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REVIEW

Outcomes of inflammatory bowel disease surgery in obese versus non-obese patients: a meta-analysis

G. Hicks[1] · A. Abdulaal[1] · A. A. P. Slesser[1] · Y. Mohsen[1]

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Abstract

Background Obesity is considered a risk factor for many chronic diseases and obese patients are often considered higher risk surgical candidates. The aim of this meta-analysis was to evaluate the outcomes of obese (body mass index ≥ 30 kg/m^2) versus non-obese patients undergoing surgery for inflammatory bowel disease (IBD).

Methods PubMed, Scopus, and Embase libraries were searched up to March 2019 for studies comparing outcomes of obese with non-obese patients undergoing surgery for IBD. A meta-analysis was conducted using Review Manager software to create forest plots and calculate odds ratios and mean differences.

Results Four thousand three hundred and eleven patients from five observational studies were included. Obese patients were older at the time of surgery and more likely to have diabetes. Obese patients had longer operative times (MD 23.28, 95% CI 14.63–31.93, $p < 0.001$), higher intra-operative blood loss (MD 45.32, 95% CI 5.89–84.76, $p = 0.02$), longer length of stay (MD 0.90, 95% CI 0.60–1.20, $p < 0.001$), higher wound infection rates (OR 1.76, 95% CI 1.39–2.23, $p < 0.001$), and higher total postoperative complication rates (OR 1.33, 95% CI 1.04–1.70, $p = 0.02$).

Conclusions Obesity is associated with significantly worse outcomes following IBD-specific surgery, including longer operative times, greater blood loss, longer length of stay, higher wound infection rates, and higher total postoperative complication rates. Clinicians should be mindful of these increased risks when counselling patients and consider weight reduction strategies where possible.

Keywords Obesity · Surgery · Inflammatory bowel disease · Perioperative outcomes

Introduction

Obesity, defined by the World Health Organisation as body mass index (BMI) ≥ 30 kg/m^2 [1], is a significant and increasingly prevalent public health burden worldwide. The economic burden of obesity to the National bHealth Service (NHS) in the UK is at least £5.1 billion per annum [2]. Obesity was previously considered a rare occurrence in patients with inflammatory bowel disease (IBD), but it is now a growing epidemic even in this population [3], with studies reporting 15–40% of patients with IBD as obese [4]. As the prevalence of IBD itself is also rising globally, there is growing interest in the complex relationship between obesity and IBD.

Theoretically, surgical outcomes may be worse in obese patients due to increased comorbidities and technical and anatomical difficulties of surgery. Numerous studies report increased rates of wound infection, conversion, incisional hernia, thromboembolism, and anastomotic dehiscence in obese patients [5–7]. However, there is still conflicting literature which reports no effect of obesity on overall complications in surgery [8, 9]. Further complicating the picture, there is a body of evidence, suggesting that obese patients undergoing general surgery may actually have better long-term outcomes, potentially due to increased metabolic reserves and an altered immune response [8, 10]. The impact of obesity on outcomes in IBD-specific surgery may be even more complex, since weight loss and poor nutrition are associated with severe IBD states, and therefore, obesity may reflect less severe disease in this group [11, 12]. However, there are data which suggest that obesity is a risk factor for developing Crohn's disease (CD) [13] and that obese patients with CD have a higher incidence of surgery, more

✉ G. Hicks
georginahicks@doctors.org.uk

[1] Hillingdon Hospital NHS Foundation Trust, Pield Heath Rd, Uxbridge UB8 3NN, UK

perianal disease, and more frequent hospital admissions [14, 15]. Interestingly, the literature also reports that bariatric surgery improves IBD outcomes for obese patients [16–18].

There is little consensus as to the association between obesity and IBD, and the effect of obesity on IBD-specific surgery. The purpose of this study was to summarise the data available for perioperative outcomes in obese patients undergoing surgery for IBD specifically.

Materials and methods

Search strategy and study selection

The preferred reporting items for systematic reviews and meta-analysis (PRIMSA) guidelines were followed [8]. A literature search was performed through Pubmed, Scopus and Embase libraries using the terms 'inflammatory bowel disease', 'obesity', and 'surgery'. Reference lists of identified articles were searched separately to identify further potential articles. The latest date for the search was March 2019. Two review authors (GH and AA) independently read titles, abstracts and full texts to find eligible studies and any discrepancies were discussed with AS

Studies comparing at least one postoperative outcome in obese versus non-obese patients undergoing any type of surgery for IBD were included. Obese patients were defined as BMI $\geq$ 30 kg/m^2 and non-obese as BMI < 30 kg/m^2. Studies which had combined data of obese patients without a diagnosis of IBD or studies which had pooled obese with overweight patients (BMI > 25–30 kg/m^2) were excluded.

Data collection and analysis

Data were independently extracted by GH and AA and entered into a Microsoft Excel proforma. Study characteristics were entered as well as preoperative baseline data, intra-operative and postoperative outcomes. The primary endpoint was total 30-day complications and secondary endpoints were operative time, blood loss, conversion rate, length of stay, wound infection, wound dehiscence, venous thromboembolism (VTE), and ileus.

Means and standard deviations were extracted directly into the proforma and median and interquartile ranges from one paper were converted using a recognised formula [19]. Data from overweight and normal weight patients were grouped together to compare obese versus non-obese patients. Underweight patients were excluded.

Statistical analysis was performed using a random-effects model in RevMan Version 5.3 to determine the pooled estimate and corresponding 95% confidence interval (95% CI). For dichotomous outcomes, an odds ratio (OR) was used as the summary statistic, and for continuous outcomes, the mean difference (MD) was used. A p value < 0.05 was considered statistically significant. We evaluated statistical heterogeneity using the I^2 statistic.

The quality of included studies was assessed by AA and GH independently using the Newcastle–Ottawa Scale (NOS) with scoring based on patient selection, comparability of the study groups, and assessment of outcomes. A score of 0–9 was allocated to each study.

Results

Figure 1 details the study selection process. The literature search yielded 1126 papers and 18 full-text articles were screened for eligibility. On reading full texts, 10 papers were excluded, as results were not grouped by BMI categories, 1 paper was excluded as the results included patients without an IBD diagnosis, and 2 papers were excluded, as there were no results for postoperative outcomes. Table 1 shows the characteristics of the five studies finally included [20–24] and their quality assessment scores. Most studies were observational and retrospective in design, conducted in the United States from single-centre data, with only one study conducted in the United Kingdom [24] and one reporting from a national database [23].

Study population

In total, 4311 patients were included in the meta-analysis, and their characteristics are shown in Table 1. Two papers [20, 22] included patients with Crohn's disease (CD) and ulcerative colitis (UC), whilst the others considered patients with either diagnosis alone. A range of operations were assessed, as shown in Table 2. All studies were assessing abdominal surgery bowel resections with only 5% of total patients included having other types of surgery for IBD such as stoma revision or reversal. Two studies [22, 24] only looked at laparoscopic surgery, whilst the others included both open and laparoscopic approaches.

There were some differences in baseline characteristics between patients. All papers reported on patient age and the meta-analysis showed that obese patients were significantly older at the time of surgery (MD 4.04, 95% CI 1.24–6.85, $p = 0.005$).

Three papers [20, 22, 23] reported on preoperative diabetes and the meta-analysis found that obese patients were significantly more likely to have diabetes (OR 3.51, 95% CI 2.47–5.00, $p < 0.001$). The overall rate of diabetes was 10% in obese patients and 3% in non-obese patients. The other two papers [21, 24] found no significant difference in ASA grade between the two groups.

Four papers [20–23] reported on preoperative steroid use and the meta-analysis found that there was no significant

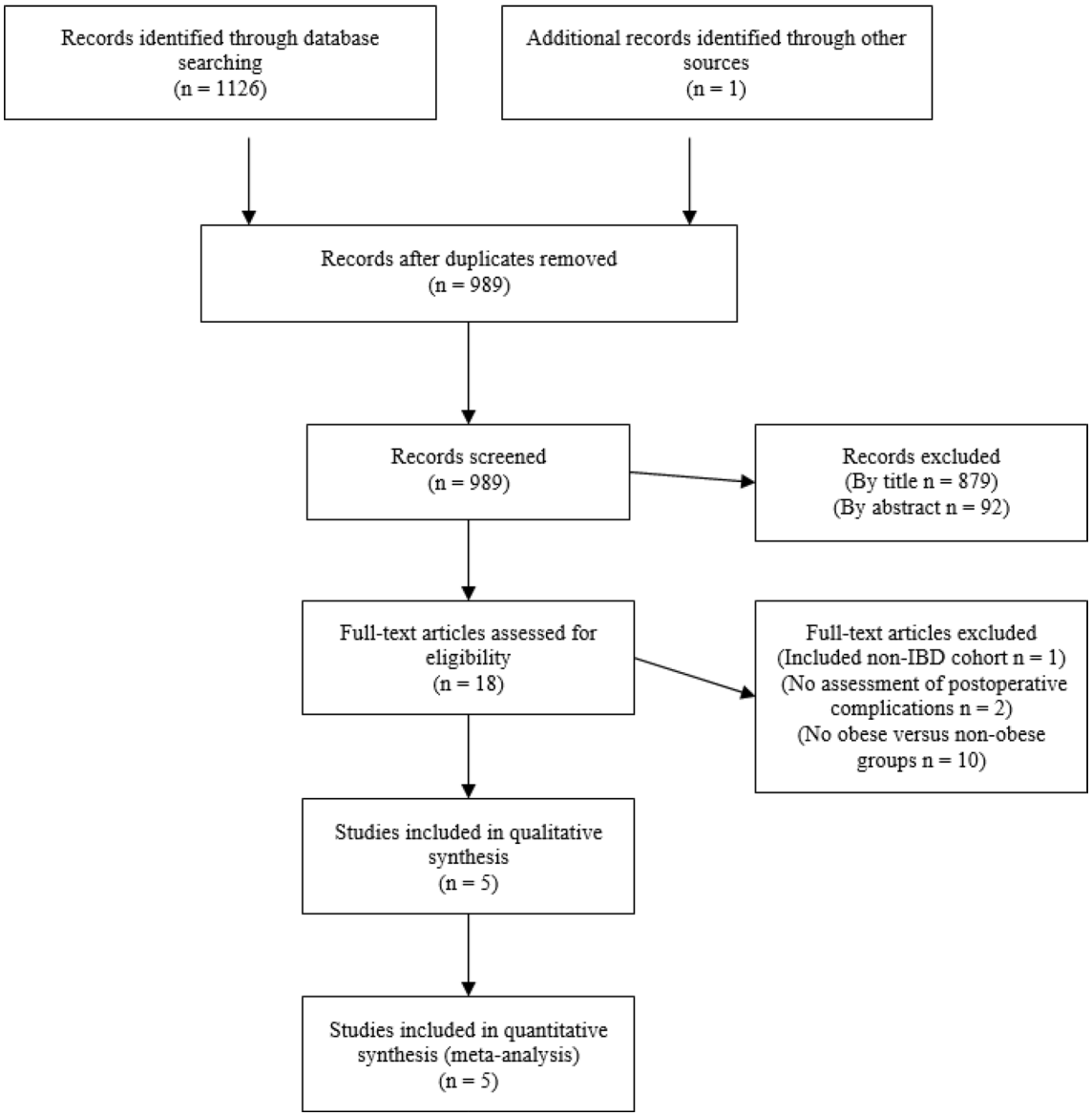

Fig. 1 PRISMA flow diagram

difference in the use of preoperative steroids between obese and non-obese patients (OR 0.97, 95% CI 0.75–1.26, $p = 0.84$). McKenna [21] and Krane [22] performed univariate and multivariate analyses to determine that steroid use was not a good predictor of surgical site infection and overall complications.

Total 30-day complications

All studies reported on the primary endpoint, with the meta-analysis showing obese patients, had significantly higher total 30-day complication rates (OR 1.33, 95% CI 1.04–1.70, $p = 0.02$) (Fig. 2).

Operative time

Operative time was reported by all papers and the meta-analysis demonstrated that operative times were significantly longer in obese patients (MD 23.28, 95% CI 14.63–31.93, $p < 0.001$) (Fig. 3).

Blood loss

Four papers reported intra-operative blood loss and the meta-analysis demonstrated intra-operative blood loss was significantly higher in obese patients (MD 45.32, 95% CI 5.89–84.76, $p = 0.02$) (Fig. 4).

Table 1 Characteristics of selected studies

Study	Year	Setting	Study type	Group	No. patients	Age (mean)	Gender (M/F)	Diagnosis	Surgery	NOS
Causey [23]	2011	USA	Retrospective national database	Obese	379	44.1	142/237	CD	All abdominal surgery (90% were resections)	9
				Non-obese	1940	41.1	871/1069			
Krane [22]	2013	USA	Retrospective Single centre	Obese	85	43.5	44/41	42.4% CD/57.6% UC	All laparoscopic resection	8
				Non-obese	541	37.3	298/243	44.5% CD/55.5% UC		
Guardado [20]	2016	USA	Retrospective Single centre	Obese	65	47.5	26/39	69.2% CD/30.8% UC	All abdominal resection	7
				Non-obese	292	41.1	139/153	67.5% CD/32.5% UC		
Pares [24]	2016	UK	Prospective Single centre	Obese	17	37	38/45	CD	Laparoscopic ileocecal resection	7
				Non-obese	83	40	89/65			
McKenna [21]	2017	USA	Retrospective Single centre	Obese	154	42.5	89/65	UC	Proctocolectomy or proctectomy with ileal pouch–anal anastomosis	8
				Non-obese	755	37.1	451/304			

CD Crohn's disease, *UC* ulcerative colitis, *NOS* Newcastle Ottowa Scale

Conversion

Three papers reported on the conversion rate from laparoscopic to open and the meta-analysis showed that there was no significant difference between obese and non-obese patients (OR 1.50, 95% CI 0.87–2.58, $p = 0.14$) (Fig. 5).

Length of stay

Three papers reported on length of hospital stay with the meta-analysis, showing that length of hospital stay was significantly longer in obese patients (MD 0.90, 95% CI 0.60–1.20, $p < 0.001$) (Fig. 6), corresponding to an increased hospital stay of nearly 1 day.

Wound infection

All papers reported on wound infection with the meta-analysis showing significantly higher wound infections rates in obese patients (OR 1.76, 95% CI 1.38–2.23, $p < 0.001$) (Fig. 7).

Wound dehiscence

Three papers reported on wound dehiscence with the meta-analysis, showing that there was no significant difference in wound dehiscence between obese and non-obese patients (OR 1.81, 95% CI 0.87–3.76, $p = 0.10$) (Fig. 8).

VTE

Four papers reported on VTE with the meta-analysis, showing that there was no significant difference in VTE between obese and non-obese patients (OR 0.98, 95% CI 0.59–1.65, $p = 0.94$) (Fig. 9).

Ileus

Three papers reported on ileus with the meta-analysis, showing that there was no significant difference in ileus between obese and non-obese patients (OR 1.14, 95% CI 0.67–1.96, $p = 0.62$) (Fig. 10).

Discussion

We conducted the first meta-analysis of surgical outcomes in obese patients undergoing surgery for IBD. Our results showed that obesity had a significant effect on intra-operative and postoperative outcomes.

Pre-operatively, obese patients were significantly older. This may be due to a delayed diagnosis of IBD in patients with higher BMI or may reflect a different disease course

Table 2 Description of surgical procedures

Study	Procedure type (number)
Causey [23]	Adhesiolysis (24) Small bowel resection (283) Partial colectomy ± stoma (760) Ileocolic resection + anastomosis (548) Total colectomy ± ileostomy ± ileorectal anastomosis (161) Proctocolectomy ± ileal pouch–anal anastomosis (141) Stoma creation, revision or closure (171) Intestinal stricturoplasty (29) Closure of intestinal fistula (48)
Krane [22]	Ileocolic resection (108) Right hemicolectomy (31) Sigmoidectomy (5) Total abdominal colectomy + ileostomy (182) Total abdominal colectomy + ileorectal anastomosis (25) Proctocolectomy + ileostomy (83) Proctocolectomy + ileal pouch–anal anastomosis (58) Proctectomy + ileostomy (36) Proctectomy + ileal pouch–anal anastomosis (9)
Guardado [20]	Segmental colectomy (193) Total abdominal colectomy ± ileorectal anastomosis (78) Proctocolectomy ± ileal pouch–anal anastomosis (38) Proctectomy ± ileal pouch–anal anastomosis (27) Small bowel resection (30) Stoma closure (29)
Pares [24]	Ileocecal resection ± protective stoma (100)
McKenna [21]	Proctocolectomy or proctectomy + ileal pouch–anal anastomosis (909)

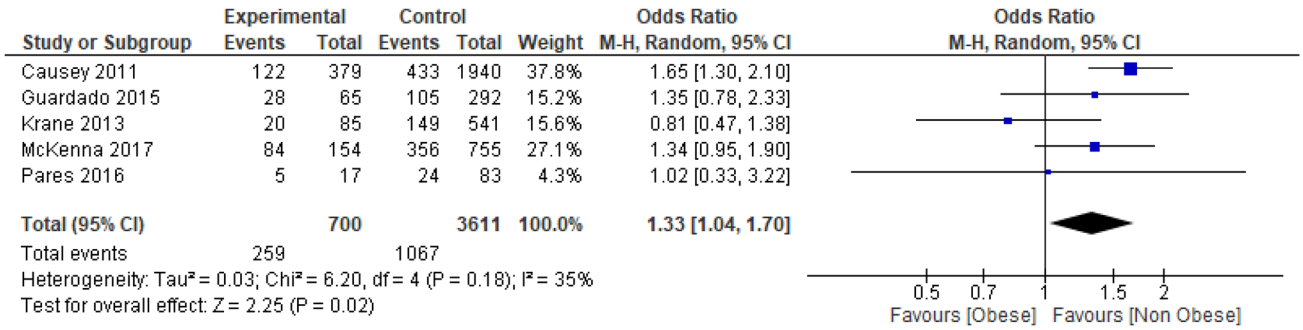

Fig. 2 Total 30-day complications, forest plot

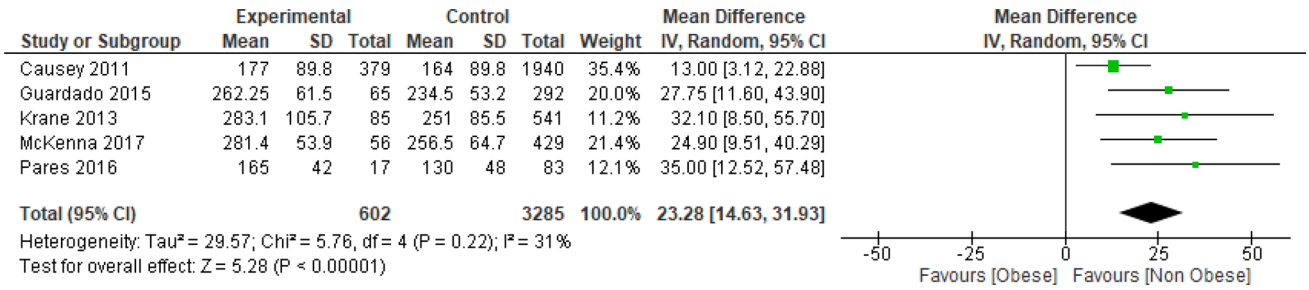

Fig. 3 Operative time, forest plot

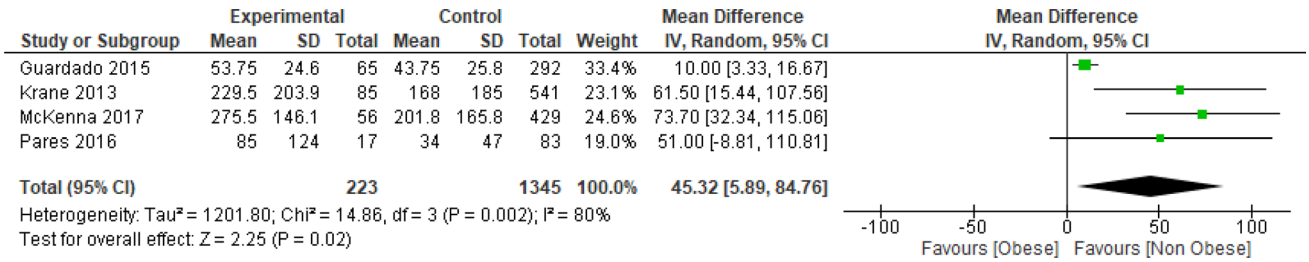

Fig. 4 Intra-operative blood loss, forest plot

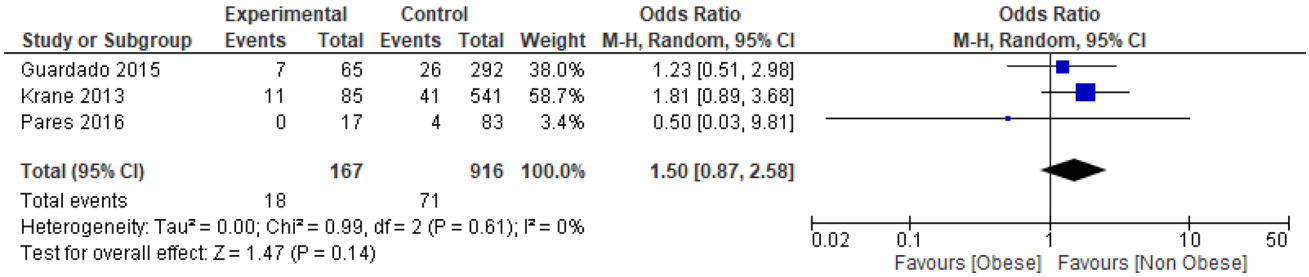

Fig. 5 Conversion, forest plot

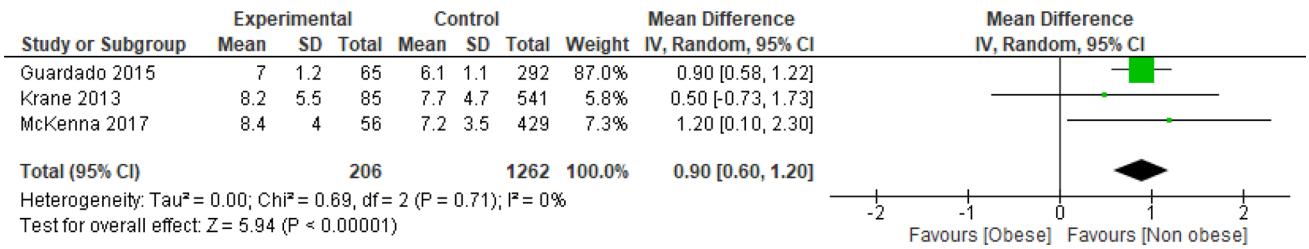

Fig. 6 Length of stay, forest plot

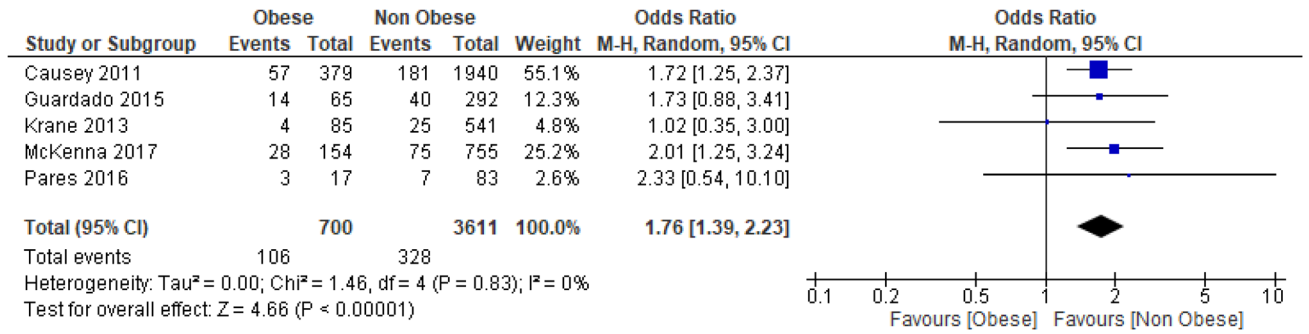

Fig. 7 Wound infection, forest plot

or disease severity in obese patients. Furthermore, surgery may be delayed in obese patients due to reluctance of surgeons to operate on a higher risk group.

Intra-operatively, we found significantly longer operative times and higher blood loss in obese patients. Causey et al. reported operative time increasing in proportion with

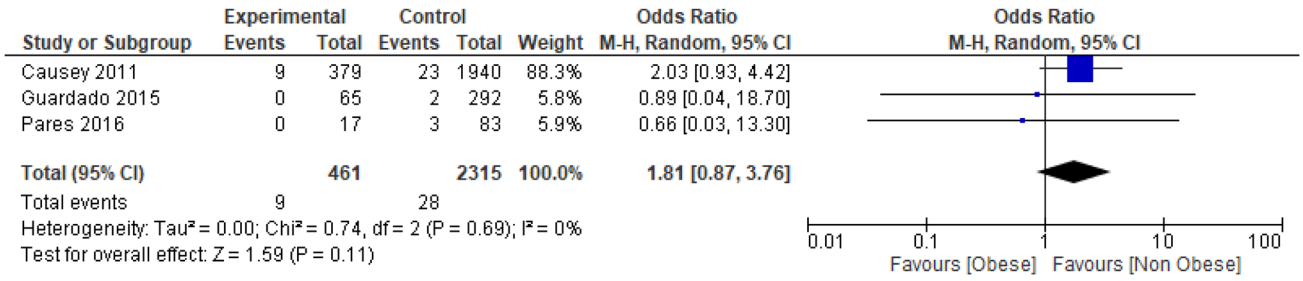

Fig. 8 Wound dehiscence, forest plot

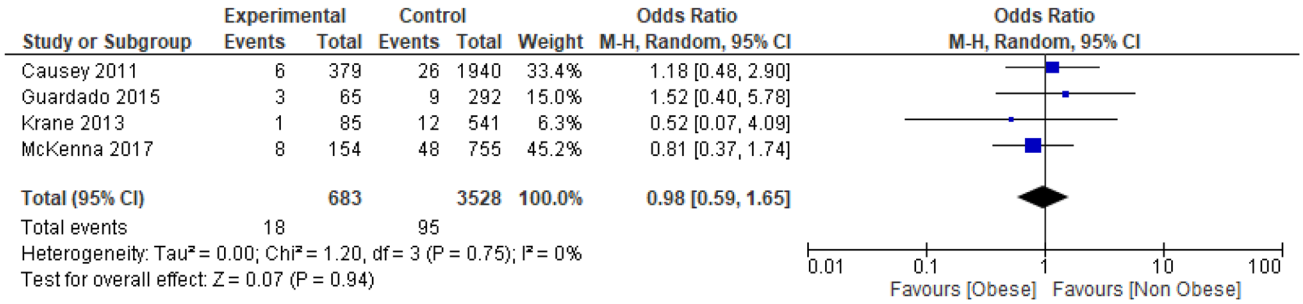

Fig. 9 Venous thromboembolism, forest plot

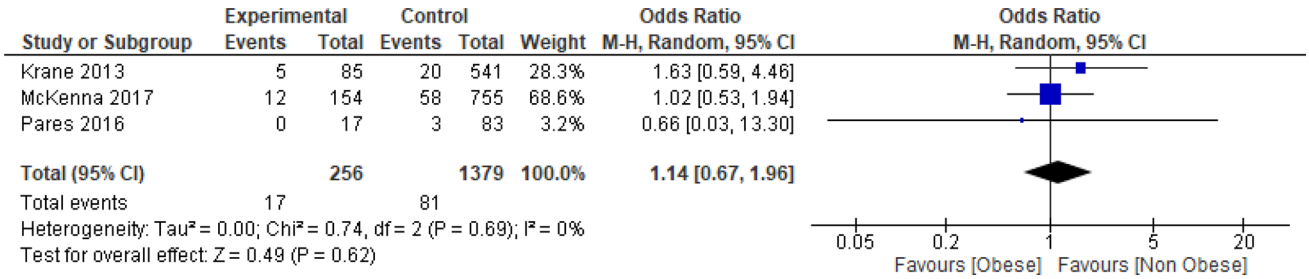

Fig. 10 Ileus, forest plot

increased BMI [23]. Obesity increases operative times due to technical demands created by a thick abdominal wall and higher intra-abdominal fat levels, which make exposure and dissection difficult. In particular, stoma creation is much more challenging with a thicker abdominal wall. Similar technical challenges are likely to account for the increased blood loss found in our meta-analysis in the obese groups. These results are consistent with higher operative times and blood loss in obese patients undergoing colorectal cancer surgery [25, 26].

Despite increased operative times and blood loss, we found no significant difference in conversion rates between the two groups. Causey et al. [23] looked at initial operative approach and showed no significant difference between initial open or laparoscopic approach, but McKenna et al. [21] reported that for both 2 and 3 stage ileal pouch–anal anastomosis (IPAA), obese patients were significantly less likely to undergo laparoscopic surgery.

Postoperatively, obese patients had a clinically and statistically significant longer length of hospital stay by nearly 1 day. Overall, the meta-analysis demonstrated higher rates of wound infection as well as total 30-day complication rates in obese patients. Causey et al. found that total postoperative complications increase directly with increasing BMI and on multivariate analysis, with diabetes and several other preoperative variables accounted for, and obesity was independently associated with significantly higher total complications [23].

Few papers considered longer term outcomes. Krane et al. [22] reported significantly increased rates of incisional hernia in obese patients. McKenna et al. [21] looked at long-term follow-up after IPAA surgery and found no significant

differences in functional outcomes including incontinence and pouchitis.

Our aim was to provide more clarity for the obese IBD population and our results have been consistent, with low statistical heterogeneity for all outcomes except blood loss. Heterogeneity in our analysis may be due to the different complexities of the surgical procedures performed, inclusion of both CD and/or UC patients, surgeon factors, and differences in severity of IBD.

The meta-analysis is primarily limited by a small number of studies available. All studies were observational and mainly retrospective which have inherent disadvantages as well as the limited generalisability of results, since most studies were from the USA. Furthermore, we found that obese patients were significantly older and more likely to have diabetes which may confound results.

We defined obesity as BMI $\geq$ 30 kg/m^2, but there is increasing discussion from many authors as to whether BMI is too simplistic a measure of risk, since it does not look at adipose tissue type or distribution. Other descriptors of risk include waist circumference, waist circumference-to-hip ratio, subcutaneous fat, visceral fat, and subcutaneous-to-visceral fat ratio. Computerised tomography scans are the gold standard for estimating distribution of visceral and subcutaneous fat and several authors have looked at adipose ratios in patients undergoing surgery for IBD. High visceral fat area was found to be associated with increased 30-day complications in patients undergoing surgery for CD [27]. Connelly et al. found that an increased visceral-to-subcutaneous fat ratio was predictive of increased postoperative morbidity in patients undergoing ileocolectomy for CD. They noted that BMI alone did not predict this increased morbidity [28]. Similarly, Stidham et al. [29] found that increased subcutaneous-to-visceral fat increased infectious complications after bowel resections in patients with CD, but BMI as a measure was not predictive of any surgical complications.

Conclusions

There is a need to further clarify the complex interplay between obesity, IBD, and surgical outcomes, in particular to evaluate stoma complications, anastomotic leak, and other long-term outcomes not considered in this paper. Further research is needed to consider if BMI is an adequate measure of risk or if other descriptors of body fat are more suitable. The role of conservative weight loss methods as well as obesity surgery prior to IBD surgery needs investigation.

Despite the limitations of a small number of observational studies, this meta-analysis shows that outcomes are significantly worse in obese patients undergoing surgery for IBD. Clinicians should be mindful of increased operative time, blood loss, length of stay, wound infections and overall early complications and counsel patients appropriately. Weight reduction strategies should be considered where possible to improve outcomes.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Ethical approval is not needed as this study corresponds to a meta-analysis of studies already published.

Informed consent Informed consent is not needed as this study corresponds to a meta-analysis of studies already published.

References

1. No Title. World Health Organization. https://www.who.int/topics/obesity/en/. Accessed 11 Sept 2019
2. Scarborough P, Bhatnagar P, Wickramasinghe KK, Allender S, Foster C, Rayner M (2011) The economic burden of ill health due to diet, physical inactivity, smoking, alcohol and obesity in the UK: an update to 2006–07 NHS costs. J Public Health (Oxf) 33:527–535. https://doi.org/10.1093/pubmed/fdr033
3. Boutros M, Maron D (2011) Inflammatory bowel disease in the obese patient. Clin Colon Rectal Surg 24:244–252. https://doi.org/10.1055/s-0031-1295687
4. Steed H, Walsh S, Reynolds N (2009) A brief report of the epidemiology of obesity in the inflammatory bowel disease population of Tayside, Scotland. Obes Facts 2:370–372. https://doi.org/10.1159/000262276
5. Pikarsky AJ, Saida Y, Yamaguchi T, Martinez S, Chen W, Weiss EG et al (2002) Is obesity a high-risk factor for laparoscopic colorectal surgery? Surg Endosc 16:855–858. https://doi.org/10.1007/s004640080069
6. Benoist S, Panis Y, Alves A, Valleur P (2000) Impact of obesity on surgical outcomes after colorectal resection. Am J Surg 179:275–281
7. Khoury W, Stocchi L, Geisler D (2011) Outcomes after laparoscopic intestinal resection in obese versus non-obese patients. Br J Surg 98:293–298. https://doi.org/10.1002/bjs.7313
8. Mullen JT, Moorman DW, Davenport DL (2009) The obesity paradox: body mass index and outcomes in patients undergoing nonbariatric general surgery. Ann Surg 250:166–172. https://doi.org/10.1097/SLA.0b013e3181ad8935
9. Blee TH, Belzer GE, Lambert PJ (2002) Obesity: is there an increase in perioperative complications in those undergoing elective colon and rectal resection for carcinoma? Am Surg 68:163–166
10. Tjeertes EKM, Hoeks SE, Beks SBJ, Valentijn TM, Hoofwijk AGM, Stolker RJ (2015) Obesity—a risk factor for postoperative complications in general surgery? BMC Anesthesiol 15:112. https://doi.org/10.1186/s12871-015-0096-7
11. Flores A, Burstein E, Cipher DJ, Feagins LA (2015) Obesity in inflammatory bowel disease: a marker of less severe disease. Dig Dis Sci 60:2436–2445. https://doi.org/10.1007/s10620-015-3629-5

12. Hu Q, Ren J, Li G, Wu X, Li J (2017) The impact of obesity on the clinical course of inflammatory bowel disease: a meta-analysis. Med Sci Monit 23:2599–2606
13. Mendall MA, Gunasekera AV, John BJ, Kumar D (2011) Is obesity a risk factor for Crohn's disease? Dig Dis Sci 56:837–844. https://doi.org/10.1007/s10620-010-1541-6
14. Hass DJ, Brensinger CM, Lewis JD, Lichtenstein GR (2006) The impact of increased body mass index on the clinical course of Crohn's disease. Clin Gastroenterol Hepatol 4:482–488. https://doi.org/10.1016/j.cgh.2005.12.015
15. Blain A, Cattan S, Beaugerie L, Carbonnel F, Gendre JP, Cosnes J (2002) Crohn's disease clinical course and severity in obese patients. Clin Nutr 21:51–57. https://doi.org/10.1054/clnu.2001.0503
16. Lascano CA, Soto F, Carrodeguas L, Szomstein S, Rosenthal RJ, Wexner SD (2006) Management of ulcerative colitis in the morbidly obese patient: is bariatric surgery indicated? Obes Surg 16:783–786. https://doi.org/10.1381/096089206777346718
17. Colombo F, Rizzi A, Ferrari C, Frontali A, Casiraghi S, Corsi F et al (2015) Bariatric surgery in patients with inflammatory bowel disease: an accessible path? Report of a case series and review of the literature. J Crohns Colitis 9:185–190. https://doi.org/10.1093/ecco-jcc/jju011
18. Aminian A, Andalib A, Ver MR, Corcelles R, Schauer PR, Brethauer SA (2016) Outcomes of bariatric surgery in patients with inflammatory bowel disease. Obes Surg 26:1186–1190. https://doi.org/10.1007/s11695-015-1909-y
19. Hozo SP, Djulbegovic B, Hozo I (2005) Estimating the mean and variance from the median, range, and the size of a sample. BMC Med Res Methodol 5:13. https://doi.org/10.1186/1471-2288-5-13
20. Guardado J, Carchman E, Danicic AE, Salgado J, Watson AR, Celebrezze JP et al (2016) Obesity does not impact perioperative or postoperative outcomes in patients with inflammatory bowel disease. J Gastrointest Surg 20:725–733. https://doi.org/10.1007/s11605-015-3060-4
21. McKenna NP, Mathis KL, Khasawneh MA, Dozois EJ, Larson DW, Pemberton JH et al (2017) Obese patients undergoing ileal pouch-anal anastomosis: short-and long-term surgical outcomes. Inflamm Bowel Dis 23:2142–2146. https://doi.org/10.1097/MIB.0000000000001238
22. Krane MK, Allaix ME, Zoccali M, Umanskiy K, Rubin MA, Villa A et al (2013) Does morbid obesity change outcomes after laparoscopic surgery for inflammatory bowel disease? Review of 626 consecutive cases. J Am Coll Surg 216:986–996. https://doi.org/10.1016/j.jamcollsurg.2013.01.053
23. Causey MW, Johnson EK, Miller S, Martin M, Maykel J, Steele SR (2011) The impact of obesity on outcomes following major surgery for Crohn's disease: an American College of Surgeons National Surgical Quality Improvement Program assessment. Dis Colon Rectum 54:1488–1495. https://doi.org/10.1097/DCR.0b013e3182342ccb
24. Pares D, Shamali A, Flashman K, O'Leary D, Senapati A, Conti J et al (2017) Laparoscopic surgical treatment of ileocecal Crohn's disease: impact of obesity on short term results. Cir Esp 95:17–23. https://doi.org/10.1016/j.ciresp.2016.12.001
25. Akiyoshi T, Ueno M, Fukunaga Y, Nagayama S, Fujimoto Y, Konishi T et al (2011) Effect of body mass index on short-term outcomes of patients undergoing laparoscopic resection for colorectal cancer: a single institution experience in Japan. Surg Laparosc Endosc Percutan Tech 21:409–414. https://doi.org/10.1097/SLE.0b013e31822e5fdc
26. Park JW, Lim S-W, Choi HS, Jeong S-Y, Oh JH, Lim S-B (2010) The impact of obesity on outcomes of laparoscopic surgery for colorectal cancer in Asians. Surg Endosc 24:1679–1685. https://doi.org/10.1007/s00464-009-0829-0
27. Ding Z, Wu X-R, Remer EM, Lian L, Stocchi L, Li Y et al (2016) Association between high visceral fat area and postoperative complications in patients with Crohn's disease following primary surgery. Colorectal Dis 18:163–172. https://doi.org/10.1111/codi.13128
28. Connelly TM, Juza RM, Sangster W, Sehgal R, Tappouni RF, Messaris E (2014) Volumetric fat ratio and not body mass index is predictive of ileocolectomy outcomes in Crohn's disease patients. Dig Surg 31:219–224. https://doi.org/10.1159/000365359
29. Stidham RW, Waljee AK, Day NM, Bergmans CL, Zahn KM, Higgins PDR et al (2015) Body fat composition assessment using analytic morphomics predicts infectious complications after bowel resection in Crohn's disease. Inflamm Bowel Dis 21:1306–1313. https://doi.org/10.1097/MIB.0000000000000360