0.56, 95% CI 0.26, 1.24) (Fig. 4h).

Methodological quality assessment

There were 10 case–control studies and nine case series studies included reporting on their experiences with robotic hernial repairs. Only three of the case series and one of the case–control studies were prospective, the remaining were all retrospective studies. All studies included data that was mentionedin their objectives with no missing data unaccounted for. The studies' methodology was explained with no inherent risk of bias detected. The results reflected the data presented. The discussions were specific with each subject matter with no obvious risk of bias and the conclusion reflected the results found.

Based on the reviewers' judgement, regarding the hierarchy of evidence for each study, the studies were considered to be of low quality, despite each study conducted well and methodically. However, collectively, the meta-analysis strengthens the level of evidence despite being a meta-analysis of case series and retrospective/prospective case–control studies.

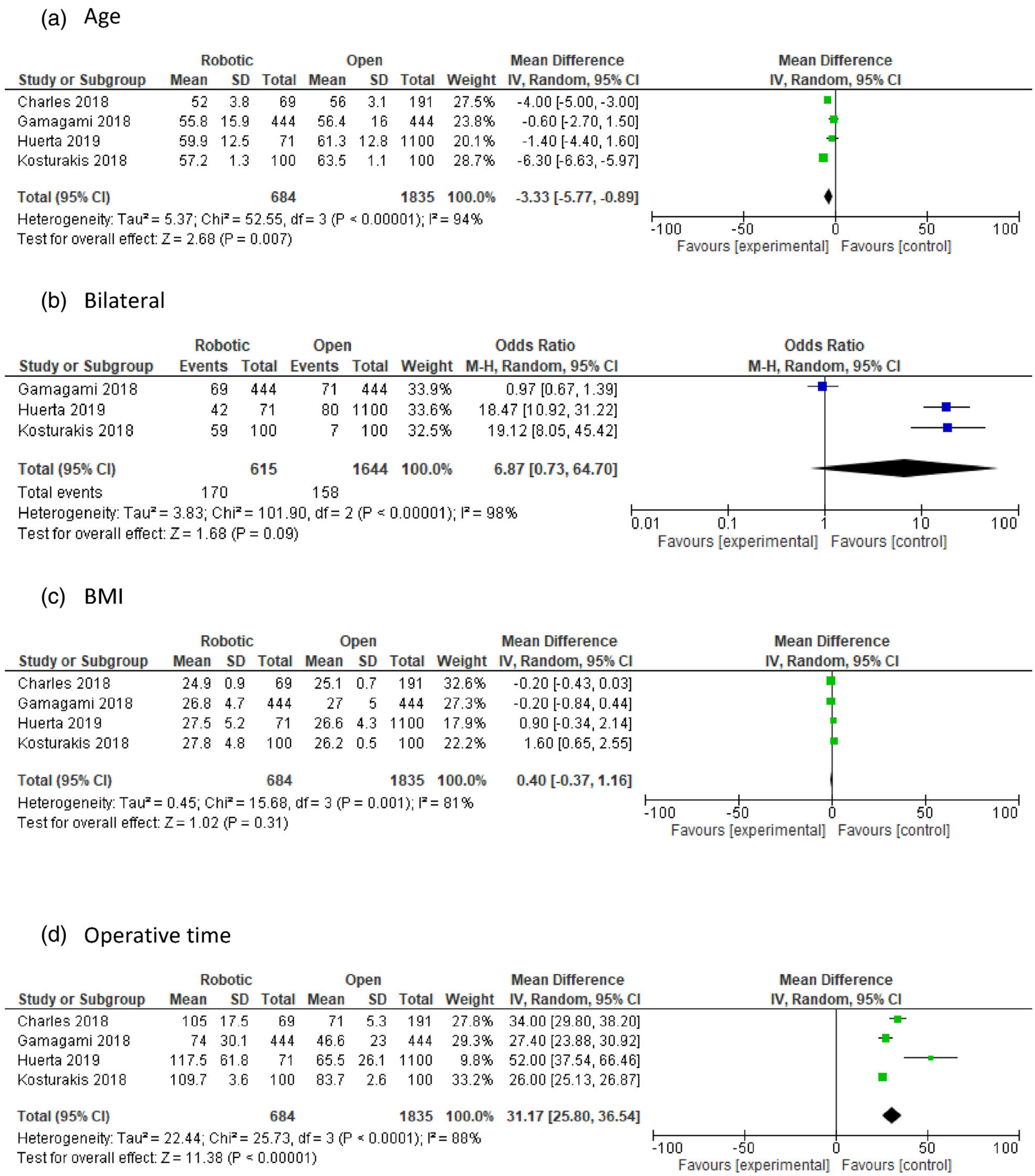


Fig 3. Robotic versus open hernia repair.

Discussion

Summary of results

Cumulative analysis of published robotic hernia repair series has shown that the procedure can take anywhere from 25 min to 3 h to complete. It has a 0.63% conversion to open rate, a 10% chance of developing a complications, a recurrence rate of 1.2% and a readmission rate of 1.6%.

Comparing robotic versus open procedures, the robotic procedure took significantly longer to carry out but had less readmission rate than the open group. Otherwise, no difference regarding complications, pain occurrence or hernia recurrence rates was found between the two groups.

Comparing robotic versus laparoscopic procedures, the robotic procedure took significantly longer to carry out but had less complications than the laparoscopic group. There was no difference

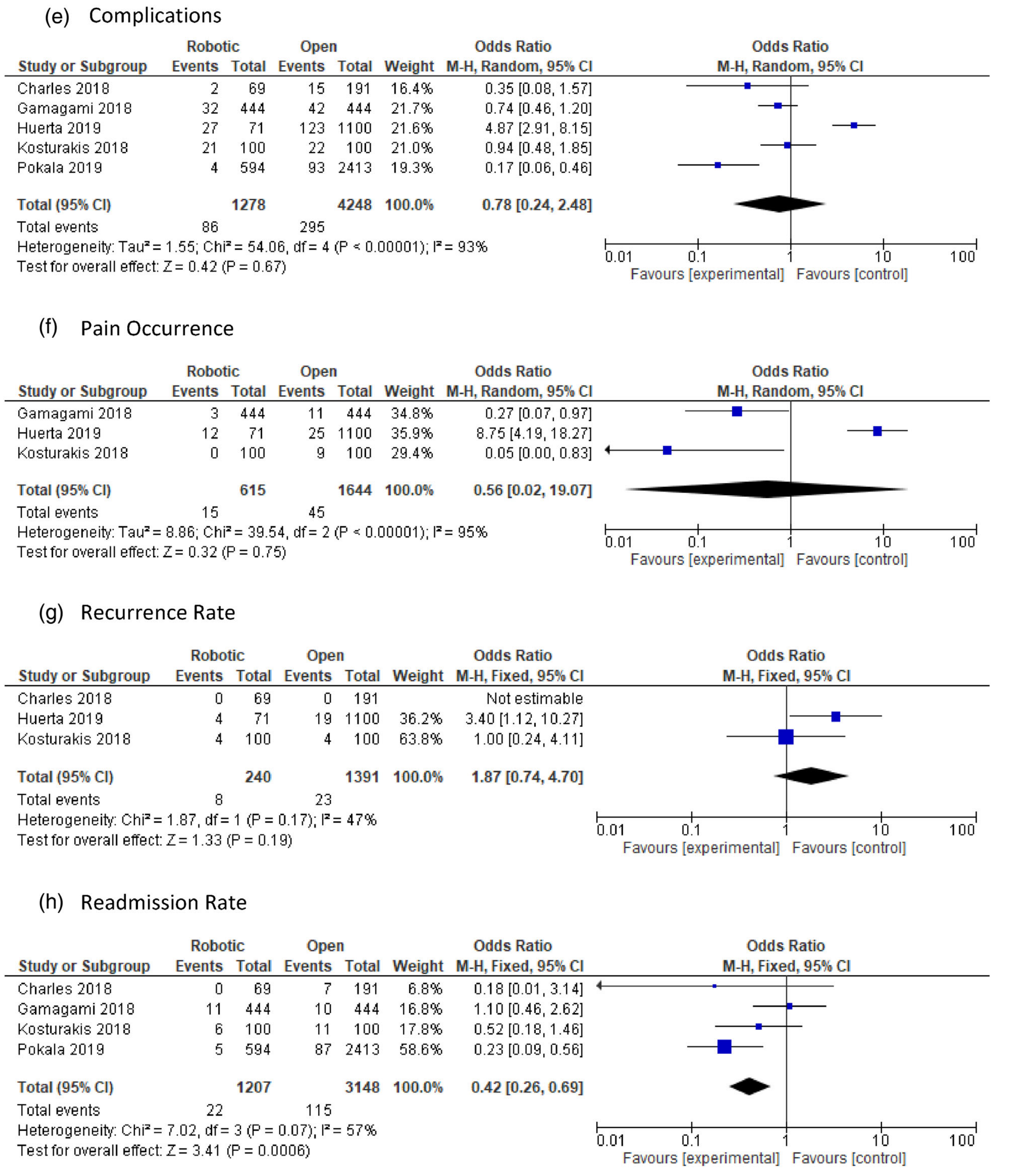


Fig 3. (Continued)

regarding pain occurrence, hernia recurrence or readmission rates between the two groups.

This review was carried out using Cochrane and Prisma guidelines; therefore, it was conducted methodically and thoroughly. Multiple reviewers carried out the literature search and the data collection individually to ensure the accuracy of data. Lastly, this review represent the most up-to-date evidence regarding robotic hernia repairs and can be used to safely counsel and advise patients while consulting to which procedures are available.

Although this review was conducted thoroughly and methodically, it remains limited by the published literature. There were no randomized control trials and the majority of included studies were

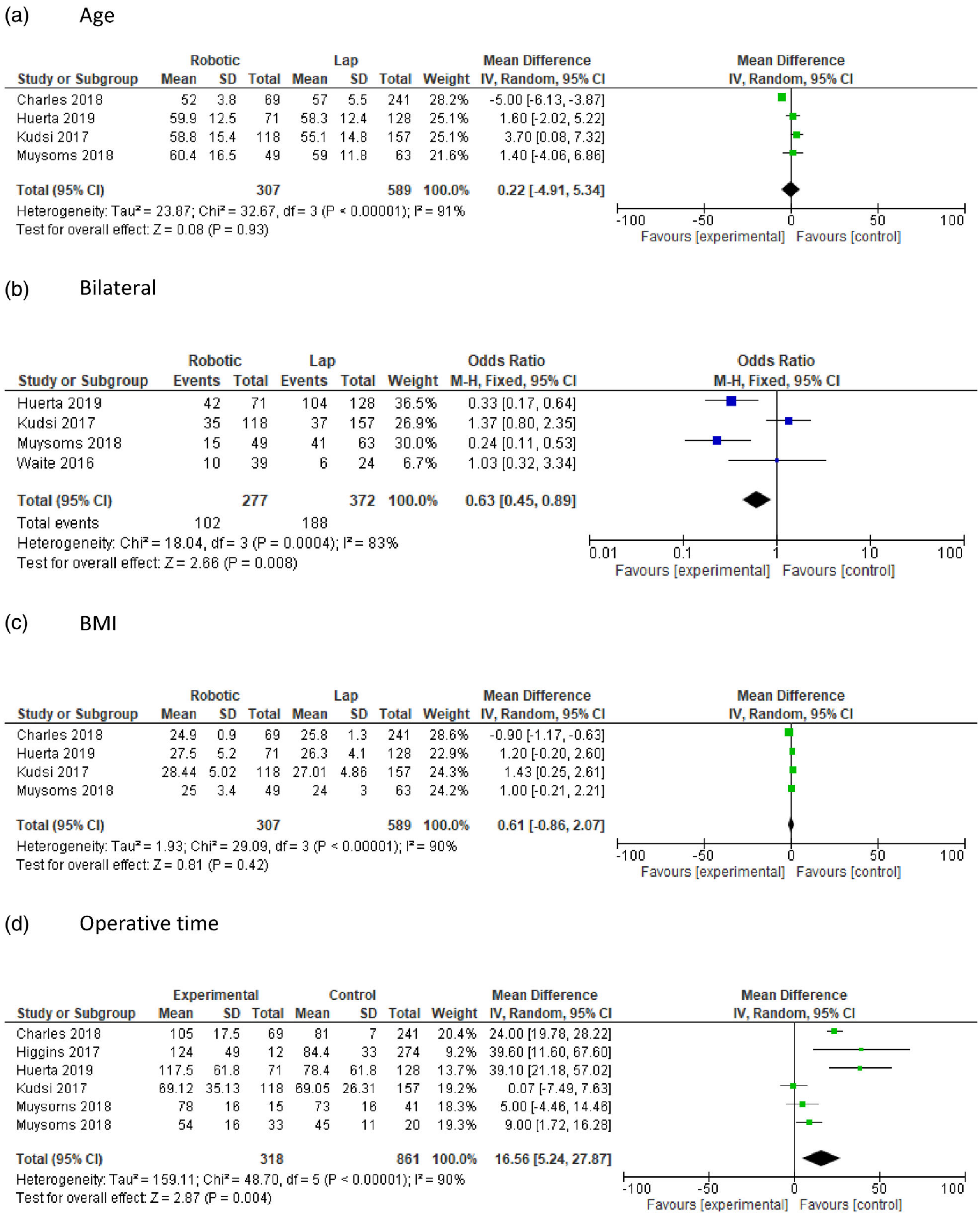
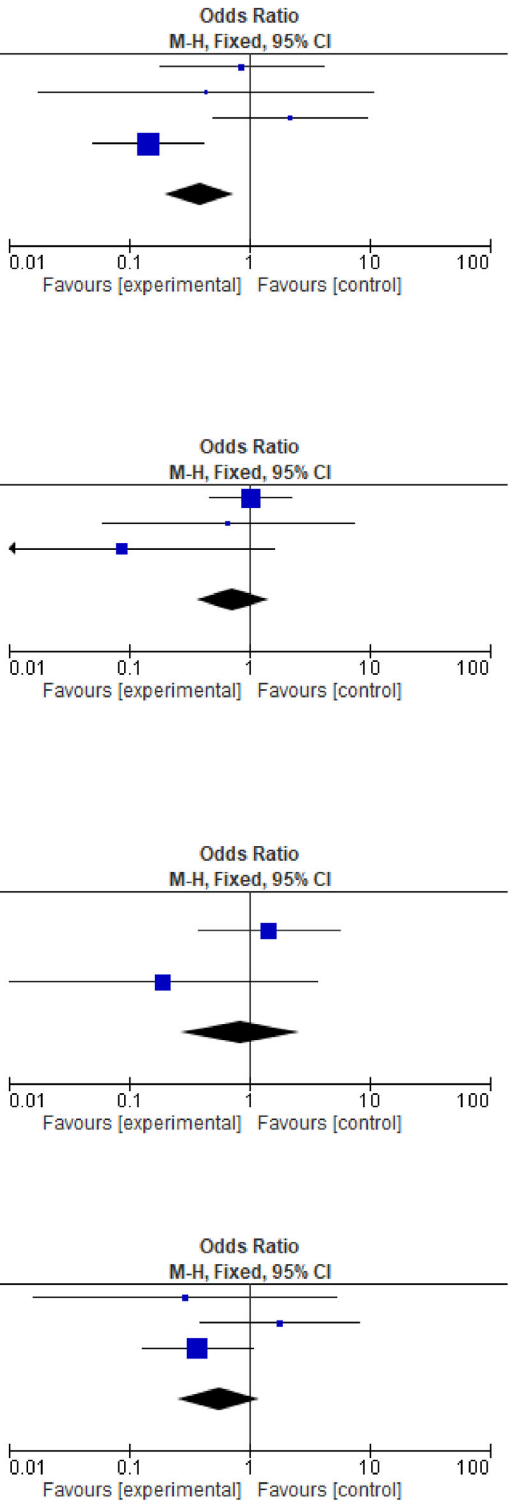


Fig 4. Robotic versus laparoscopic hernia repair.

retrospective cohorts of institutes' experiences with robotic hernia repair.

In addition, although 19 studies were included from a 5-year span, which would represent that the procedure is increasing in popularity, data for detailed comparison to established techniques would be limited. This was evident in that there were only five studies comparing robotic to open and eight comparing to laparoscopic, yet data were not unified across the studies. This



(e) Complications

Study or Subgroup	Robotic Events	Robotic Total	Lap Events	Lap Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Charles 2018	2	69	8	241	10.8%	0.87 [0.18, 4.19]
Kudsi 2017	0	118	1	157	4.0%	0.44 [0.02, 10.90]
Muysoms 2018	5	49	3	61	7.5%	2.20 [0.50, 9.69]
Pokala 2019	4	594	24	540	77.8%	0.15 [0.05, 0.42]
Total (95% CI)		**830**		**999**	**100.0%**	**0.39 [0.20, 0.76]**
Total events	11		36			

Heterogeneity: Chi² = 9.50, df = 3 (P = 0.02); I² = 68%
Test for overall effect: Z = 2.78 (P = 0.005)

(f) Pain Occurrence

Study or Subgroup	Robotic Events	Robotic Total	Lap Events	Lap Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Huerta 2019	12	71	21	128	62.9%	1.04 [0.48, 2.25]
Kudsi 2017	1	118	2	157	8.6%	0.66 [0.06, 7.39]
Waite 2016	32	39	24	24	28.5%	0.09 [0.00, 1.62]
Total (95% CI)		**228**		**309**	**100.0%**	**0.73 [0.37, 1.46]**
Total events	45		47			

Heterogeneity: Chi² = 2.80, df = 2 (P = 0.25); I² = 28%
Test for overall effect: Z = 0.89 (P = 0.38)

(g) Recurrence Rate

Study or Subgroup	Robotic Events	Robotic Total	Lap Events	Lap Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Charles 2018	0	69	0	241		Not estimable
Huerta 2019	4	71	5	128	51.6%	1.47 [0.38, 5.65]
Kudsi 2017	0	118	0	157		Not estimable
Zayan 2019	0	37	4	68	48.4%	0.19 [0.01, 3.65]
Total (95% CI)		**295**		**594**	**100.0%**	**0.85 [0.27, 2.67]**
Total events	4		9			

Heterogeneity: Chi² = 1.61, df = 1 (P = 0.20); I² = 38%
Test for overall effect: Z = 0.28 (P = 0.78)

(h) Readmission Rate

Study or Subgroup	Robotic Events	Robotic Total	Lap Events	Lap Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Charles 2018	0	69	5	228	14.6%	0.29 [0.02, 5.35]
Kudsi 2017	4	118	3	157	14.2%	1.80 [0.40, 8.21]
Pokala 2019	5	594	12	540	71.2%	0.37 [0.13, 1.07]
Total (95% CI)		**781**		**925**	**100.0%**	**0.56 [0.26, 1.24]**
Total events	9		20			

Heterogeneity: Chi² = 3.04, df = 2 (P = 0.22); I² = 34%
Test for overall effect: Z = 1.42 (P = 0.15)

Fig 4. (Continued)

limited the inclusion of all the studies data sets into a meta-analysis.

Furthermore, there was significant heterogeneity in many of the comparative outcomes. This was due to various factors, however, the most obvious was that many centres had included data of their initial experiences, i.e. surgeons were still in their learning curves for the procedures. This had led to discrepancy in the data, mainly affecting the operative times.

For the implications for practice recommendations, the robotic hernia repair is an obvious tool that is used in the armament of surgeons to treat patients. However, it was clear that the open technique remains superior, par for one outcome, hospital readmissions rates. Furthermore, regarding the laparoscopic comparison, although the robotic procedures took significantly longer to carry out, they did have significantly less complications. This would imply that centres which utilize minimally invasive surgery should use the robotic technique where possible to avoid complications.

Therefore, based on these results, one can surmise that the standard open technique remains superior; however, given the fact that there is quicker recovery periods and return to work with the minimally invasive procedures, the panel of reviewers would recommend the robotic technique over the laparoscopic technique. This was evident from Muysoms *et al.*'s study, where they found that the robotic technique was associated with a rapid improvement which improved operative outcomes.[32] Furthermore, this was corroborated by Kudsi *et al.*, where they found no difference between the robotic and laparoscopic groups; however, more complex cases were done robotically.[31] Given time and surpassing learning curves, operative times would potentially equalize as well.

Interestingly, Kolachalam *et al.* have found that the robotic procedures were indeed superior to laparoscopic repairs for obese patients.[29] The role of Ergo might be greater for selected cases.

Nonetheless, despite isolated centres reporting positive outcomes for robotic procedures, until a broader results can be achieved, a definitive recommendation for either of the minimally invasive procedures cannot be given.

A cost analysis was not possible to carry out due to the large discrepancy in cost methods between centres, in addition to lack of homogeneity regarding how costs are determined. By this, we mean centres would report on either instrumental costs, operative room costs, hospitals stay costs and/or surgeons charges. Nonetheless, there seems to be a consensus that the robotic procedure does cost more than either the laparoscopic or open procedures. However, no properly conducted trial was done to compare this outcome and this point remains an observational point.

Conclusion

Robotic hernia repair is a safe and efficient technique with minimal complications and a short learning curve; however, it remains inferior to the standard open technique. It does, however, have a role in minimally invasive technique centres.

A multicentre randomized control trial is required comparing robotic, open and laparoscopic techniques. While single-centre trials are also in need, any future research in this area should include a standardized outcome measure to properly compare between these procedures. Furthermore, subgroup analyses into selected patient cohorts are also required to validate certain outcome measures.

Conflict of interest

None declared.

Author contributions

Amjad Qabbani: Data curation; methodology; writing-original draft. **Omar M. Aboumarzouk:** Conceptualization; formal analysis; methodology; project administration; writing-original draft; writing-review and editing. **Tamer ElBakry:** Data curation; writing-original draft. **Abdulla Al-Ansari:** Conceptualization; writing-review and editing. **Mohamed S. Elakkad:** Conceptualization; methodology; project administration; supervision; writing-review and editing.

References

1. HerniaSurge Group. International guidelines for groin hernia management. *Hernia* 2018; **22**: 1–165.
2. Kingsnorth A, LeBlanc K. Hernias: inguinal and incisional. *Lancet* 2003; **362**: 1561–71.
3. Pirolla EH, Patriota GP, Pirolla FJC *et al*. Inguinal repair via robotic assisted technique: literature review. *Arq. Bras. Cir. Dig.* 2018; **31**: e1408.
4. Aiolfi A, Cavalli M, Micheletto G *et al*. Primary inguinal hernia: systematic review and Bayesian network meta-analysis comparing open, laparoscopic transabdominal preperitoneal, totally extraperitoneal, and robotic preperitoneal repair. *Hernia* 2019; **23**: 473–84.
5. Charles EJ, Mehaffey JH, Tache-Leon CA, Hallowell PT, Sawyer RG, Yang Z. Inguinal hernia repair: is there a benefit to using the robot? *Surg. Endosc.* 2018; **32**: 2131–6.
6. Aiolfi A, Cavalli M, Micheletto G *et al*. Robotic inguinal hernia repair: is technology taking over? Systematic review and meta-analysis. *Hernia* 2019; **23**: 509–19.
7. Ishii H, Rai BP, Stolzenburg JU *et al*. Robotic or open radical cystectomy, which is safer? A systematic review and meta-analysis of comparative studies. *J. Endourol.* 2014; **28**: 1215–23.
8. Higgins JPT, Thomas J, Chandler J *et al*. (eds). *Cochrane Handbook for Systematic Reviews of Interventions Version 6.0*. UK: Cochrane, 2019.
9. Vossler JD, Pavlosky KK, Murayama SM, Moucharite MA, Murayama KM, Mikami DJ. Predictors of robotic versus laparoscopic inguinal hernia repair. *J. Surg. Res.* 2019; **241**: 247–53.
10. Finley DS, Rodriguez E Jr, Ahlering TE. Combined inguinal hernia repair with prosthetic mesh during transperitoneal robot assisted laparoscopic radical prostatectomy: a 4-year experience. *J. Urol.* 2007; **178** (4 Pt 1): 1296–9.
11. Fernando H, Garcia C, Hossack T *et al*. Incidence, predictive factors and preventive measures for inguinal hernia following robotic and laparoscopic radical prostatectomy: a systematic review. *J. Urol.* 2019; **201**: 1072–9.
12. Engan C, Engan M, Bonilla V, Dyer DC, Randall BR. Description of robotically assisted single-site transabdominal preperitoneal (RASS-TAPP) inguinal hernia repair and presentation of clinical outcomes. *Hernia* 2015; **19**: 423–8.
13. Tam V, Rogers DE, Al-Abbas A *et al*. Robotic inguinal hernia repair: a large health system's experience with the first 300 cases and review of the literature. *J. Surg. Res.* 2019; **235**: 98–104.
14. Liberati A, Altman DG, Tetzlaff J *et al*. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS Med.* 2009; **6**: e1000100.
15. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med.* 2009; **6**: e1000097.

16. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ* 2003; **327**: 557–60.
17. Higgins JP, Sally G. *Cochrane Handbook for Systematic Reviews of Interventions*. Xxxx: The Cochrane Collaboration, 2011. Available from URL: www.cochrane-handbook.org.
18. National Institutes of Health. Study Quality Assessment Tools. 2020. Available from URL: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools
19. Arcerito M, Changchien E, Bernal O, Konkoly-Thege A, Moon J. Robotic inguinal hernia repair: technique and early experience. *Am. Surg.* 2016; **82**: 1014–7.
20. Dickens EO, Kolachalam R, Gonzalez A *et al*. Does robotic-assisted transabdominal preperitoneal (R-TAPP) hernia repair facilitate contralateral investigation and repair without compromising patient morbidity? *J. Robot. Surg.* 2018; **12**: 713–8.
21. Ebeling PA, Beale KG, Van Sickle KR *et al*. Resident training experience with robotic assisted transabdominal preperitoneal inguinal hernia repair. *Am. J. Surg.* 2020; **219**: 278–82.
22. Edelman DS. Robotic inguinal hernia repair. *Am. Surg.* 2017; **83**: 1418–21.
23. Escobar Dominguez JE, Ramos MG, Seetharamaiah R, Donkor C, Rabaza J, Gonzalez A. Feasibility of robotic inguinal hernia repair, a single-institution experience. *Surg. Endosc.* 2016; **30**: 4042–8.
24. Gamagami R, Dickens E, Gonzalez A *et al*. Open versus robotic-assisted transabdominal preperitoneal (R-TAPP) inguinal hernia repair: a multicenter matched analysis of clinical outcomes. *Hernia* 2018; **22**: 827–36.
25. Gonzalez-Hernandez J, Prajapati P, Ogola G, Burkart RD, Le LD. Surgical training in robotic surgery: surgical experience of robotic-assisted transabdominal preperitoneal inguinal herniorrhaphy with and without resident participation. *J. Robot. Surg.* 2018; **12**: 487–92.
26. Higgins RM, Frelich MJ, Bosler ME, Gould JC. Cost analysis of robotic versus laparoscopic general surgery procedures. *Surg. Endosc.* 2017; **31**: 185–92.
27. Huerta S, Timmerman C, Argo M *et al*. Open, laparoscopic, and robotic inguinal hernia repair: outcomes and predictors of complications. *J. Surg. Res.* 2019; **241**: 119–27.
28. Iraniha A, Peloquin J. Long-term quality of life and outcomes following robotic assisted TAPP inguinal hernia repair. *J. Robot. Surg.* 2018; **12**: 261–9.
29. Kolachalam R, Dickens E, D'Amico L *et al*. Early outcomes of robotic-assisted inguinal hernia repair in obese patients: a multi-institutional, retrospective study. *Surg. Endosc.* 2018; **32**: 229–35.
30. Kosturakis AK, LaRusso KE, Carroll ND, Nicholl MB. First 100 consecutive robotic inguinal hernia repairs at a Veterans Affairs hospital. *J. Robot. Surg.* 2018; **12**: 699–704.
31. Kudsi OY, McCarty JC, Paluvoi N, Mabardy AS. Transition from laparoscopic totally extraperitoneal inguinal hernia repair to robotic transabdominal preperitoneal inguinal hernia repair: a retrospective review of a single surgeon's experience. *World J. Surg.* 2017; **41**: 2251–7.
32. Muysoms F, Van Cleven S, Kyle-Leinhase I, Ballecer C, Ramaswamy A. Robotic-assisted laparoscopic groin hernia repair: observational case-control study on the operative time during the learning curve. *Surg. Endosc.* 2018; **32**: 4850–9.
33. Oviedo RJ, Robertson JC, Alrajhi S. First 101 robotic general surgery cases in a community hospital. *JSLS* 2016; **20**: e2016.00056.
34. Pokala B, Armijo PR, Flores L, Hennings D, Oleynikov D. Minimally invasive inguinal hernia repair is superior to open: a national database review. *Hernia* 2019; **23**: 593–9.
35. Waite KE, Herman MA, Doyle PJ. Comparison of robotic versus laparoscopic transabdominal preperitoneal (TAPP) inguinal hernia repair. *J. Robot. Surg.* 2016; **10**: 239–44.
36. Zayan NE, Meara MP, Schwartz JS, Narula VK. A direct comparison of robotic and laparoscopic hernia repair: patient-reported outcomes and cost analysis. *Hernia* 2019; **23**: 1115–21.