

Obese patients and robotic colorectal surgery: systematic review and meta-analysis

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Background: Obesity is a major health problem, demonstrated to double the risk of colorectal cancer. The benefits of robotic colorectal surgery in obese patients remain largely unknown. This meta-analysis evaluated the clinical and pathological outcomes of robotic colorectal surgery in obese and non-obese patients.

Methods: MEDLINE, Embase, Global Health, Healthcare Management Information Consortium (HMIC) and Midwives Information and Resources Service (MIDIRS) databases were searched on 1 August 2018 with no language restriction. Meta-analysis was performed according to PRISMA guidelines. Obese patients (BMI 30 kg/m² or above) undergoing robotic colorectal cancer resections were compared with non-obese patients. Included outcome measures were: operative outcomes (duration of surgery, conversion to laparotomy, blood loss), postoperative complications, hospital length of stay and pathological outcomes (number of retrieved lymph nodes, positive circumferential resection margins and length of distal margin in rectal surgery).

Results: A total of 131 full-text articles were reviewed, of which 12 met the inclusion criteria and were included in the final analysis. There were 3166 non-obese and 1420 obese patients. A longer duration of surgery was documented in obese compared with non-obese patients (weighted mean difference -21.99 (95 per cent c.i. -31.52 to -12.46) min; $P < 0.001$). Obese patients had a higher rate of conversion to laparotomy than non-obese patients (odds ratio 1.99, 95 per cent c.i. 1.54 to 2.56; $P < 0.001$). Blood loss, postoperative complications, length of hospital stay and pathological outcomes were not significantly different in obese and non-obese patients.

Conclusion: Robotic surgery in obese patients results in a significantly longer duration of surgery and higher conversion rates than in non-obese patients. Further studies should focus on better stratification of the obese population with colorectal disease as candidates for robotic procedures.

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Introduction

Obesity remains a major global health concern associated with a continuous drain of healthcare resources in the context of both high- and low-income settings. Since 1980, the prevalence of obesity has doubled in over 70 countries, with largest increases in children and adolescents¹. In addition, obesity increases the risk of colorectal cancer, which is currently the second most common cause of cancer-related death worldwide²⁻⁵. Accordingly, the

number of obese individuals requiring curative colorectal cancer surgery continues to rise.

Colorectal surgery in the obese patient has always presented a technical challenge. These difficulties include: the logistics of the theatre environment and having an operating table to accommodate patients with a high BMI; risk of peripheral nerve injury due to lack of protection of pressure areas; and the anatomical challenge of manipulating a significant depth of adipose tissue to obtain adequate access and visualization^{6,7}. In the context of laparoscopic

colorectal surgery, obese patients have higher conversion rates, longer operating times and a higher risk of postoperative complications^{8–12}. The field of view and operative space may be limited in obese patients for several reasons, including: the bulky mesocolon causing difficulty in distinguishing operative planes, dissection, mobilization and ligation of vessels⁸; motion restriction due to increased abdominal wall thickness; and friable fatty tissue which causes difficulty in retraction and has a high risk of bleeding. Owing to patient positioning difficulties, obese patients have a reduced physiological reserve, and this may affect their ability to tolerate a laparoscopic procedure⁶.

Robotic surgery has the potential to overcome the challenges of laparoscopic approaches as a result of greater manual dexterity, multiarticulated instruments, enhanced surgical ergonomics¹³, augmented visualization and three-dimensional imaging. Since the introduction of the first da Vinci[®] telerobotic surgical system (Intuitive Surgical, Sunnyvale, California, USA) in 2001, the worldwide incidence of robotic colorectal resection has been increasing^{14,15}.

The benefits of robotic colorectal surgery on obese patients remain unclear. The Robotic *versus* Laparoscopic Resection for Rectal cancer (ROLARR) trial¹⁶ compared laparoscopic and robotic-assisted colorectal surgery, and found that obese patients had higher overall rates of conversion to open surgery (23.4 per cent) than non-obese patients (6.1 per cent) for laparoscopic and robotic surgery combined. When comparing laparoscopic and robotic surgery in obese patients, laparoscopic surgery had a higher conversion rate than robotic surgery (27.8 *versus* 18.9 per cent respectively)¹⁶. Similar results were found in another study¹⁷ comparing obese and non-obese patients undergoing laparoscopic and robotic surgery.

The aim of the present study was to appraise the literature systematically to identify the clinical outcomes of robotic colorectal surgery in obese *versus* non-obese patients, in order to clarify the evidence regarding the application of this technology in clinical practice.

Methods

A meta-analysis was performed according to the PRISMA and MOOSE guidelines^{18–20}.

Studies were included for quantitative meta-analysis if the following criteria were met: the study compared the outcome between obese and non-obese patients undergoing robotic colonic and/or rectal surgery; obesity was defined as a BMI of 30 kg/m² or above^{21,22}; at least one

of the main outcome measures (see below) was reported; adequate raw data were reported to allow for the exact percentage or number of events to be extracted and standard deviations calculated.

The included outcome measures were: duration of surgery, conversion to laparotomy, blood loss, postoperative complications, length of hospital stay, number of retrieved lymph nodes, positive circumferential resection margin (CRM), and length of distal margin in rectal surgery.

Only full-text, peer-reviewed, published and indexed studies were included. Abstracts, congress proceedings, reviews and case reports were excluded. For the purposes of this review, studies reviewing transanal procedures and laboratory-based studies were also excluded.

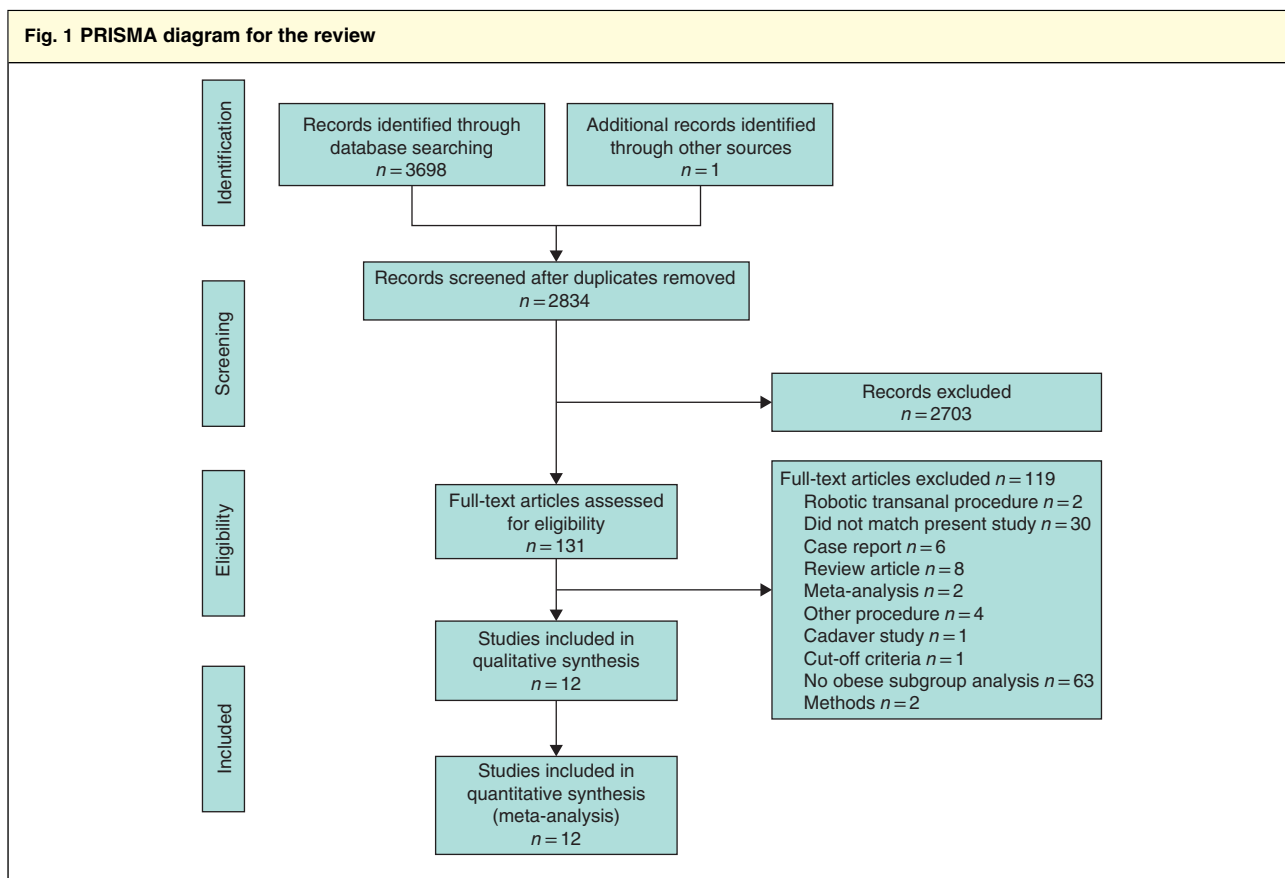
Literature search

All studies were identified using electronic databases and reference lists of articles. Using the OvidSP search engine, MEDLINE, Embase, Global Health, Healthcare Management Information Consortium (HMIC) and Midwives Information and Resources Service (MIDIRS) databases were searched on 1 August 2018. Search terms used were: ‘robot* AND (colon OR rectum OR rectal OR colorectal) AND (obes* OR BMI OR Body Mass Index)’. There was no limit for date and no language restriction. Relevant review articles found through the search strategy were also hand-searched to identify any remaining studies.

Data collection and analyses

Articles were screened from titles and abstracts by two independent authors. Potentially relevant articles that appeared to fit the inclusion and exclusion criteria were obtained in full text. All articles were assessed independently for eligibility by the same authors. Articles were excluded if they were duplicates or data were incomplete. Any disputes in agreement for study inclusion or exclusion were resolved by discussion with the senior author.

Data were registered in Excel[®] (Microsoft, Redmond, Washington, USA), and reviewed subsequently. Data extracted from each trial included: authors and publication year; study design used; inclusion and exclusion criteria; type of procedure (laparoscopic, robotic); outcome measures of interest (operative outcomes: length of operation, rate of conversion and blood loss; postoperative outcomes: anastomotic leak, wound infection, prolonged ileus, postoperative infection and length of hospital stay; oncological outcomes: lymph node harvest, length of distal margin and CRM positivity).



Statistical analysis

Analyses were performed using Stata® version 12 (Stata-Corp, College Station, Texas, USA). For continuous outcomes, the weighted mean difference (MD) between groups with 95 per cent c.i. was calculated. The proportional difference between histological outcomes was calculated and pooled using DerSimonian and Laird random-effects modelling. A quality assessment of non-RCTs was performed using a modification of the Newcastle–Ottawa scale^{20,23}. Studies were assessed in three domains: selection of the treatment group, comparability of the treatment groups, and assessment of outcomes. Studies with a score of seven or more were considered to be of high quality and included in subgroup analyses^{20,23}.

Results

A total of 3698 articles were identified on initial search of the bibliographic databases. After removal of duplicates and full-text screening, 12 articles^{16,17,24–33} subsequently met

the inclusion and exclusion criteria and were included in the meta-analysis (Fig. 1).

The characteristics of each study are shown in Table 1. Across all studies, there was a total of 3166 non-obese and 1420 obese patients. Study types included: one RCT at 29 sites across ten countries¹⁶, two prospective studies^{24,25} and nine retrospective studies^{17,26–33}. In eight studies^{16,17,24,26,28,29,31,33} all patients had malignant disease, whereas four studies^{25,27,30,32} included patients with a benign disease process. In seven studies^{16,17,24,26,28,31,33} only rectal surgery was performed, two^{29,32} did only colonic surgery, and three^{25,27,30} did colonic and/or rectal surgery. As all but one study¹⁶ had a non-randomized design, the Newcastle–Ottawa Scale (NOS) was used (results are shown in Table S1, supporting information). All studies that had used NOS in their methodology were found to be of higher quality.

Duration of operation

Nine articles^{24–28,30–33} included the duration of surgery, with a total of 1306 patients in the obese group and 2491

Table 1 Characteristics of studies included in the meta-analysis

Reference	Country	Study design	Malignant or benign	Location of surgery	No. of patients		NOS
					Non-obese	Obese	
Ackerman <i>et al.</i> ¹⁷	USA	Retrospective (PSM)	Malignant	Rectal	469	64	7
Bayraktar <i>et al.</i> ²⁶	Turkey	Retrospective	Malignant	Rectal	71	20	9
Duchalais <i>et al.</i> ³³	USA	Retrospective	Malignant	Rectal	125	58	9
Jayne <i>et al.</i> ¹⁶	UK, other	RCT	Malignant	Rectal	183	53	9
Baukloh <i>et al.</i> ²⁴	Germany	Prospective	Malignant	Rectal	291	57	6
Harr <i>et al.</i> ²⁷	USA	Retrospective (CMS)	Benign and malignant	Colorectal	108	108	9
Pai <i>et al.</i> ²⁸	USA	Retrospective	Malignant	Rectal	68	33	7
Schootman <i>et al.</i> ³²	USA	Retrospective	Benign and malignant	Colon	1415	815	9
Cardinali <i>et al.</i> ²⁹	Italy	Retrospective	Malignant	Colon	23	7	5
Keller <i>et al.</i> ³⁰	USA	Retrospective (CMS)	Benign and malignant	Colorectal	45	45	7
Lagares-Garcia <i>et al.</i> ²⁵	USA	Prospective	Benign and malignant	Colorectal	69	34	9
Hellan <i>et al.</i> ³¹	USA	Retrospective	Malignant	Rectal	299	126	9

NOS, Newcastle–Ottawa Quality Assessment Scale; PSM, propensity score matching; CMS, case-matched study.

in the non-obese group. Pooled analysis confirmed that duration of surgery was 22.0 per cent longer in obese compared with non-obese patients using robotic surgery (MD -21.99 (95 per cent c.i. -31.52 to -12.46) min; $P < 0.001$) ($I^2 = 30.5$ per cent) (Fig. 2a). In one study²⁵, which organized patients into ‘increasing BMI’ groups, there was a reported mean operating time of 123.4, 137.9 and 154.7 min for patients with a BMI of less than 25 kg/m², 25 to less than 30 kg/m², and 30 kg/m² or more respectively. Patients with a higher BMI had significantly longer operating times²⁵.

Blood loss

Seven articles^{24–28,30,31} included estimated blood loss, with a total of 433 patients in the obese group and 951 in the non-obese group. Pooled analysis showed that estimated blood loss was not significantly lower in non-obese compared with obese patients, although there was a 20.9 per cent reduction in estimated blood loss in non-obese patients (MD -20.86 (95 per cent c.i. -43.23 to 1.52) ml; $P = 0.068$) ($I^2 = 18.8$ per cent) (Fig. 2b).

Conversion rate

All 12 studies included the conversion rate, which is often used as a surrogate marker of difficulty during surgery. There was a total of 1420 patients in the obese group and 3166 in the non-obese group. Pooled results from the 12 studies confirmed a significantly higher conversion rate in the obese patients undergoing robotic surgery (odds ratio (OR) 1.99 (95 per cent c.i. 1.54 to 2.56; $P < 0.001$)) ($I^2 = 0$ per cent) (Fig. 2c).

Complications

Seven studies^{25–27,30–33} reviewed overall postoperative complications relating to the use of robotic surgery, with a total of 1216 patients in the obese group and 2132 in the non-obese group. A pooled OR of 1.09 (95 per cent c.i. 0.94 to 1.28; $P = 0.264$) found no difference in overall complications between the two groups ($I^2 = 0$ per cent) (Fig. 3a).

Anastomotic leak

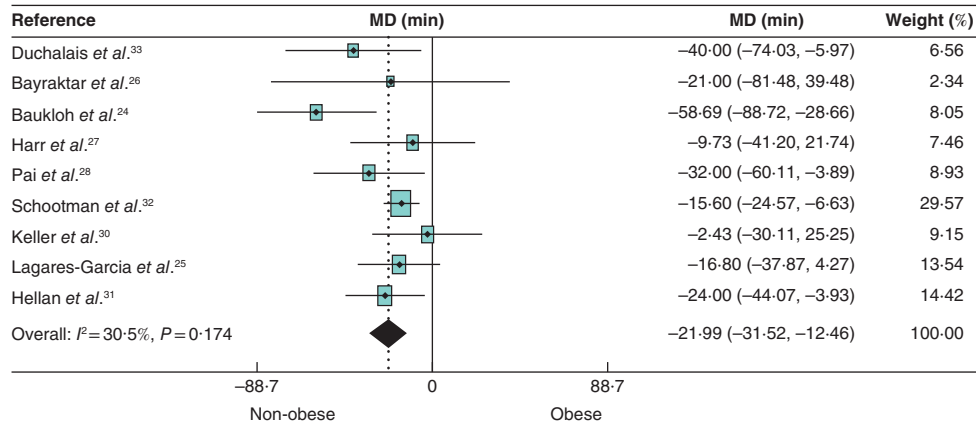
Eight articles^{24–28,30,31,33} included the rate of anastomotic leak, with a total of 464 patients in the obese group and 1043 in the non-obese group. A pooled OR of 1.07 (95 per cent c.i. 0.68 to 1.67; $P = 0.776$) indicated no difference in anastomotic leak rate between the two groups for colonic and/or rectal surgery ($I^2 = 0$ per cent) (Fig. 3b). Five^{24,26,28,31,33} of the seven articles on rectal surgery reviewed anastomotic leakage; pooled results gave an odds ratio of 1.218 and showed no significant difference between the obese and non-obese patient groups (OR 1.22, 0.74 to 2.02; $P = 0.444$) ($I^2 = 0$ per cent) (Fig. 3c).

Wound infection

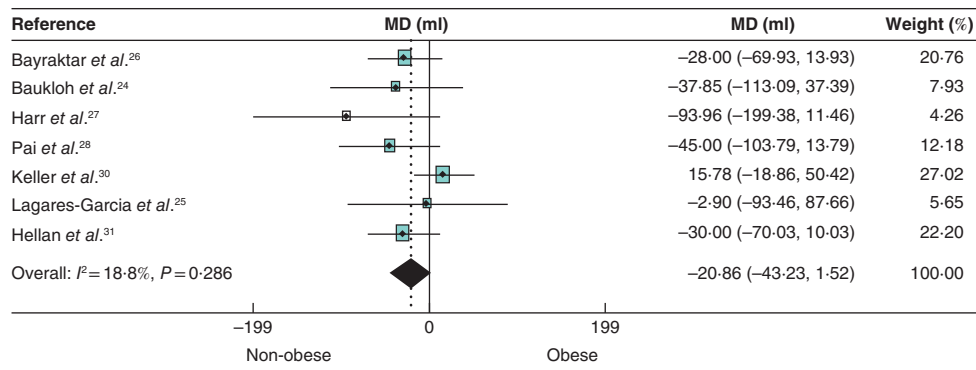
Six articles^{25,26,28,30,31,33} reviewed the rates of wound infection, superficial surgical-site infection or minor wound complication, with a total of 326 patients in the obese group and 677 in the non-obese group. Pooled results indicated no difference in rates of wound infection between the two groups (OR 1.76, 95 per cent c.i. 0.89 to 3.48; $P = 0.106$) ($I^2 = 0$ per cent) (Fig. 3d).

Fig. 2 Forest plots comparing operative outcomes in obese and non-obese patients undergoing robotic colorectal surgery

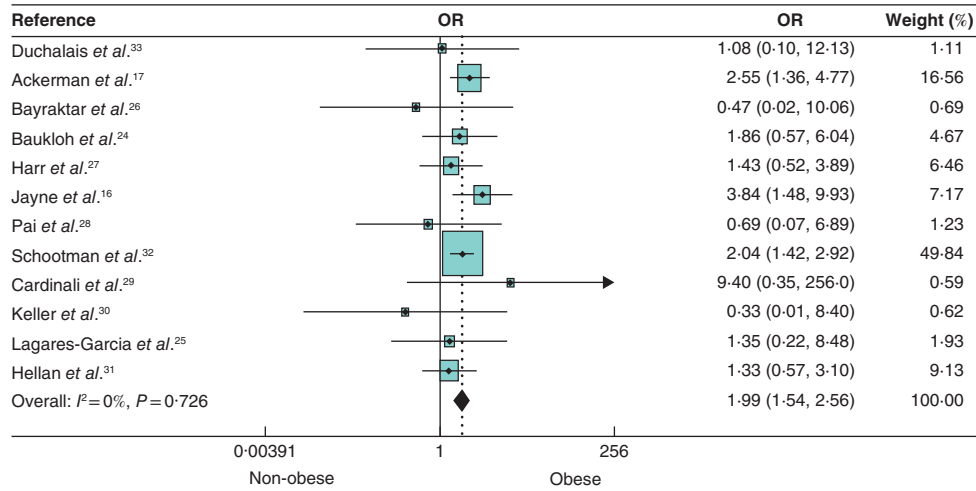
a Duration of surgery



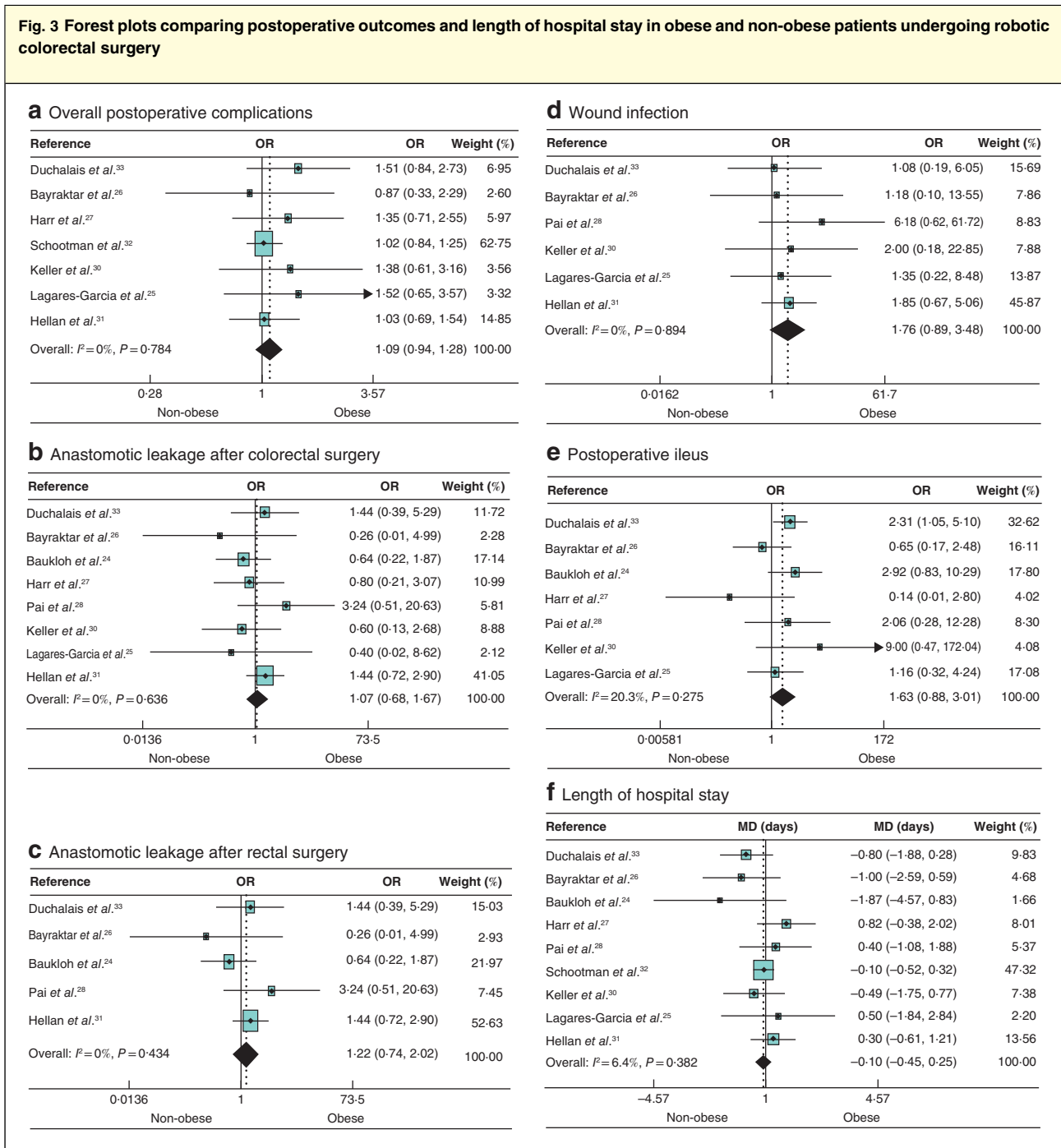
b Blood loss



c Conversion rate



a Duration of operation, **b** blood loss, **c** conversion rate to laparotomy. **a,b** Weighted mean differences (MDs) and **c** odds ratios (ORs) are shown with 95 per cent confidence intervals. Weights are from random-effects analysis.



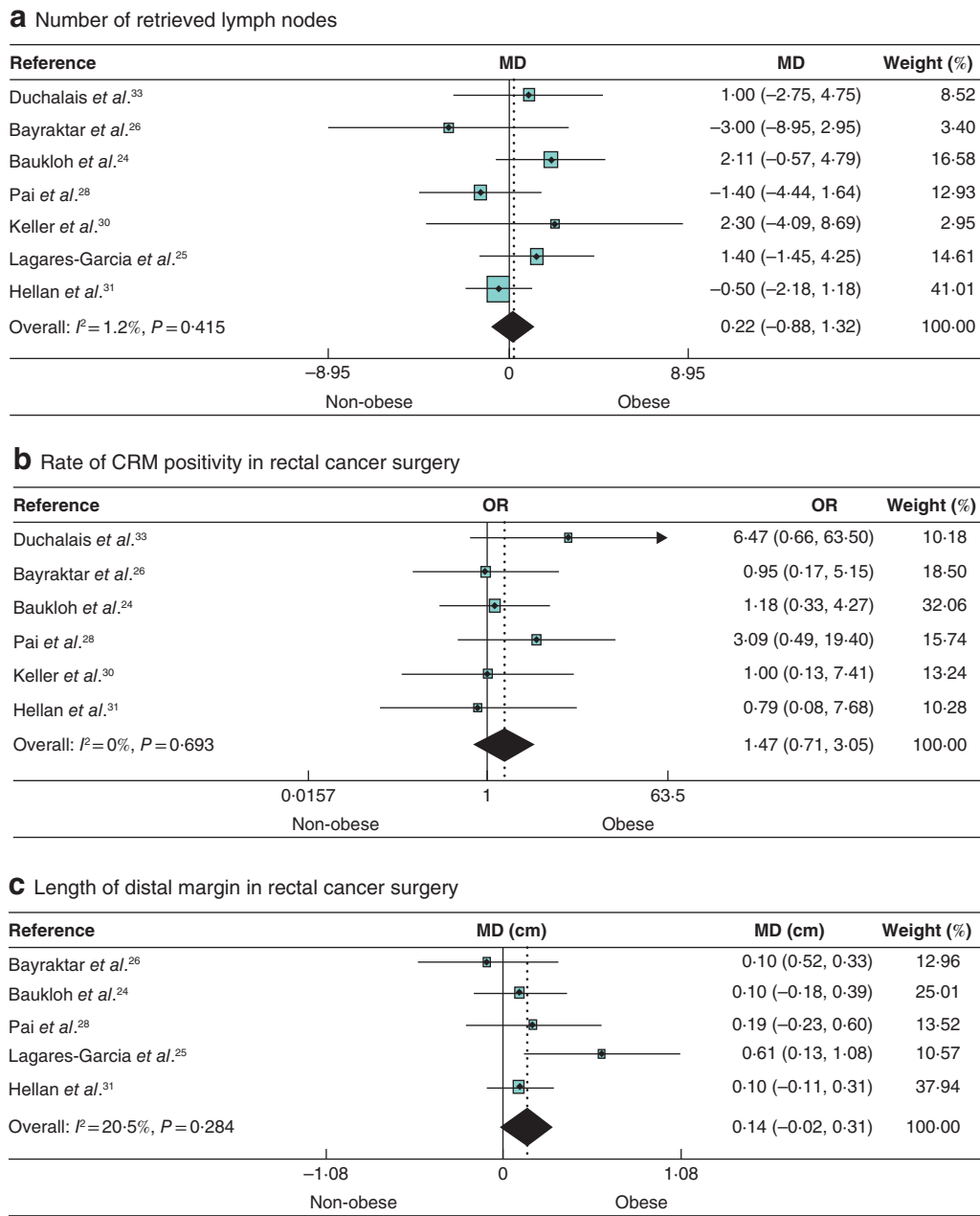
a Overall postoperative complications, b anastomotic leakage following colorectal surgery, c anastomotic leakage following rectal surgery, d wound infection, e postoperative ileus, f length of hospital stay. Odds ratios (ORs) are shown with 95 per cent confidence intervals. Weights are from random-effects analysis.

Postoperative ileus

Seven articles^{24–28,30,33} compared rates of prolonged ileus, with a total of 365 patients in the obese group and 777

in the non-obese group. Pooled analysis demonstrated no difference between the groups (OR 1.63, 95 per cent c.i. 0.88 to 3.01; $P = 0.118$) ($I^2 = 20.3$ per cent) (Fig. 3e).

Fig. 4 Forest plots comparing pathological outcome measures in obese and non-obese patients undergoing robotic colorectal surgery



a Number of retrieved lymph nodes, **b** rate of circumferential resection margin (CRM) positivity in rectal cancer surgery, **c** length of distal margin in rectal cancer surgery. **a** Weighted mean differences (MDs) **b** odds ratios (ORs) and **c** MDs are shown with 95 per cent confidence intervals. Weights are from random-effects analysis.

Length of hospital stay

Nine articles^{24–28,30–33} included the length of hospital stay, with a total of 1306 patients in the obese group and 2491 in the non-obese group. Pooled results showed a non-significant difference of 0.1 days between non-obese and obese patients (MD –0.10 (95 per cent c.i. –0.45 to 0.25) days; $P = 0.571$) ($I^2 = 6.4$ per cent) (Fig. 3f).

Lymph node harvest

Seven articles^{24–26,28,30,31,33} reported the number of retrieved lymph nodes, with a total of 355 patients in the obese group and 907 in the non-obese group. Pooled results showed no significant difference between the two groups (MD 0.22, 95 per cent c.i. –0.88 to 1.32; $P = 0.695$) ($I^2 = 1.2$ per cent) (Fig. 4a).

Circumferential resection margin positivity in rectal cancer

Six articles^{24,26,28,30,31,33} reviewed the rate of CRM positivity in rectal cancer surgery, with a total of 349 patients in the obese group and 899 in the non-obese group. Pooled analysis showed no difference between the groups (OR 1.47, 95 per cent c.i. 0.71 to 3.05; $P = 0.299$) ($I^2 = 0$ per cent) (Fig. 4b).

Distal resection margin in rectal cancer

Five articles^{24–26,28,31} reviewed the length of distal margin in patients who had rectal surgery for malignancy, with a total of 280 patients in the obese group and 765 in the non-obese group. Pooled results showed no significant difference between the groups (MD 0.19 (95 per cent c.i. –0.10 to 0.47) cm; $P = 0.200$) ($I^2 = 0$ per cent) (Fig. 4c).

Discussion

The clinical value of routine robotic colorectal surgery remains controversial. The results of this meta-analysis of robotic colorectal surgery in obese patients found results comparable to those for non-obese patients for oncological and postoperative outcomes. Duration of surgery and conversion rate to laparotomy were, however, significantly greater in obese subjects.

The finding of longer operating times in obese patients undergoing robotic colorectal surgery is supported by a similar trend in obese patients having laparoscopic surgery^{8,9,12,34–38}. Specific factors that could account for this longer duration of surgery in obese patients having robotic surgery include: robotic surgery set-up in the

obese patient; anaesthesia in obese patients; additional intraoperative port access; and need to manoeuvre obese patients during surgery.

The overall conversion rate in laparoscopic colorectal surgery has been reported to be as high as 29 per cent in some studies^{39–44}. Minimally invasive colorectal surgery in obese patients has consistently demonstrated higher conversion rates in comparison with rates in non-obese patients^{8,9,11,12,45}. The conversion rates reported in the present analysis are similar to those found in a previous systematic review⁸ of obese *versus* non-obese patients undergoing laparoscopic colorectal surgery (OR for conversion 2.11, 95 per cent c.i. 1.58 to 2.81). Although these results are not directly comparable (as they are derived from different sets of studies), they suggest non-inferiority for robotic surgery in the risk of conversion to a laparoscopic procedure, and may indicate a slight advantage. This may be due to the enhanced ergonomics and increased degrees of freedom in a tight operative space afforded by robotic platforms, for example in obese men with a narrow pelvic inlet or when surgical planes are limited by extensive adhesions⁴⁶. As a result, the significant proportion of conversion in some laparoscopic colorectal studies has not been demonstrable for robotic colorectal surgery⁴⁷.

Obese patients undergoing laparoscopic colorectal surgery typically have more postoperative complications than non-obese patients^{8–12,48–51}, including anastomotic leak^{8,10–12,49,50}, surgical-site infection or wound complications^{8–12,49,51}, postoperative ileus^{9,12,52}, urinary events¹² and pulmonary events⁹. These may be due to the underlying co-morbidity of obesity, which includes diabetes mellitus, cardiac disease and sleep apnoea^{53,54}, although these issues were not reported in the present meta-analysis.

Anastomotic leak is perhaps the most feared postoperative surgical complication, owing to high associated morbidity and mortality rates⁵⁵. Several studies have demonstrated obesity to be an independent risk factor of anastomotic leakage in all colorectal surgery^{8,10–12,49,50,56}, and in rectal surgery alone^{11,57}. This has been traditionally explained by factors ranging from increased intraoperative technical difficulty in obesity to poorer postoperative healing due to co-morbidities associated with obesity, such as type 2 diabetes mellitus and its associated arteriopathy, and poor local tissue perfusion.

The similar rates of anastomotic leakage in obese and non-obese patients found in this study may be due to the enhanced intraoperative technical capability of robotic surgery, particularly in areas that are difficult to access, such as the pelvis.

Robotic surgery offers the advantages of enhanced instrument manipulation (with 7 degrees of freedom) and three-dimensional visualization (including the potential for augmented reality) on a stable camera platform with zoom magnification^{58–60}.

Consistent with existing laparoscopic studies⁸, this meta-analysis demonstrated no significant difference in oncological outcomes (rate of rectal CRM positivity, number of retrieved lymph nodes, and length of distal rectal margin) between obese and non-obese patients. The specific issue of CRM positivity on recurrence and prognosis in rectal cancer surgery, however, remains controversial^{61–64}. Some studies, such as the ROLARR trial, have reported lower CRM positivity rates in robotic compared with laparoscopic surgery (5.1 *versus* 6.3 per cent respectively, although not statistically significant); this could be associated with long-term prognosis and may derive from evidence reporting enhanced macroscopic completeness for total mesorectal excision (TME) in robotic rectal surgery compared with laparoscopic approaches, perhaps indicating a possible technical advantage of the robotic approach for TME dissection. However, more evidence from larger trials is necessary to confirm both these findings and any further associations with patient prognosis. In addition, there is controversy over the issues of length of resection margin (greater than 2 cm)⁶⁵ and lymph node yield (more than 12)⁶⁶ on long-term prognosis.

There are some limitations relating to interpretation of the present results. One is a possible selection bias for patients having robotic surgery, as most of the studies in the analysis were observational. Here, obese subjects may have had specific characteristics that led to their selection as candidates for robotic surgery. Second, owing to the limited number of studies in robotic surgery, sample sizes across all studies in this meta-analysis were relatively small. In addition, the quality of many of the available studies was low, with 11 of the 12 studies being observational in study design and only one RCT¹⁶ being conducted. Furthermore, due to limited data in robotic surgery, it was not possible to review all co-morbidities, and this may have created a further reporting bias. Specifically, there were insufficient study numbers to review cardiopulmonary complications, venous thromboembolic and urinary complication events. There was a paucity of long-term survival data, and therefore it was not possible to analyse prognosis robustly.

A number of surgical limitations have been reported with the current da Vinci[®] system, including lack of haptic feedback, limitations with instruments, learning curve and training needs for all theatre staff, operating

room space, and the potential risk of clashing of surgical arms.

The rising prevalence of global obesity has also resulted in a higher prevalence of obese colorectal patients requiring surgery. These results suggest that robotic colorectal resection surgery in obese subjects is comparable to robotic colorectal surgery in non-obese patients in terms of post-operative or oncological outcomes. Robotic procedures did however increase the duration of operation and conversion rate to laparotomy in obese patients. The decision on selecting the most appropriate surgical approach for obese colorectal patients will however require higher levels of evidence derived from larger prospective and randomized studies of a longer duration. Future studies should consider emerging robotic technologies, and individual surgical anatomy of individual subjects when considering the role of robotic surgery in obese patients.

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Supporting information

Additional supporting information can be found online in the Supporting Information section at the end of the article.