Received date: 11-Jan-2016
Accepted date: 28-Apr-2016
Article Type: Systematic Review

The influence of obesity and body-mass index on the outcome of laparoscopic colorectal surgery: a systematic literature review

Short title: Obesity and laparoscopic colorectal surgery

Alexander Hotouras[1,2] BSc MSc MBBS(Lon) MRCS (Eng) MD(Res), **Yolanda Ribas**[3] MD PhD**, Simon A Zakeri**[2] MBChB, MRes, **Quentin M Nunes**[4] MS PhD MRCS **Jamie Murphy**[5] PhD FRCS **Chetan Bhan**[2] FRCS **Steven D Wexner**[6] MD, PhD (Hon), FACS, FRCS, FRCS(Ed)**,**

1. National Centre for Bowel Research and Surgical Innovation, London, UK
2. Department of Surgery, Whittington Hospital NHS Trust, London, UK
3. Department of Surgery, Consorci Sanitari de Terrassa, Terrassa (Barcelona), Spain
4. NIHR Liverpool Pancreas Biomedical Research unit, Royal Liverpool & Broadgreen University Hospitals NHS Trust, Liverpool, UK
5. Academic Surgical Unit, Imperial College London, UK
6. Digestive Disease Center, Cleveland Clinic Florida Fort Lauderdale, Florida, USA

Corresponding Author

Alexander Hotouras BSc, MSc, MBBS (Lon), MRCS(Eng) MD(Res)

National Centre for Bowel Research and Surgical Innovation

Barts and the London School of Medicine and Dentistry

2 Newark Street, London E12AT

Tel: 0207 8828751 Email: alex007@doctors.org.uk

Category: Systematic Review **Conflict of interest:** None declared

Authorship Credits

All authors contributed to the literature review and the preparation of this manuscript. AH and YR contributed equally.

ABSTRACT

Aim: The relationship between obesity, body-mass index (BMI) and laparoscopic colorectal resection is unclear. Our object was to assess systematically the available evidence to establish the influence of obesity and BMI on the outcome of laparoscopic colorectal resection.

Method: A search of PubMed/Medline databases was performed in May 2015 to identify all studies investigating the impact of BMI and obesity on elective laparoscopic colorectal resection performed for benign or malignant bowel disease. Clinical end points examined included operation time, conversion rate to open surgery, post-operative complications including anastomotic leakage, length of hospital stay, readmission rate, reoperation rate and mortality. For patients who underwent an operation for cancer, the harvested number of lymph nodes and long-term oncological data were also examined.

Results: 45 studies were analysed, the majority of which were Level IV with only four level III case-controlled studies**.** Thirty comparative studies containing 23649 patients including 17895 non-obese and 5754 obese showed no significant differences between

the two groups with respect to intraoperative blood loss, overall postoperative morbidity, anastomotic leakage, reoperation rate, mortality and the number of retrieved lymph nodes in patients operated on for malignancy. Most studies, including 15 non-comparative studies, reported a longer operation time in patients who underwent a laparoscopic procedure with the BMI being an independent predictor in multivariate analyses for the operation time.

Conclusion: Laparoscopic colorectal resection is safe and technically and oncologically feasible in obese patients. These results, however, may be different outside high volume centres of expertise.

What does this paper add to the literature?

This is the most up-to-date review of the literature demonstrating the feasibility and safety of colorectal resection in obese patients.

INTRODUCTION

Worldwide, obesity has more than doubled in the last three decades with 39% of adults currently thought to be overweight while 13% are classified as obese.[1] The increased incidence is expected to continue and has implications for colorectal surgeons not only because obesity is traditionally considered a risk factor for postoperative complications but also because of the potential challenges of laparoscopy in this population. In the United Kingdom, for example, 40% of colorectal operations in 2012% were performed laparoscopically compared with only 5% in 2005.[2]

The increased prevalence of laparoscopic surgery has been accompanied by a reduction in the operative risk for many patients including those with class III obesity (body-mass index> 40kg/m2).[3] The impact of obesity and body-mass index on the outcome of

laparoscopic colorectal surgery is, however, still unknown. While some surgeons have reported that laparoscopic colectomy can be safely performed in overweight and obese patients,[4] others have noted the conversion rate to open surgery, the anastomotic leakage rate and the rate of complications to be greater compared with non-obese patients.[5-6] Furthermore, it has also been argued that laparoscopic colorectal resection is technically more difficult in obese patients with some even suggesting that obesity is a relative contraindication. [6-8] Due to these assumptions, obesity has been an exclusion criterion in studies recruiting patients undergoing colorectal resections.[9-10] The aim of this systematic review is to assess current evidence and establish the influence of obesity and body mass index on the outcome of laparoscopic colorectal resection.

METHOD

A search of PubMed and Medline databases was performed in May 2015 to identify all studies investigating the impact of body mass index (BMI) and obesity on the clinical outcome of elective laparoscopic colectomy performed for benign or malignant bowel disease. A clinical trials database (www.clinicaltrials.gov) was also searched for randomised controlled trials. The search strategy included the text terms “laparoscopic”, “colorectal resection”, “colectomy” “obesity” and “body-mass index”. Studies assessing the impact of BMI and/or obesity on non-resectional laparoscopic colorectal procedures were excluded from the analysis. The search strategy was restricted to articles written in English, with available abstracts, only involving human adult subjects from 1980-2015. Selected articles were also cross-referenced by hand. Three reviewers (AH, SZ and YR) qualitatively assessed all studies using the Oxford Centre for Evidence-Based Medicine 2011 levels of evidence. Any disagreements were settled by consensus. A

diagrammatic illustration of the search process is shown in Figure 1.

Clinical outcomes examined included operation time, conversion rate to open surgery, post-operative complications including anastomotic leakage, length of hospital stay (LOS), readmission rate, reoperation rate and mortality. Furthermore, for patients who underwent colectomy for cancer, a subanalysis was performed to assess the number of lymph nodes harvested and the disease-free and overall survival when available.

RESULTS

The literature search (Figure 1) revealed 45 studies summarised in Table 1.The majority were retrospective (level IV). Four studies were case-controlled (Level III).[11-14] There were no randomised controlled trials.

Thirty studies including 23649 patients compared the outcome of obese with non-obese patients. [4-6, 11-37] According to the definition of obesity used in the different studies, there were 17895 non-obese and 5754 obese patients. Most studies assessed the short-term outcome following laparoscopic colorectal surgery and only two included data on the long-term outcome.[11, 19] Sixteen studies reported data on the oncological results [11, 15-18, 20, 23-27, 29, 31, 34, 36, 38], but only four included data on long-term survival. [11, 20, 23, 25] The other 15 non-comparative studies mostly assessed the relationship between BMI and conversion, the outcome after conversion or the morbidity of laparoscopic colorectal resection [38-51]

The indication for colorectal resection was colorectal cancer in 22 studies. [11, 16-18, 20, 22, 24-30, 33-34, 38, 41-45, 48] Five studies included only patients with benign aetiology such as inflammatory bowel disease or diverticular disease. [4, 19, 28, 40, 47] Other studies included both benign and malignant disease [5-6, 12-14, 21, 31, 35-37, 39, 49-52]. In two studies the aetiology was not specified. [15, 32] Regarding the type of resection, eleven studies included only colonic resection [4-5, 11, 17-18, 33-34, 36, 50-52], nineteen colonic and rectal resection [6, 12, 14-16, 21-22, 24-25, 27, 30-32, 35, 37, 39, 42, 46, 49], whereas ten only included rectal resection. [20, 23, 26, 29, 38, 41, 43-45, 48] Very few studies included all types of procedure including restorative

proctocolectomy with ileal pouch anal anastomosis. [13, 19, 28, 40, 47]

PREOPERATIVE PERIOD

Definition of obesity

Most comparative studies defined obesity using BMI, but the cut-off point for obesity differed according to the region of origin. According to the WHO [53], European and American studies considered obesity to include patients with a BMI > 30. [4-6, 11-14, 19-22, 25-26, 28-29, 31-32, 35-37, 39, 45] Most Asian studies defined obesity as a BMI > 25 [15-16, 18, 23-24, 27, 30, 33] according to the Japanese Society for the Study of Obesity and the Steering Committee of the Regional Office for Western Pacific of WHO [54], whereas others considered patients with BMI > 22 [17], or >28 [34] to be obese.

Given the evidence of an association between visceral obesity and the metabolic syndrome, three studies measured the visceral fat area (VFA). [18, 23, 33] The VFA was measured using a cross-sectional computerised tomographic (CT) scan obtained at the level of the umbilicus or L4-L5. Two studies classified patients with VFA $\geq$ 130 cm^2 [23, 33] as obese, and another one used VFA $\geq$ 100 cm^2 as the cut-off point.[18]

Comorbidity

Co-morbidity was not systematically reported in all studies. Overall comorbid disease was significantly higher in obese patients in three studies. [6, 18, 37] Few studies reported significantly higher incidence of hypertension [11, 18, 37], cardiovascular disease [14-15, 19, 23, 28, 37] or diabetes [15, 25, 28, 37] in the obese group. The American Society of Anesthesiologists (ASA) score was significantly higher in the obese group in four studies. [12-13, 29, 35]

INTRAOPERATIVE PERIOD

Anaesthetic difficulties

None of the comparative studies reported intraoperative anaesthetic difficulties or elevated peak airway pressures that required interruption of the procedure. Anaesthetic difficulties were only mentioned as the reason for conversion in very few patients in two of the oldest studies. [48, 50]

Operation time

Operation time was significantly longer in the obese group in most comparative studies. [4-5, 11-12, 14-19, 21-24, 27, 29, 32-33] BMI was an independent predicting factor of the operation time in a multivariate analysis in two studies. [11, 21] Nevertheless, there were no statistical differences in twelve studies. [6, 13, 25-26, 28, 30-31, 34-37, 45] Interestingly, one study reported a shorter mean operation time in the obese group, although the difference was not statistically significant. [36] This study compared technical aspects and postoperative outcome in patients undergoing left hemicolectomy so the findings cannot not be generalised.

Conversion

The definition of conversion was very variable among the assessed studies. Conversion to an open procedure, according to each authors' definition, ranged between 0-29% and it was similar in obese and non-obese patients in most studies. [4, 11-13, 15-18, 22, 24, 26, 28, 30-31, 33-34, 36-37, 39-40, 46] Nevertheless, several studies reported a significantly higher conversion rate in obese patients [5-6, 14, 19-20, 23, 25, 27, 29, 32, 38, 41-43, 48-52], which ranged between 10.8-45.8%, compared with 2.6-14% in non-obese patients. Multivariate analysis showed obesity to be an independent predictor for conversion to open surgery, together with male gender, Crohn's disease (rather than ulcerative colitis) and intraoperative complications in a study involving various procedures for IBD including restorative proctocolectomy and ileoanal pouch formation. [19] In another study of restorative proctocoloctomy with ileoanal pouch in patients with ulcerative colitis or familial polyposis, the risk of conversion was increased eight-fold by an increase in the BMI by 5 units.[47] Similarly, obesity has been an independent predictor of conversion in a multivariate analysis. [23]

In three out of four studies that exclusively involved patients with rectal cancer, conversion was significantly higher in obese patients. [20, 23, 29] Singh *et al* reported that conversions in obese patients were mostly in rectal cancer operations. [25]

The impact of conversion

Few studies compared the outcome between converted and non-converted patients undergoing laparoscopic colorectal resections. Conversion was not associated with higher morbidity or longer hospital stay in four studies [22, 29, 41, 49] ,, but others reported a worse outcome in converted cases. [38, 42-43, 47-48] Marusch *et al* noted that more patients in the converted group required blood transfusion (36% *vs*. 12%, p<0.05) and had higher postoperative overall morbidity (47.7% *vs.* 26.1%, p<0.05). [48] Conversion has also been associated with significantly longer operation time, greater blood loss and higher postoperative morbidity in some studies. [38, 43]

Nineteen studies reported on blood loss. In eight of them, blood loss was significantly higher in the obese group, [12, 17, 19, 22-24, 27, 45] whereas there were no statistically significant differences in all other studies. [6, 11, 13, 15-16, 26, 30-31, 33-34] In those in which blood loss was significantly higher in obese patients, differences in mean blood loss were limited to 25-103 mL, except in one study in which it was higher (mean 150mL for BMI 25-30 *vs.* 500mL for BMI>30, *p*=0.01). [45]

The surgical incision

Three studies reported that the length of the surgical incision was significantly longer in the obese patients compared with those with normal weight group. [13, 19, 34] Differences in mean length were 4 *vs.* 4.5 cm (*p*=0.003) [34], 8.5 *vs.* 9.6 (*p* <0.001) [19] and 5 *vs.* 6.9 (*p*=0.02) in one study that compared patients with normal weight than those with a BMI of over 40 kg/m^2. [13]

POSTOPERATIVE PERIOD

Morbidity and mortality

Overall morbidity

Morbidity tended to be higher in obese patients, but most studies did not show statistically significant differences in the overall incidence of postoperative complications. [4, 11-17, 19-20, 22-23, 26-34, 36-37, 39-40] Nevertheless, other studies reported overall

morbidity to be significantly higher in obese patients. [5-6, 14, 18, 24-25, 44, 47] Interestingly, in three of these studies higher morbidity did not correlate with longer hospital stay. [5, 14, 18] An increased VFA was shown to be a predictive factor for postoperative complications, anastomotic leakage and surgical site infection in multivariate analysis. [18]

Wound infection

Most studies that reported specifically on wound infection showed no statistically significant differences between obese and non-obese patients. [5, 11-13, 16, 19, 22-23, 26-30, 32-33] Nevertheless, some investigators found significantly higher rates in the obese group. [6, 14-15, 18, 21, 24-25] Wound infection was five times more frequent in obese patients in one study [14], and obesity was an independent risk factor for wound infection in multivariate analysis in two other studies. [15, 21]

Postoperative ileus

Few studies assessed the incidence of postoperative ileus and most did not find any statistically significant difference between obese and non-obese patients. [11-13, 16, 22, 24, 27, 32] In one study, ileus was significantly higher in the former (32.3% *vs.* 7.6%, $p<0.01$) but it was not clear whether this correlated with a longer hospital stay. [6] Another study reported more ileus in the obese group (13% *vs.* 3%, $p<0.05$) with hospital stay being more than double for obese patients converted to open surgery, although data provided in the study do not allow direct correlation between these two variables. [25]

Cardiopulmonary complications

Eight of the ten studies that reported cardiopulmonary complications did not find significant differences between obese and non-obese patients. [6, 11, 13, 16, 21-22, 31-32] Despite the use of mechanical ventilation with positive end-expiratory pressure (PEEP) to prevent postoperative atelectasis, Bège *et al* reported significantly more respiratory complications (atelectasis) in the obese group (3.2% *vs.* 16.6%, $p=0.02$). [29] Systemic complications, especially pulmonary complications, were significantly higher in obese patients in another study, visceral obesity being the only significant independent risk factor for the development of systemic complications in the multivariate analysis. [30]

Anastomotic leakage

Most of the 26 comparative studies with available data, showed no differences in the incidence of anastomotic leakage between obese and non obese patients, [6, 11-17, 19, 22-23, 25-34, 36-37] with only three studies reporting significantly higher rates of leakage in the former. [5, 18, 24] One of these studies involved 1194 patients operated on for colorectal cancer and the multivariate analysis showed that rectal cancer and obese II group (BMI >30) were independent predictive factors for anastomotic leakage. [24]

Reoperation

Reoperation rates in obese and non-obese were similar in most of the studies in which this variable had been reported. [4, 13-14, 19, 22, 28, 32-33, 36-37] Only one study reported significantly higher reoperation rates in the pre-obese (BMI 25-28) compared with non obese patients (2 out of 11 cases, 18.2% vs. 1 out of 49 cases, 2%; p=0.047), whereas there were no reoperations in the obese group. [34] Two articles reported on reoperations for incarceration of small bowel into a port site but they were not in obese patients [34] or they did not specify the group.[31]

Long-term surgical outcome

Very few articles reported on long-term surgical outcome. With a median follow-up of 37 months there were no differences between the incidence of incisional hernia in one study (9% *vs*. 9%, p >0.99) [11], whereas it was significantly higher in obese patients in another at a mean follow up of 61 months (4.7% *vs*. 0.6%, p=0.021). [19] Singh *et al* reported two cases of incisional hernia formation in the obese group, while there were none in the non-obese, but the duration of follow-up was unclear. Another study did not find differences in the incidence of port-site hernia formation when comparing both groups but, likewise, length of follow-up was not specified. [37]

Mortality

None of the comparative studies that reported on mortality showed any statistically significant difference between obese and non-obese patients. [4-5, 11-13, 15-17, 19-20, 22-25, 27-28, 31-33, 37]

Hospital stay

Most studies did not find any statistically significant difference in the length of hospital stay between obese and non-obese patients. [4-5, 11-16, 18-20, 22-23, 26, 28-32, 34-35, 37] A few studies reported a longer hospital stay in obese patients [6, 21, 24, 27, 33] and in most it correlated with a higher morbidity in these patients. [6, 21, 24, 33] Singh *et al* did not find any difference in the proportion of laparoscopically completed cases, but hospital stay of converted cases was significantly longer in the obese. [25] In one study the length of hospital stay was significantly shorter in the obese group (7 *vs.* 9 days, $p<0.01$).[36]

ONCOLOGICAL DATA

Number of harvested lymph nodes

Most of the sixteen studies that compared the oncological safety between obese and non obese patients showed no statistically significant difference in the number of retrieved lymph nodes (**Table 2**). [11, 15-17, 25-26, 29, 31, 34, 36, 38] Nevertheless, others have reported significantly fewer harvested lymph nodes, [18, 20, 24] although the mean number of nodes was over 12 in all the groups. Park *et al* reported significantly higher harvested lymph nodes in non-obese patients compared with those with a BMI of 25-29.9 kg/m^2 (27.4 *vs.* 24.3, p= 0.004), but there were no differences between non obese patients and those with a BMI of over 30 kg/m^2 (27.4 *vs.* 26.2, p= 0.908). [27] Interestingly, Kang *et al* reported significantly fewer patients with less than 12 retrieved lymph nodes in the obese group when they were classified according to the visceral fat area (VFA) (65.5% *vs.* 34.5%, *p*=0.002) but there were no differences when groups were based on BMI (43% *vs.* 40%, *p*=0.73). [23]

Long-term oncological outcome

Few studies reported overall survival and disease-free survival (**Table 2**). [11, 20, 23, 25] Two studies on rectal cancer [20, 23, 25] and two on colorectal cancer [11, 25] found no difference in overall survival and disease free survival between obese and non-obese patients.

DISCUSSION

Advances in surgical expertise and technology have resulted in the increased uptake of laparoscopic surgery worldwide.[55-56] Several studies point to its increasing acceptance in the treatment of colorectal cancer and benign colorectal conditions. [57-59] Similarly, obesity has also been increasing worldwide with many clinicians describing it as an epidemic. [60-61] The impact of obesity on the outcome of laparoscopic colorectal surgery is currently debated but this comprehensive systematic review has demonstrated that laparoscopic colorectal resection performed in obese patients is feasible, safe and reproducible with similar results compared with non-obese patients although the operation time is, unsurprisingly, prolonged. In conjunction with any unavoidable anaesthetic difficulty in intubation or ventilation this highlights the importance of careful preoperative planning including adequate operating theatre time and surgical assistance.

BMI has been used worldwide to define obesity, being over 30 kg/m^2 in the Western population according to the WHO classification[53] Asian populations, however, have a higher proportion of body fat and prominent abdominal obesity compared with people of European origin with similar BMI values. [62] A WHO consultation addressed this debate and a BMI of over 25 kg/m^2 is widely accepted as cut off for obesity in Asian populations. [63] Also, BMI does not accurately correspond with intracorporeal fat distribution. [64] This is particularly relevant to intra-abdominal surgery and laparoscopy from a technical point of view. The measurement of visceral obesity using the visceral fat area (VFA), measured by cross-sectional imaging, has been proposed as an alternative to BMI. [33, 65] There is a relation between VFA measured at the level of the umbilicus and total volume of visceral fat. [66-67] The study by Kang *et al* has shown that visceral fat obesity is a more reliable predictor of outcome than BMI in patients undergoing laparoscopic total mesorectal excision. [23] In this review, obesity was defined using BMI, but the cut-off point for obesity differed according to the geographical region of origin. European and American studies considered as obese those patients with a BMI of over 30 kg/m^2. [4-6, 11-14, 19-22, 25-26, 28-29, 31-32, 35-37, 39, 45] Most Asian studies defined obesity as a BMI over 25 kg/m^2 [15-16, 18, 23-24, 27, 30, 33] according to the Japanese Society for the Study of Obesity and the Steering Committee of the Regional Office for Western Pacific of the WHO [54], whereas others considered patients to be obese with a BMI of over 22kg/m^2 [17], or 28 kg/m^2. [34]

Obesity is associated with comorbidity including glucose intolerance, dyslipidemia, diabetes, hypertension, kidney failure and depression. [68] The accompanying pathophysiological alterations in obese patients may result in intraoperative anaesthetic difficulties and perioperative management mainly from a respiratory point of view, due to reduced vital capacity, atelectasis, decreased chest wall compliance, hypoxaemia and water and electrolyte replacement. [69] Co-morbidity was not systematically reported in all studies in this review and none of the studies reported intraoperative anaesthetic difficulties. Moreover, many of the postoperative problems which could have been expected to occur in obese patients such as hyperglycaemia have not been reported in the analysed publications.

The operation time was significantly longer in obese patients in a number of studies. [4-5, 11-12, 14-19, 21-24, 27, 29, 32-33] BMI was an independent predicting factor for operation time in a multivariate analysis in two studies. [11, 21] The increased visceral fat in obese patients may contribute to the increased technical difficulty of the procedure with respect to visualization of vascular structures in the mesentery, mobilization of bowel and manoeuvering instruments in a restricted space. [16, 27] An important factor possibly contributing to a higher operation time is the surgeon's learning curve. Laparoscopic colorectal surgery is technically complex, with a lower adoption rate than other laparoscopic procedures and with an estimated learning curve of between 30 and 60 cases with some authors suggesting that larger numbers of cases are required to surpass the learning curve. [52, 70-71] The learning curve also has an impact on the conversion rate [8, 43], which in turn may influence postoperative morbidity. [38, 42-43] More effective simulation training in a risk-free environment could be used to reduce the learning curve.[72] Male gender associated with a narrower pelvis, previous irradiation, T4 tumours and lower location of the tumour have been shown to be associated with a higher conversion rate in laparoscopic rectal resection. [43, 45] These problems were once thought to support the adoption of robotic surgery to facilitate pelvic dissection in obese male patients, but the recently reported ROLARR trial which included at least 500 patients failed to demonstrate any significant benefit of robotic pelvic dissection. Conversion was also significantly associated with a longer operation time, greater blood loss and higher postoperative morbidity in other studies. [38, 43] In this review, the conversion rate in the studies ranged between 0-29% and was similar in obese and non-

obese patients in most of these. [4, 11-13, 15-18, 22, 24, 26, 28, 30-31, 33-34, 36-37, 39-40, 46] Some studies reported a significantly higher conversion rate in obese patients. [5-6, 14, 19-20, 23, 25, 27, 29, 32, 38, 41-43, 48-52]

Laparoscopic colorectal surgery offers the potential of early ambulation and oral intake and a shorter hospital stay. [73] [74] Enhanced recovery programmes, which are an important development in postoperative management [75], have further reduced the postoperative hospital stay. [76] There is, however, a shortage of studies investigating enhanced recovery programmes in laparoscopic colorectal surgery.[77] In this review, the time to oral intake and ambulation was variable following an expectant approach [11, 17-19] and few studies followed a fast-track protocol or an enhanced recovery programme. [25, 29] Most studies in this review did not find any statistically significant difference in the length of hospital stay between obese and non obese patients. [4-5, 11-16, 18-20, 22-23, 26, 28-32, 34-35, 37] Singh *et al* found no difference in the laparoscopically completed cases, but hospital stay of the converted cases was significantly longer in obese patients. [25]

There were no significant differences in the obese and non-obese groups with respect to intraoperative blood loss, overall postoperative morbidity, anastomotic leakage, reoperation rate and mortality, which indicate that laparoscopic colorectal resection is safe and technically feasible in obese patients. Postoperative morbidity tended to be higher in obese patients, but most studies did not show statistically significant differences in the overall incidence of postoperative complications. [4, 11-17, 19-20, 22-23, 26-34, 36-37, 39-40] Some studies reported overall morbidity to be significantly higher in the obese [5-6, 14, 18, 24-25, 44, 47] and in three of these studies a higher morbidity did not correlate with a longer hospital stay. [5, 14, 18] Increased VFA was shown to be a predictive factor for postoperative complications, anastomotic leakage and surgical site infection in a multivariate analysis. [18]

Most studies that reported specifically on wound infection showed no statistically significant differences between obese and non-obese patients [5, 11-13, 16, 19, 22-23, 26-30, 32-33] ,but few studies defined wound infection in accordance with the Centers for Disease Control (CDC) criteria [18, 21, 33]. Only a few studies assessed the incidence of postoperative ileus and most of these did not find any statistically significant difference between obese and non-obese patients. [11-13, 16, 22, 24, 27, 32] While one study reported a

prolonged ileus in the obese group (13% *vs.* 3%, p<0.05) with hospital stay being more than double for obese patients converted to open surgery, the data provided in the study does not allow correlating these two variables. [25] Most studies that reported on cardio-pulmonary complications did not find any significant differences between obese and non-obese patients. [6, 11, 13, 16, 21-22, 31-32] The pathophysiological alterations in respiratory function that accompany obesity pose a challenge in postoperative management and Bège *et al*. reported significantly more respiratory complications (atelectasis) in the obese group (3.2% *vs.* 16.6%, p=0.02). [29] This occurred despite the use of mechanical ventilation with positive end-expiratory pressure (PEEP) to prevent postoperative atelectasis in this study.

Laparoscopic colorectal surgery gives comparable oncological results in the number of harvested lymph nodes, resection margin clearance, disease-free survival, overall survival and recurrence compared with open surgery. [78-79] Most of the studies included in this review showed no difference in oncological parametres between obese and non-obese patients including the number of retrieved lymph nodes. [11, 15-17, 25-26, 29, 31, 34, 36, 38] Four studies did not find any difference in overall and disease free survival between obese and non-obese patients. [11, 20, 23, 25] This indicates that laparoscopic colorectal surgery is oncologically feasible, but further studies investigating the long-term oncological outcome are warranted.

One of the most complex colorectal operations might be restorative proctocolectomy (RPC). Efron *et al* compared 31 obese with 31 non-obese patients who underwent this operation laparoscopically [80]. They reported not only a significantly higher longer operation time but also a significantly higher rate of postoperative pelvic sepsis in the obese group. Thus, not all data can be extrapolated to all clinical situations. Similarly, Kinle *et al*[45], noted a a higher conversion rate in patients with an "elevated BMI" undergoing laparoscopic RPC.

This detailed systematic review of the literature has demonstrated that laparoscopic colorectal resection is safe and technically and oncologically feasible in obese patients, but the results may be different in regional colorectal units compared with high volume centres of excellence.

Figure 1. – PRISMA diagram illustrating the search strategy

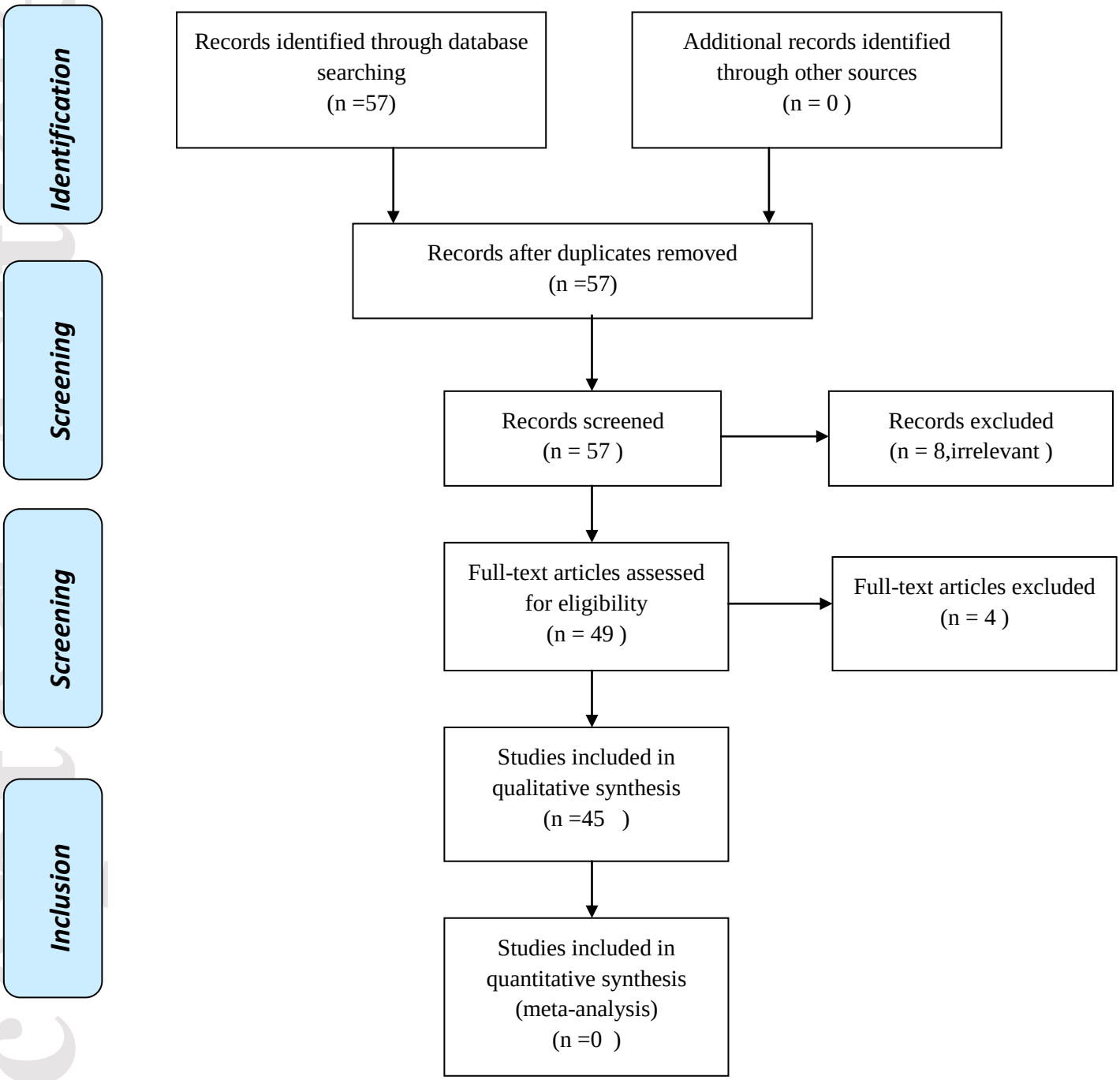

Table 1. – Summary of studies investigating the impact of obesity and body-mass index on the outcome of laparoscopic colorectal surgery

Author	Year	n	Design and Evidence Level	Age (years) and Gender ratio (%)	Mean/Median BMI (kg/m²)	Operating time (mins)	Conversion rate	Anastomotic leak rate (%)	Complication rate (%) and other conclusions
Mori et al[17]	2015	31	Retrospective study Right colon cancer NOG (BMI <22) and OG (BMI≥22)	Overall: 71.9 (52–92) 45.2 ♂/ 54.8 ♀ p =0.142 (age difference in the two groups)	Mean 22.6	NOG: 225.4 ± 16.5 OG: **297.8 ± 13.1** p=0.002	0% vs. 0%	0% vs. 0%	Blood loss (mL) higher in OG: 15.8 ± 16.2 vs. **54.1 ± 12.9** (p=0.033); *Morbidity: n=* 3 patients (overall, BMI not revealed)
Miyamoto et al[18]	2014	561	Retrospective study Colorectal cancer NOG (BMI <25) vs OG (BMI≥25)	NOG: 66. 7±10.8;57♂/ 43♀ OG: 65.9±9.6;72.1♂/27.9♀ p=0.422 (age), p=0.002 (gender)	Mean 22.9	206.7 (±69.2) vs. **220.9 (±62.3)** p=0.025	1.2% vs. 2.9% p=0.157	2.9% vs. 6.4% p=0.053	No significant difference in blood loss (mL): 33.9±70.8 vs. 32.9±55.1 (p=0.868); Hospital stay similar in both groups (9 days; p=0.663) No significant difference in overall postoperative complications: 18.3% vs. 24.3% (p=0.122) Wound infection significantly higher in obese (p=0.05)
Xia et al[19]	2014	527	Retrospective study Colorectal cancer Patients NOG (BMI <25); OG I (BMI 25 – 29.9); and OG II (BMI≥30.0)	NOG: 68.6; 49.9♂/ 50.1♀ OG I: 69.7;54.9♂/45.1♀ OG II:72.5;57.1♂/42.9♀ p= 0.109 (age)	Mean 23.0 ± 3.2	NOG= 135 (70 – 300); OG I= 145 (85 – 360); OG II= 162.5 (115 – 280) p=0.001	2.6% vs. 2.7% vs. 12.5% p=0.113	Treated conservatively: 3.0% vs. 2.8% vs. 0% (p= NA) Requiring reoperation: 1.3% vs. 0.7% vs. 0% (p=NA)	Blood loss (mL): 100 (10-750) vs. 100 (20-750) vs. 100 (50-600); p=0.076 Overall postoperative complications: 30.2% vs. 32.4% vs. 42.9%; p=0.561 No difference in postoperative hospital stay (p=0.358)
Watanabe et al[18]	2014	398	Retrospective study Cancer. NOG (BMI <25) and OG (BMI≥25) VFA nonobese (VNO, VFA <100 cm^2) and VFA obese (VO, VFA ≥100 cm^2).	VNO group: 64.8 (35–87) 97.1♂/ 62.9♀ VO group: 66. 2 (35–90); 74.3♂/ 25.7♀ p= 0.23 (age) p<0.001 (gender)	Mean 22.9 ± 3.2	VNO: 178 (55–919) VO: 197 (86–576) p=0.001	VNO 2.1% vs. VO 3.6% p=0.50	VNO 1.0% vs. VO 6.2% p=0.01	Overall postoperative complication rate (VNO vs VNO): 13.9% vs. 25.7%, p=0.008 Surgical site infection : 9.8% vs 19.4% (p=0.016) No difference in hospital stay (p=0.955
Makino et al[11]	2014	152	Case-matched study Colon cancer NOG (BMI<30; n= 76) and OG (BMI ≥30; n= 76)	NOG: 67.8±11.8;58♂/ 42♀ OG: 67.5 ± 11.7;54♂/ 46♀ p=0.90 (age) p=0.74 (gender)	Median (IQ range) 25 (22.7–26.7) vs. 33 (30.9–36.8) p<0.0001	157 ± 55 min vs. **182 ± 59** (p<0.0084) **BMI (hazard ratio 2.11, 95% confidence interval 0.64-3.56, p=0.0049) is an independent predicting factor for operative time**	9% vs. 9% (p=0.99)	3% vs. 4% (p=0.99)	Obesity had no adverse influence on estimated blood loss (100 ml vs 100 ml; p=0.10), overall morbidity (NOG 21% vs. OG 25%; p=0.563), postoperative duration of stay (median 5.5 vs. 6.0 days; p=0.22), or long-term complications
Krane et al[18]	2013	626	Retrospective study IBD NW (BMI <25; n=335); OW (BMI 25-29.9; n=206); and obese (BMI≥30; n=85).	NW: 35.2±13.5;52♂/ 48♀ OW: 40.7±14.9; 60♂/ 40♀ OG: 48.5±14.6;52♂/ 48♀ p< 0.001 (age) p= 0.202 (gender)	NW: 21.9 ± 1.7 OW: 27.3 ± 1.5 OG: 35.1 ± 5.8 p<0.001	Significantly higher in OW and OG than the NW (p<0.001)	5.7% vs. 10.7% vs. 12.9% Significantly higher in OW and OG (p=0.049 and p=0.037 respectively) Obesity was an independent predictor of conversion	No significant difference in the three groups (p=0.147)	Blood loss higher in OW and OG than the NW (p<0.001) No significant differences in intraoperative blood transfusions (p=0.738) or complications (p=0.196) Incisional hernias more common in the OG than NW(p=0.020). On multivariate analysis, obesity was **not** an
									independent risk factor for early or late postoperative complications.
Denoist et al[20]	2013	490	Retrospective study Rectal cancer Classified as BMI< 20 (n=43); BMI 20-25 (n=223); BMI 25-30 (n=177) ; and BMI≥ 30 (n=47)	Overall: 65 (20–90) 58.2♂/ 41.8♀	Overall median BMI=25	NA	5%, 14%, 23% and 32% in the 4 groups respectively p=0.001	12% "pelvic sepsis" 10.6% in obese group	Mortality (overall 1%) and morbidity (overall 19%) not significantly different.
Haas et al[12]	2013	160	Retrospective study Benign or malignant colorectal diseases Morbidly obese patients (BMI >40, n=40) were matched to three normal weight patients (n=120)	NW:60.0±15.1;42.5♂/57.5♀ Morbid obesity: 56.3±11.0 42.5♂/ 57.5♀ p=0.15 (age) p=1 (gender)	NW 22.7 (18.5-24.9 Morbid obesity group: 43.9 (40-61.8) p<0.00001	NW: 139 (70-420) Morbid obesity: **199** (70-420) p=0.0004	2.5% vs. 7.5% p=0.15	1.7% vs. 2.5% p= 1	Significantly higher median blood loss (mL) in morbid obesity group: **100** (25-3000) vs. 75 (25-1200); p=0.004 Overall complications rate 17.5% vs. 30%; p=0.09
Mustain et al[13]	2012	9693	Retrospective study Laparoscopic colectomy Patients classified as underweight (BMI <18.5), NW (BMI 18.5–24.9), OW(BMI 25–29.9), OG I (BMI 30–34.9),OG II (BMI: 35–39.9), and OG III (BMI >40)	Overall: 61.5 ± 15.9 Overall: 46.7♂/ 53.3♀ NB patient groups had significantly different ages and genders.	NA. However, 30% of patients were obese (BMI ≥ 30).	Median times: 137 vs. 135 vs. 146 vs. 151 vs. 160 vs. 169 (p<0.01) Operation time correlated with BMI class	NA	NA	BMI independently predicted wound complications (p<0.001) Higher incidence of renal impairment in OW and OG (p=0.02) Median length of stay 1 day longer in underweight and in the OG III groups (p<0.01)
Poulsen et al[14]	2012	425	Retrospective study Cancer Patients classified as BMI≥30 (n=98) and BMI<30 (n=332)	BMI<30 group: 69(37–91) 55♂/ 45♀ BMI≥30 group: 68 (36–89) 58♂/ 42♀	NA. Data divided into 2 groups: BMI≥30 (n=93) and BMI<30 (n=332)	BMI≥30: 240 [95–510] BMI<30: 225 [60–540] p=0.021	29% vs. 21% p=0.122	Anastomotic leak (reoperation): 11% vs. 9% p=0.616	Only significant difference was greater mean perioperative blood loss (mL) in OG: 348 [0–2,500] vs. 285 [0–4,000] (p=0.034) All postop complications: 41% vs. 36% (p=0.347)
Kang et al[21]	2012	142	Korean study Rectal cancer Patients were divided into NOG (BMI <25 or VFA <130 cm^2), and OG (BMI≥ 25 or VFA ≥130).	NOG:62.4±10.9; 63.8♂/ 36.2♀ OG: 61.8± 10.4; 59.5♂/ 40.5 p= 0.782 for age p=0.638 for gender	NA. However, 26% of patients were classified as obese using BMI, compared with 20.4% of patients using VFA.	NOG: 252.6 ± 83 OG: 289.8 ± 76.8 p=0.02	6.7% vs. 10.8%; p= not available. Higher conversion rate in VFA obese group than BMI obese group (17.2% vs. 5.3%; p=0.05)	8.6% vs. 8.1% p=1.0 Also, no significant difference using VFA (p=0.27)	Blood loss similar in the two BMI groups (p=0.85); using VFA, blood loss higher in OG (p=0.03) No difference in hospital stay between all groups, mortality and morbidity (whether defined by BMI or VFA)
Akiyoshi et al[14]	2011	1194	Japanese study Colorectal cancer Patients were classified as NOG (BMI <25; *n=* 926), OG I (25 ≤ BMI < 30; *n=* 243), and OG II (BMI ≥ 30; *n=* 25).	NOG: 63.9 (29-91) 56.6♂/ 49.4♀ OG I: 63. 2 (33-90) 66.7♂/ 33.3♀ OG II: 62.9 (43-78) 52♂/ 48♀ p=0.6661 (age) p<0.0001 (gender nonobese vs obese I groups)	21.4 (14.2-24.9) vs. 26.7 (25.0-29.9) vs. 31.7 (30.1-36.8) p<0.0001	Mean operating times: 214 vs. 244 vs. 293 (p<0.0001)	0.4% vs. 0.8% vs. 4% (p= 0.0605)	1% vs. 0.4% vs. 8% (p=0.0005)	Mean blood loss (mL) increased with BMI (23 vs. 42 vs. 88; p<0.0001) Postoperative complications significantly higher in **obese II** (9.2% vs. 9.1% vs. **24%**, p=0.0428). Wound infection significantly higher in obese (2.9% vs 4.9% vs **16%**; p<0.001.)] Anastomotic leakage significantly higher in obese /1% vs 0.4% vs **8%**; p<0.0005) Mean hospital stay (days) significantly longer in **obese II group** (13.5 vs. **17.8**; p=0.0301) Multivariate analysis showed BMI in obese II range was an independent predictive factor for anastomotic leak developing (OR= 10.27, 95% CI :1.98 – 53.44)
Singh et al[15]	2011	234	Single centre study Colorectal cancer Classified as NOG (*n=*172) and OG (BMI>30; n=62)	NOG: 70.4± 10.3;56♂/ 44♀ OG: 69.0±10.9; 61♂/ 39♀ p= NS for both age and gender	24.1 ± 2.52 vs. 33 ± 2.8 (p=NA)	*Median (range)* 180 (60–330) vs. 180 (90–360); p=0.3416	13% vs. **29%** (<0.05) For rectal cancer, rates were 17% vs. **44%** (p<0.05)	6% vs. 14% (p=NS)	More patients required blood transfusion in OG (P<0.005) Higher postoperative morbidity in OG (more postoperative ileus and wound infections; p<0.05)

									Hospital stay similar in laparoscopically completed cases. However, stay in the obese-converted group was significantly longer (p<0.05).
Karahasanoglu et al[28]	2011	100	Retrospective study Rectal cancer Patients classified as: normal weight (BMI < 25; n=43), overweight (25 ≤ BMI < 30; n=41) and obese (BMI ≥ 30; n=14)	Overall: 60 (40–91) 51♂/49♀	Overall median BMI: 27 (18.5 - 40) Per group median BMI: 22 (18.5–24.8) vs. 27.4 (25–29.7) vs. 32.5 (30–40)	*Median (range)* 180 (110–390) vs. 195 (140–270) vs. 190 (130–300) p=NS	4.7% in the overweight group and 0% in the other groups p=NS	2.9% vs. 5.8% vs. 0% p=NS	No significant difference in complications and oncological outcomes between the groups (p>0.05).
Park et al[27]	2010	984	Retrospective study Colorectal cancer Patients classified into nonobese (BMI<25), Obese I (BMI 25.0–29.9), and Obese II (BMI≥30).	Nonobese: 59.1; 63♂/37♀ Obese I: 60.1; 59♂/41♀ Obese II: 61.6; 44♂/56♀ P=0.226 (age) P=0.090 (gender)	Means per group: 22.0 vs. 26.6 vs. 32.1(p< 0.001) Overall mean BMI 23.7 ± 3.1	201.2 vs. 215.2 vs. **258.4** (p< 0.001)	2.6% vs. 2.9% vs. **14.8%** Obese II patients had an 8.36-fold greater risk of conversion than nonobese patients (p<0.001).	r= 3 vs. 1 vs. 0 (p= not available)	Estimated blood loss significantly higher in OG (p=0.015) No significant difference in intraoperative complications between NOG and OG (p=0.634) Postoperative complications (%): 15.2 vs. 15.1 vs. 22.2 (p=0.603) Hospital stay higher in OG (9.5 vs 12.1 days, p=0.035)
Del Rio et al[26]	2010	262	Retrospective study Laparoscopic colectomies NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients.	Overall: 66.4 (36-88) Overall: 59.6♂/40.4♀	Mean BMI 25.7 (range 15.6-34.7) Patients with obesity (BMI≥30)= 20 (range 30-34.7)	Overall operating time 214.12	Overall conversion rate 11.45% BMI≥30 not a risk factor for conversion	3.8% overall	BMI≥30 did not influence incidence of complications There were more intraoperative complications with rectal resection than left hemicolectomy (p=0.034) Risk factors for intraoperative complications: age>75; male gender; hypertension; diabetes; and heart disease Conversions more common with: age>75; advanced cancer (T3/T4); diabetes; and hypertension
Canedo et al[24]	2010	213	Retrospective study IBD BMI <25 vs BMI > 25	Group I (normal weight): 36.1 ± 1.5; 52♂/46♀ Group II (overweight + obese patients): 41 ± 1.4; 42.1♂/57.9♀ p=0.02 for age difference, and p= NS for gender	Group I: 21.7 ± 0.2 Group II: 28.8 ± 0.3	200.5 ± 6.3 vs. **207.2 ± 10.5** p=NS	18% vs. 22.1% p=NS	4 vs. 2 p=NS	No significant difference in intraoperative complications (1 for group I vs. 2 for group II, p=0.05). No significant difference in length of stay
Holubar et al[41]	2010	92	Retrospective study Crohn's disease NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients.	40 (26-51) 39♂/61♀	Median BMI 22.9 (IQ range 19.9-26.4)	Overall median operating team: 248 (IQ range 190–292).	16% overall BMI not a risk factor for conversion	3.8% overall	Small bowel disease predicted conversion: odds ratio 7 (1.6–35) Perianal disease predicted postoperative complications: odds ratio 2.6 (1.0-6.6). BMI not a risk factor for postoperative complications
Khoury et al[23]	2010	72	Retrospective study laparoscopic colorectal surgery (any indication) Classified as nonobese (BMI<30) and morbidly obese (BMI≥40).	Nonobese: 60.8 ± 16.3 47.2♂/52.8♀ Morbidly obese: 54.1±11.6 33.3♂/66.7♀ p=0.04 for age and p= 0.18 for gender	Nonobese group: 25.1 ± 3.1 Morbidly obese: 44.1 ± 4.7 (p< 0.001) Overall mean	136.4 ± 71.3 vs. 177.9 ± 89.1 p=0.12	8.3% vs. 13.9% p=0.7	5.6% vs. 8.3% p=0.9	Mean blood loss (mL): 157.1 ± 140.7 vs. 222.9 ± 196.4; p=0.1 Intraoperative complications: 2.8% vs. 2.8%; p=1 No significant differences for short term postoperative outcomes in the two groups

					BMI= 44.1				Comment: higher mean incision length (cm) required in the morbidly obese group: 5 ± 1.7 vs. 6.9 ± 2.6; p= 0.02
Yamamoto et al[39]	2009	1073	Retrospective study Rectal or anal cancer Converted group (n=79) was compared with the non-converted group (n=994). NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients.	Converted group: 63.8 (38–81); 61.5♂/38.5♀ Nonconverted group: 62.9 (24–94); 62.6♂/37.2♀ p=0.504 for age, and p=0.809 for gender	*Mean BMI (range)* **24.6 (16.6-34.8)** vs. 22.7 (13.7–36.7) p<0.0001	**Median 295 (138–630)** vs. median 270 (80–780) p=0.007	7.5% overall	**18%** vs. 7.2% (p=NA)	Converted patients had a higher rate of low anterior resection: 94.9% vs. 83.5% (p=NA) Conversion was associated with: longer operation time; greater blood loss; longer hospital stay; and higher rates of intraoperative and postoperative complications. *Multivariate analysis: BMI and rate of low anterior resection were predictive of conversion (p<0.0001 for BMI)*
Bège et al[29]	2009	210	Retrospective study laparoscopic mesorectal excision, using case control format: nonobese group with BMI< 30 (n=186) vs. obese group with BMI≥ 30 (n= 24)	NOG: mean age 62 (O: 10.7); gender ratio 1.7 OG: mean age 62.5 (O: 7.6); gender ratio 1.2 p=0.98 for age, and p=0.58 for gender	Overall mean BMI= 24.7	NOG = 421 (O: 97) vs. OG = **513 (O: 127)**; p<0.001	12.4% vs. **45.8%**; p<0.001	NA	Postoperative respiratory complications (primarily grade 1 atelectasis) more common in obese group: 3.2% vs. **16.6%**; p=0.02. Grade 1 morbidity (wound infection+ileus+atelectasis) more common in obese group: 9.7% vs. **29.2%**; p=0.012
Kamoun et al[31]	2009	180	Prospective case-matched study of 118 NOG and 62 OG (BMI≥30) patients who underwent laparoscopic colorectal surgery	NOG: 54±13; 48.3♂/51.7♀ OG: 55±13; 48.4♂/51.6♀ p=NS for both age and gender	24 ± 3 vs. **33 ± 3** p<0.0001	Mean 232 ± 59 vs. mean **268 ± 74** p<0.001	14% vs. **32%**; p<0.01	1.7% vs. 1.6% (p=NS)	Overall postoperative morbidity: 18% vs. 31% (p=NS) Wound infection more common in OG: 3.4% vs. **14.5%** (p<0.05) No difference in reoperation rate (4.2% vs. 3.2%; p=NS) or hospital stay (9 vs. 11 days; p=NS)
Flottoll et al[43]	2009	173	Retrospective study Laparoscopic rectal resection The study focused on impact of conversion on short and long term outcomes. NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients.	Overall: 63 ± 11.6 Overall: 61.3♂/38.7♀	Mean BMI 25.3 ± 15.3 n= 52 patients (30.1%) had BMI>27	Median operating time 280 (range 135–437)	15% overall Mean BMI was significantly higher in converted patients than non-converted patients: 27.3 vs. 24.9; p<0.001	12% overall	**BMI >27** was a prognostic factor for **conversion** Operation time longer in **converted** patients: **342** vs. 285 min; p=0.006 Intraoperative complications higher in **converted** patients: **31%** vs. 5%; p<0.001) Similar postoperative complications (15.4% vs 11.6%, p=0.38)
Nitori et al[30]	2009	98	Prospective study Colorectal cancer surgery Patients classified as non-visceorally obese (NVO; n=77) and visceorally obese (VO; BMI ≥25 and waist circumference ≥85cm in male, or waist circumference ≥90cm in female; n=21)	NVO: 64 (28-83); 49.4♂/50.6♀ VO: 59 (39-77); 90.5♂/9.5♀ p=0.4180 for age, and p=0.0008 for gender	NA However, n=30 patients had BMI≥25, and n=68 patients had BMI<25.	Non-VO: median 175 (108-463) VO: median 191 (132-329) p=0.3157	1.1% vs. 8.3%; p=0.3844	6.6% vs. 9.5%; p=0.6482	Systemic complication (3.9% vs. 19.0%, p=0.04) and pulmonary complication (1.3% vs. 14.3% , p=0.03) more common in VO No significant difference in blood loss (p=0.9083), overall complications (33.8% vs. 47.6%; p=0.3085) or hospital stay (8 vs. 9 days; p=0.5465) Comment: multivariate analysis showed visceral obesity was a risk factor for systemic complication (OR 8.14; CI 1.44 - 46.18; p=0.02). BMI alone had no influence on outcome.
Blumberg et al[42]	2009	83	Prospective case control study laparoscopic colectomy Patients classified as nonobese (n=58), and obese (30≤BMI<35; n=25)	Overall: 70 (37–96) Overall: 48♂/52♀	Overall mean BMI: 26.5 (range 15–44)	Nonobese group: 220±65 vs. obese group 220±79 p=NS	2% vs. 4% p=NS	0% vs. 0%	Blood loss (mL): 78 vs. 134, p=NS Major complication rates: 9% vs. 16%, p=NS Postoperative morbidity: 19% vs. 28%, p=NS Hospital stay similar: 4.9 vs. 5.0 days, p=NS
Scheidbach	2008	5568	Retrospective study	Overall: 62.1 (15.1–84.4)	Not recorded.	*Average (range):*	5.5% vs. 7.9% vs. 13.1%	Leaks treated	No differences in intraoperative complications (5.0% vs.

et al[32]			laparoscopic colorectal surgery Sigmoid resection was the most common procedure. Patients classified as nonobese (BMI<30); obesity grade I (BMI 30–34.9); obesity grade II (BMI 35–39.9); and obesity grade III (BMI≥40). Patients with BMI<18.5 were excluded.	Overall: 44.5♂/ 55.5♀	However, 86.5% patients were nonobese; 10.2% were obesity grade I; 2.5% were obesity grade II; and 0.5% were obesity grade III.	Nonobese= 166.9 (70–300) vs. obesity grade I= 181.7 (78–325) vs. obesity grade II/III= 191.1 (85–350) p<0.001	p<0.001	conservatively: 1.7% vs. 2.5% vs. 1.3%; p=0.423 Leaks requiring reoperation: 1.3% vs. 1.4% vs. 0.6%; p=0.346	6.2% vs. 7.1%; p=0.219), postoperative complications (20.7% vs. 21.0% vs. 20.2%; p=0.954), perioperative mortality (1.1% vs. 1.9% vs. 1.8%; p=0.192) and reoperation rate (4.0% vs. 3.7% vs. 3.0%; p=0.761). Hospital stay (significantly higher in the **OG grade II/III** : 11 vs. 11 vs. **13**; p=0.005
Thorpe et al [41]	2008	488	Retrospective study laparoscopic colorectal cancer, using Conventional versus Laparoscopic-Assisted Surgery In Colorectal Cancer (CLASICC) Trial data. Study focused on patient factors influencing conversion. NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients.	Mean age ± SD; gender ratio (%). Below figures take into consideration BMI as a risk factor (NB BMI was missing in 30.7% of patients) Laparoscopic group (n=194): 68.1 ± 11.5; 53: 47% **Conversion group** (n=67): 67.3 ± 9.9; 67: 33%	24.9 ± 4.3 vs. **26.2 ± 4.1** p=0.026 in univariate analysis	NA	29.3% overall	NA	Conversion was more common with: • larger BMI (OR 1.10; p=0.006)) • male sex (OR 2.07; p=0.020) • extent of tumour spread from muscularis propria (OR 1.08; p<0.001)
Agha et al [42]	2008	300	German retrospective study Rectal cancer Study compared nonconverted and converted groups with respect to surgical outcome. NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients.	Nonconverted group (n=274): 64.7 (35.1-90.5); 60.5♂/ 39.5♀ Converted group: 64.5 (45.1-80.9); 80.7♂/ 19.3♀ p=0.7 for age, and p=0.046 for gender	*Mean BMI (range)* Nonconverted group: 26.2 (16.7–37.5) Converted group: **29.0** (22.6–43.9) p=0.002	*Mean ± SD* 215.9 ± 57.2 vs. **258.2** ± 80.3 p<0.001	6.7% overall Mean BMI higher in converted group	NA	BMI and male gender predicted conversion Overall postoperative complications higher in converted group: 36.8% vs. 61.2%; p<0.025 Blood transfusion more common in converted group: 1.9% vs. 11.5%; p=0.001 Hospital stay (days) similar in both groups: 10.0 vs. 10.5; p=0.542
Tsujinaka et al [43]	2008	139	Japanese retrospective study Sigmoidectomy for cancer Patients dassified as nonobese, and obese (VFA ≥130 cm^2 or BMI ≥25). Outcomes of obesity defined by VFA were compared with obesity defined by BMI.	Nonobese: 64 [31–84]; 46.2♂/ 53.8♀ Obese: 65.5 [41–88]; 72.1♂ / 27.9♀ p=0.372 (age) p=0.002 (gender)	Not recorded. However, n= 65 (46.9%) patients were nonobese, and n= 68 (51.1%) patients were obese as defined by VFA.	Nonobese 190 (115–325) vs. **obese 220** (125–410) p=0.006. Data displayed as median (range)	4.6% vs. 8.8% p=0.469	1 patient of the whole population suffered anastomotic leak but obesity classification not revealed. Unlikely to be statistically significant.	Median blood loss (mL): 10 [10–890] vs. 42.5 [10–530]; p=0.109 Overall postoperative complications higher in obese group: 12% vs. **32.4%**; p=0.006 Median postoperative hospital stay higher in obese group: 9 (5–29) vs. **10.5** (5–31); p=0.007. NB postoperative complications and hospital stay were not significantly higher in BMI-defined obese group. Therefore, VFA was better at predicting outcome than BMI.
Targarona et al [44]	2008	60	Spanish prospective study Rectal cancer Study assessed pre-operative factors associated with postoperative outcome. NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients.	Overall: 72 [r38-87) 60♂/ 40♀	Median 25 (range 19–39)	172 [90–360)	15% BMI did not predict conversion.	NA	Multivariate analysis: • BMI predicted postoperative morbidity: OR 1.2 (CI: 1–1.5); p<0.02 • Craniocaudal tumour diameter predicted conversion: OR 1.5 (CI: 1–2.2); p<0.04
Veenhof et al [45]	2008	50	Dutch prospective study Rectal cancer Study looked at several preoperative factors and correlated these with postoperative outcomes. NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients.	Overall: 67 (IQ range 58–75) 56♂/ 44♀	Median BMI 25 (IQ range 23–27)	BMI 25–30: 240 BMI>30: 253 Spearman 0.13; p=0.391	NA	NA	Blood loss (mL): 150 for BMI 25–30 vs. **500** for **BMI>30** (Spearman 0.38; P<0.01) No significant association between VAS (visual analogue scale) for operation difficulty and BMI (Spearman 0.06; p=0.704) BMI did not correlate with radicality of the procedure (Spearman –0.12; p=0.402)
Sakamoto et al [46]	2007	69	Japanese retrospective study Rectal cancer Patients dassified as nonobese (BMI <25; n=49); pre-obese (BMI 25.0-27.9; n=11); and obese (BMI ≥28.0; n=9)	Nonobese: 59.8 ± 10.9; 63.3♂/ 34.7♀ Pre-obese: 60.6 ± 8.4; 72.8♂ / 36.4♀ Obese: 60.6 ± 10.0; 55.6♂/ 33.3♀ p=0.103 (age) p=0.725 (gender)	*Mean ± SD* 22.1 ± 1.7 vs. 26.3 ± 0.9 vs. 29.8 ± 1.4 p<0.001	*Median (range)* 224 (165-412) vs. 245 (185-420) vs. 225 (195-342) p=0.112	2% (staple misfire) vs. 0% vs. 0% p=0.813	No leaks reported in all groups	Median wound incision 0.5cm larger in **obese group** (**4.5cm** vs. 4.0cm in other groups; p=0.007). Reoperation rate higher in **pre-obese group**: 2% vs. **18.2%** vs. 0%; p=0.047 Median blood loss (mL): 25 (2-147) vs. 26 (5-115) vs. 40 (5-270); p=0.576 Intraoperative complication rate: 26.5% vs. 27.3% vs. 11.1%; p=0.600 Postoperative complication rate: 66.7% vs. 33.3% vs. 0%; p=0.188 Median postoperative hospital stay: 12 (7-58) vs. 12 (9-40) vs. 11 (7-18); p=0.583
Tekkis et al [47]	2005	900	Descriptive single centre study of 900 patients undergoing laparoscopic surgery from 1991–2003 Level III	50.3 ±18.7 (10.1–92.4) 51.2♂/ 48.9♀	BMI 25.8 ± 5.1 (range, 14.1–49.2)	$F_{3,824}$ = 6.405, p=0.012 (Multivariate covariance analysis only)	**18.3% for BMI >28.5** vs. 6.6% for BMI <22 Odds ratio 3.2 for BMI >28.5 vs. 1 for BMI <22 Odds ratio = 1.07 per unit increase in BMI	NA	Complication rate was 28.2% for BMI >28.5 vs. 14.9% for BMI <22 (Readmission rate 11.3% vs. 5.6% respectively)
Dostalik et al [48]	2005	435	Czech Republic study laparoscopic colorectal surgery Obesity defined as BMI ≥30	Nonobese group: 63 ± 14; 56.6♂/ 43.4♀ Obese group: 62 ± 10; 53.7♂/ 46.3♀ p=NS for age and gender	NA However, n= 355 (82%) patients were nonobese, and n=80 (18%) were obese.	*Mean ± SD* 141 ± 55 vs. 151 ± 50 p=NS	*Converted patients were excluded from the study.* However, before exclusion, conversion was 8% in nonobese vs. 9% in obese patients.	NA, but see right column for overall postoperative complication rate (which included leaks)	Perioperative complication rate (injury to adjacent organs + bleeding requiring transfusion): 2.5% vs. 4%; p=NS Postoperative complication rate (including leak): 24% vs. 33%; p=NS Hospital stay (days): 12 ± 9 vs. 14 ± 11; p=NS Reoperation rate: 7% vs. 13%; p=NS Also, no significant differences in use of IV analgesia, time to starting solid diet, and time to first bowel movement
Leroy et al [49]	2005	111	Retrospective study Obesity defined as BMI>30, and nonobese group was defined as BMI<30.	Nonobese: 63 ± 12; 54♂/ 46♀ Obese: 59 ± 10; 54.2♂/ 45.8♀ p=NS (for age and gender)	Obese group **BMI 34 ± 5** vs. nonobese group BMI 24.5 ± 3 (p<0.001)	Obese group 160 ± 59 vs. nonobese group 184 ± 62 (p=NS)	0% in obese group vs. 6% in nonobese group (p=NS)	0% in obese group vs. 3.3% in nonobese group (p=NS)	Complications 9% in obese group vs. 9% in nonobese group (p=NS) Hospital stay (days) longer in nonobese group: 7 ± 2.5 in obese group vs. 9.5 ± 7 in nonobese group (p<0.01)

Schwandner et al [47]	2004	589	German retrospective study laparoscopic colorectal surgery Patients dassified as NOG (BMI<30) and OG (BMI≥30)	NOG: 59.3 ± 11.6; 25.8♂/74.2♀ OG: 59.4 ± 13.7; 44.2♂/55.8♀ p=NS (age) p=0.001 (gender)	NA However, n= 494 patients in nonobese group, and n=95 in obese group	Nonobese group 135 ± 76 vs. obese group 220 ± 71 p=NS	9.5% vs. 7.3% p=NS	No difference reported (although numbers not shown)	No significant difference in transfusion requirements (units): 0.8 ± 2.5 vs. 0.5 ± 1.8; p=NS Overall morbidity rate similar: 24.5% vs. 25.3%; p=NS No significant difference in hospital stay (days): 12.5 vs. 13.4 (p=NS) Higher stay in ICU for **obese patients**: 0.5 vs. **1.2** days; p=0.020 Reoperation rate : 8.1% vs. 14.0%; p=NS
Senagore et al [3]	2003	260	Retrospective study Obesity defined as BMI>30	NOG: 52 ± 18; 48.2♂/51.8♀ OG: 51 ± 13; 44♂/56♀	OG **BMI 34 ± 4** NOG BMI 24 ± 3 (p<0.005)	OG 109 ± 36 vs. NOG 94 ± 39 (p<0.005)	OG 24% vs NOG 11% (p<0.005)	5% in OG vs 1% in NOG (p<0.005)	Similar hospital stay, wound infection, reoperation rate Overall morbidity higher in OG (p<0.005)
Schlochta et al [48]	2003	248	Canadian prospective study laparoscopic colorectal surgery The study aimed to develop a risk stratification model for conversion. NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients	Age NA 45♂/55♀	BMI not recorded However, median weight= 71kg	NA	8.9%	NA	A risk model of conversion was developed for weight: <60 kg: 6.8% 60–90 kg: 9.0% >90 kg: 12.1% However, this did **not** reach significance (p>0.05)
Kienle et al [49]	2003	59	German prospective study Ulcerative colitis and familial polyposis (laparoscopic colectomy and ileoanal pouch formation) NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients	Overall : 31 (8–69) 66.1♂/33.9♀	Median 22.8 (range 14.1–34.1)	Median 320 (range 210–690)	8.5% NB: the converted group had a higher median BMI than the overall population (**28** vs. 22.8; p<0.001)	10.2%	Increased BMI predicted conversion: OR per one-unit increase= 1.59 (95% CI 1.17–2.47; p<0.001) Increased BMI predicted major complications: OR per one-unit increase= 1.36 (95% CI 1.0 to 1.37; p=0.05)
Pikarsky et al [9]	2002	162	Descriptive single centre study laparoscopic or laparoscopic-assisted segmental colorectal resection BMI > 30 used to define obesity Level III	Mean age 60; 50.6♂/ 49.4♀	NA However, there were 31 obese patients (19.1%) vs. 131 nonobese patients (80.9%)	177.1 ± 70 in obese group vs. 170.6 ± 64.1 (p=NS)	**39% in obese group** vs. 13.5% in nonobese group (p =0.01)	0 in obese group vs. 1.5% in nonobese group (p=NS)	Maj or complications higher with obesity: **52%** vs. 12% (p<0.01) Ileus higher with obesity: **32.3%** vs. 7.6% (p<0.01) Wound infection rate higher with obesity: **12.9%** vs. 3.1% (p=0.03) Hospital stay higher in OG (6.9 vs 9.5 days, p=0.02)
Marusch et al [50]	2001	1658	Multinational, prospective, observational study laparoscopic colorectal surgery Study focussed on rate and impact of conversion. NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients	Overall: 63.5 (38-94) 43.5♂/56.5♀	NA	NA	5.2%	15.2%	Higher BMI in **converted** patients: **26.5** vs. 24.9; p<0.05 Intraoperative complications: 27.9% in converted group vs. 3.8% in nonconverted group; p<0.05 Postoperative complications: 38.4% in converted group vs. 20.9% in nonconverted group; p<0.05
Tuech et al [4]	2001	77	French prospective study Sigmoidectomy (diverticular	Normal weight: 58.4 (37–	Not recorded.	187 vs. 210 vs. **247**	13.8% vs. 14.8% vs. 14.3%	3.4% vs. 0% vs. 3.4%	Overall postoperative morbidity similar : 17.2% vs. 14.8% vs. 19% (p=NS)
			disease) Patients dassified as normal weight (BMI 18–24.9); overweight (BMI 25.0–29.9); and obese (BMI 30.0–39.9)	78); 16: 13 Overweight: 55.2 (31–83); 14: 13 Obese: 54.1 (33–86); 14: 13 p=NS for both age and gender	However, there were n= 29 patients in normal weight group; n=27 in overweight group; and n= 21 in obese group.	(p=0.003 for difference between normal weight and **obese** group)	p=NS	p=NA	Mean hospital stay (days) similar: 8.2 vs. 8.5 vs. 9.8 (p=NS) Postoperative parenteral analgesia required (days) longer in **obese** group: 5.7 vs. 7.7 vs. **8.5** (p= 0.03 when comparing normal weight group with **obese** group)
Schwandner et al [51]	1999	300	German prospective study laparoscopic colorectal surgery Study focussed on rate of conversion and the associated factors. NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients	61.4 (17–93) 27.3♂/72.7♀	n= 239 patients had BMI 20.0–27.4 n= 61 patients had extremes of BMI (<20.0 or ≥27.5)	NA	7.3% overall	NA	Conversion rate higher at extremes of BMI (13.7%) vs. normal BMI (4.2%); p= 0.0001 Logistic regression analysis for conversion risk: • Male gender: OR 2.47 (probability= 3.3%; p=0.0726) • Age (55–64 years): OR 6.39 (probability= 8.2%; p=0.0002) • Extreme BMI: OR 2.96 (probability= 4.0%; p=0.0217) • Diverticular disease: OR 4.36 (probability= 5.8%; p=0.0038)
Pandya et al [52]	1999	200	Single centre retrospective study laparoscopic colon surgery Study explored conversion rates and indications at 4 timepoints. NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients	NA	NA	NA	23.5% overall	NA	BMI correlated with need for conversion Conversion rates: 14.7% for BMI<28 vs. vs. **27.6%** for **BMI< 29**; p<0.05
Dean et al [53]	1994	122	Retrospective study laparoscopic segmented colectomy NB this was a noncomparative study for BMI, i.e. it did not compare nonobese with obese patients	NA	NA	NA	Raten 75% for patients weighing>90 kg p<0.009	NA	Converted patients had slower return of bowel function, and longer hospital stay. Higher conversion rate (>75%) with weight >90kg

OG obese group; NOG non obese group; VOG viscerally obese group; VNOG viscerally non obese group; NW normal weight; OW overweigth; VFA visceral fat area

Table 2. Histopathological assessment of the surgical specimen based on BMI in patients who underwent laparoscopic colectomy for cancer

OG obese group; NOG non-obese group; VOG viscerally obese group: VNOG viscerally non obese group

Author	Year	Number of resections for cancer (obese vs. nonobese)	TNM staging	Number of lymph nodes harvested	Resection margins (cm)	Oncological Outcomes
Mori et al [17]	2015	31 (OG =19) Right colon cancer	No difference in primary tumour stage (p=0.756), size (p=0.614) or histology type (p=0.320)	26.9 ± 2.9 vs. 23.0 ± 2.3 p=0.290	NA	
Miyamoto et al [15]	2014	561 (OG = 140) Colorectal cancer	No difference in primary tumour stage (p=0.074)	Mean (±SD): 25.5 (±11.4) vs. 24.3 (±12.8) p=0.353	Equivalent in both groups (p= 0.412)	
Xia et al [16]	2014	527 (OG I= 142; OG II= 14) Colorectal cancer	No difference in primary tumour stage (p=0.861)	13 (1-79) vs. 12 (1-36) vs. 15 (4-26) p=0.111	NA	
Watanabe et al [19]	2014	338 (VOG n=144) Colon cancer	VO Stage I/II 71.5% Stage III/IV 28.5% VNO Stage I/II 74.7% Stage III/IV 25.3%	VO group = 23.6 (2–76) VNO group = 30.8 (9–92) p<0.001	NA	
Makino et al [11]	2014	152 (OG = 76) Colon cancer	No difference in final TNM stage (p=0.90)	OG= median 17.0 (13.3–21.8) NOG= median 17.0 (13.3–21.0) p=0.97	NA	5-year overall survival rate 89 (nonobese) vs. 86% (obese), p=0.72, 5-year disease-free survival rate 77 vs. 70%, p=0.70).
Denost et al [20]	2013	490 patients classified by BMI (<20; 20-25; 25-30; ≥30) Rectal cancer	No difference in stage (p=0.243)	Significantly higher number of nodes analysed in group with BMI≥30 (p=0.031)	No difference (p=0.497)	No difference in size of tumour (p=0.164). No difference in 5 year local recurrence rates (0%, 4.6%, 5.3% and 5.9% respectively; p=0.823) Overall and disease-free survival not affected by BMI.
Kang et al [23]	2012	142	No difference in TNM staging OG: pathological complete response (pCR) or T1 or T2 = 37.8% T3 or T4= 62.2% NOG: pCR or T1 or T2= 41.9% T3 or T4 = 58.1%	% patients with < 12 nodes harvested: VOG 65.5% vs. VNOG 34.5% (p=0.002). However, no difference seen in BMI-defined OG and NOG (43% vs. 40%, p=0.73)	NA	No difference in 3-year disease free survival between nonobese and obese groups categorised by BMI or VFA.
Akiyoshi et al [24]	2011	1194 (OG I n=243; OG II n= 25) Colorectal cancer	No difference in final TNM stage (p=0.1925)	Mean number of harvested lymph nodes tended to be higher in nonobese group than in the obese I and obese II groups (16.8 vs. 16.0 and 14.7; p=0.0310 and 0.0524, respectively)	NA	
Singh et al [25]	2011	62 vs. 172. Laparoscopic colorectal surgery for cancer.	Similar in both groups	10.3 ± 4.6 vs. 11.2 ± 5.7 (p=NS)	Equivalent in both groups	For a median follow up of 2 years (range 6-45), disease-free survival and overall survival were similar in both groups.
Karahasanoglu et al [26]	2011	100 patients had laparoscopic surgery for	No significant difference in TNM stage	No significant difference	No difference	

		rectal cancer. Included normal weight (BMI < 25; *n*=43), overweight (25 ≤ BMI < 30; *n*=43) and obese (BMI ≥ 30; *n*=14)			in proximal or radial margins. Median distal margin greater in **overweight** vs. normal and obese groups (**3** vs. 2.5 vs. 2.5; p<0.05)	
Park et al [27]	2010	984	Of the 975 Adenocarcinomas reviewed: no significant difference in stage (p=0.081)	27.4 (nonobese) vs. 24.3 (obese I) vs. 26.2 (obese II) (p=0.004 comparing nonobese and obese 1)	NA	
Yamamoto et al [39]	2009	1073 patients underwent surgery for anal or rectal cancer (n=78 required conversion vs. 995 nonconverted cases). Mean BMI was higher in converted group.	No overall difference in stage (p=0.193)	*Median (range)* 16 (0-84) vs. 15 (0-52); p=0.260	Distal margins equivalent (p=0.573)	
Bège et al [29]	2009	24 vs. 186 had mesorectal excisions	No overall difference in stage (p=0.17)	Obese 14.3 (7.5) vs. nonobese 12.7 (6.1); p=0.23	Equivalent in both groups	
Blumberg et al [31]	2009	83 patients (n=25 obese vs. n=58 nonobese) underwent laparoscopic colectomy for cancer or polys excluding T4 tumours, obstructing tumours, and rectal tumors.	NA	Obese 13±6 vs. 11±6 (p=NS)	Surgical margins were negative in all patients	

Sakamoto et al [34]	2007	obese (n=9) vs. preobese (n=11) vs. nonobese (n=49) had laparoscopic anterior resection for sigmoid/rectum cancer	No overall difference in stage (p=0.517)	obese 10 (4-16) vs. preobese 12 (2-28) vs. nonobese 14 (2-47); p=0.305	NA	
Leroy et al [36]	2005	9 vs. 42	OG: n= 2 (25%) ≤pT2; n=6 (75%) > pT2 NOG: n= 11 (26%) ≤pT2; n=31 (74%) > pT2 (NS)	7.2 ± 6.4 vs. 9.1 ± 5.5 (p=NS)	5.1 ± 8.5 vs. 7.2 ± 3.8 (NS)	

REFERENCES

1. World Health Organisation. http://www.who.int/mediacentre/factsheets/fs311/en/. Website accessed 27th January 2015.
2. The English National training programme for laparoscopic colorectal surgery. http://lapco.nhs.uk. Website accessed 27th January 2015.
3. Nguyen NT, Goldman C, Rosenquist CJ, Arango A, Cole CJ, Lee SJ, Wolfe BM. Laparoscopic versus open gastric bypass: a randomized study of outcomes, quality of life, and costs. Annals of surgery 2001;234:279-89; discussion 89-91.
4. Tuech JJ, Regenet N, Hennekinne S, Pessaux P, Bergamaschi R, Arnaud JP. Laparoscopic colectomy for sigmoid diverticulitis in obese and nonobese patients: a prospective comparative study. Surgical endoscopy 2001;15:1427-30.
5. Senagore AJ, Delaney CP, Madboulay K, Brady KM, Fazio VW. Laparoscopic colectomy in obese and nonobese patients. Journal of gastrointestinal surgery : official journal of the Society for Surgery of the Alimentary Tract 2003;7:558-61.
6. Pikarsky AJ, Saida Y, Yamaguchi T, Martinez S, Chen W, Weiss EG, Nogueras JJ, Wexner SD. Is obesity a high-risk factor for laparoscopic colorectal surgery? Surgical endoscopy 2002;16:855-8.
7. Hazebroek EJ, Color Study G. COLOR: a randomized clinical trial comparing laparoscopic and open resection for colon cancer. Surgical endoscopy 2002;16:949-53.
8. Marusch F, Gastinger I, Schneider C, Scheidbach H, Konradt J, Bruch HP, Kohler L, Barlehner E, Kockerling F, Laparoscopic Colorectal Surgery Study G. Experience as a factor influencing the indications for laparoscopic colorectal surgery and the results. Surgical endoscopy 2001;15:116-20.
9. Hazebroek EJ. COLOR: a randomized clinical trial comparing laparoscopic and open resection for colon cancer. Surg Endosc 2002;16:949-53.
10. Marusch F, Gastinger I, Schneider C, Scheidbach H, Konradt J, Bruch HP, Kohler L, Barlehner E, Kockerling F. Experience as a factor influencing the indications for laparoscopic colorectal surgery and the results. Surg Endosc 2001;15:116-20.
11. Makino T, Trencheva K, Shukla PJ, Rubino F, Zhuo C, Pavoor RS, Milsom JW. The influence of obesity on short- and long-term outcomes after laparoscopic surgery for colon cancer: a case-matched study of 152 patients. Surgery 2014;156:661-8.
12. Haas EM AA, Nieto J et al. . Minimally Invasive Colorectal Surgery in the Morbidly Obese: Does High Body Mass Index Lead to Poorer Outcomes? . Surgery Curr Res 2013;3.
13. Khoury W, Kiran RP, Jessie T, Geisler D, Remzi FH. Is the laparoscopic approach to colectomy safe for the morbidly obese? Surgical endoscopy 2010;24:1336-40.
14. Kamoun S, Alves A, Bretagnol F, Lefevre JH, Valleur P, Panis Y. Outcomes of laparoscopic colorectal surgery in obese and nonobese patients: a case-matched study of 180 patients. American journal of surgery 2009;198:450-5.
15. Miyamoto Y, Ishii T, Tashiro J, Satoh T, Watanabe M, Baba H, Yamaguchi S. Effects of obesity on the outcome of laparoscopic surgery for colorectal cancer. Surgery today 2014;44:1293-9.
16. Xia X, Huang C, Jiang T, Cen G, Cao J, Huang K, Qiu Z. Is laparoscopic colorectal cancer surgery associated with an increased risk in obese patients? A retrospective study from China. World journal of surgical oncology 2014;12:184.
17. Mori S, Baba K, Yanagi M, Kita Y, Yanagita S, Uchikado Y, Arigami T, Uenosono Y, Okumura H, Nakajo A, Maemuras K, Ishigami S, Natsugoe S. Laparoscopic complete mesocolic excision with radical lymph node dissection along the surgical trunk for right colon cancer. Surgical endoscopy 2015;29:34-40.
18. Watanabe J, Tatsumi K, Ota M, Suwa Y, Suzuki S, Watanabe A, Ishibe A, Watanabe K, Akiyama H, Ichikawa Y, Morita S, Endo I. The impact of visceral obesity on surgical outcomes of laparoscopic surgery for colon cancer. International journal of colorectal disease 2014;29:343-

51.
19. Krane MK, Allaix ME, Zoccali M, Umanskiy K, Rubin MA, Villa A, Hurst RD, Fichera A. Does morbid obesity change outcomes after laparoscopic surgery for inflammatory bowel disease? Review of 626 consecutive cases. Journal of the American College of Surgeons 2013;216:986-96.
20. Denost Q, Quintane L, Buscail E, Martenot M, Laurent C, Rullier E. Short- and long-term impact of body mass index on laparoscopic rectal cancer surgery. Colorectal disease : the official journal of the Association of Coloproctology of Great Britain and Ireland 2013;15:463-9.
21. Mustain WC, Davenport DL, Hourigan JS, Vargas HD. Obesity and laparoscopic colectomy: outcomes from the ACS-NSQIP database. Diseases of the colon and rectum 2012;55:429-35.
22. Poulsen M, Ovesen H. Is laparoscopic colorectal cancer surgery in obese patients associated with an increased risk? Short-term results from a single center study of 425 patients. Journal of gastrointestinal surgery : official journal of the Society for Surgery of the Alimentary Tract 2012;16:1554-8.
23. Kang J, Baek SE, Kim T, Hur H, Min BS, Lim JS, Kim NK, Lee KY. Impact of fat obesity on laparoscopic total mesorectal excision: more reliable indicator than body mass index. International journal of colorectal disease 2012;27:497-505.
24. Akiyoshi T, Ueno M, Fukunaga Y, Nagayama S, Fujimoto Y, Konishi T, Kuroyanagi H, Yamaguchi T. Effect of body mass index on short-term outcomes of patients undergoing laparoscopic resection for colorectal cancer: a single institution experience in Japan. Surgical laparoscopy, endoscopy & percutaneous techniques 2011;21:409-14.
25. Singh A, Muthukumarasamy G, Pawa N, Riaz AA, Hendricks JB, Motson RW. Laparoscopic colorectal cancer surgery in obese patients. Colorectal disease : the official journal of the Association of Coloproctology of Great Britain and Ireland 2011;13:878-83.
26. Karahasanoglu T, Hamzaoglu I, Baca B, Aytac E, Kirbiyik E. Impact of increased body mass index on laparoscopic surgery for rectal cancer. European surgical research Europaische chirurgische Forschung Recherches chirurgicales europeennes 2011;46:87-93.
27. Park JW, Lim SW, Choi HS, Jeong SY, Oh JH, Lim SB. The impact of obesity on outcomes of laparoscopic surgery for colorectal cancer in Asians. Surgical endoscopy 2010;24:1679-85.
28. Canedo J, Pinto RA, Regadas S, Regadas FS, Rosen L, Wexner SD. Laparoscopic surgery for inflammatory bowel disease: does weight matter? Surgical endoscopy 2010;24:1274-9.
29. Bege T, Lelong B, Francon D, Turrini O, Guiramand J, Delpero JR. Impact of obesity on short-term results of laparoscopic rectal cancer resection. Surgical endoscopy 2009;23:1460-4.
30. Nitori N, Hasegawa H, Ishii Y, Endo T, Kitagawa Y. Impact of visceral obesity on short-term outcome after laparoscopic surgery for colorectal cancer: a single Japanese center study. Surgical laparoscopy, endoscopy & percutaneous techniques 2009;19:324-7.
31. Blumberg D. Laparoscopic colectomy performed using a completely intracorporeal technique is associated with similar outcome in obese and thin patients. Surgical laparoscopy, endoscopy & percutaneous techniques 2009;19:57-61.
32. Scheidbach H, Benedix F, Hugel O, Kose D, Kockerling F, Lippert H. Laparoscopic approach to colorectal procedures in the obese patient: risk factor or benefit? Obesity surgery 2008;18:66-70.
33. Tsujinaka S, Konishi F, Kawamura YJ, Saito M, Tajima N, Tanaka O, Lefor AT. Visceral obesity predicts surgical outcomes after laparoscopic colectomy for sigmoid colon cancer. Diseases of the colon and rectum 2008;51:1757-65; discussion 65-7.
34. Sakamoto K, Niwa S, Tanaka M, Goto M, Sengoku H, Tomiki Y. Influence of obesity on the short-term outcome of laparoscopic colectomy for colorectal cancer. Journal of minimal access surgery 2007;3:98-103.
35. Dostalik J, Martinek L, Vavra P, Andel P, Gunka I, Gunkova P. Laparoscopic colorectal surgery in obese patients. Obesity surgery 2005;15:1328-31.
36. Leroy J, Ananian P, Rubino F, Claudon B, Mutter D, Marescaux J. The impact of obesity

on technical feasibility and postoperative outcomes of laparoscopic left colectomy. Annals of surgery 2005;241:69-76.
37. Schwandner O, Farke S, Schiedeck TH, Bruch HP. Laparoscopic colorectal surgery in obese and nonobese patients: do differences in body mass indices lead to different outcomes? Surgical endoscopy 2004;18:1452-6.
38. Yamamoto S, Fukunaga M, Miyajima N, Okuda J, Konishi F, Watanabe M, Japan Society of Laparoscopic Colorectal S. Impact of conversion on surgical outcomes after laparoscopic operation for rectal carcinoma: a retrospective study of 1,073 patients. Journal of the American College of Surgeons 2009;208:383-9.
39. Del Rio P, Dell'Abate P, Gomes B, Fumagalli M, Papadia C, Coruzzi A, Leonardi F, Pucci F, Sianesi M. Analysis of risk factors for complications in 262 cases of laparoscopic colectomy. Annali italiani di chirurgia 2010;81:21-30.
40. Holubar SD, Dozois EJ, Privitera A, Pemberton JH, Cima RR, Larson DW. Minimally invasive colectomy for Crohn's colitis: a single institution experience. Inflammatory bowel diseases 2010;16:1940-6.
41. Rottoli M, Bona S, Rosati R, Elmore U, Bianchi PP, Spinelli A, Bartolucci C, Montorsi M. Laparoscopic rectal resection for cancer: effects of conversion on short-term outcome and survival. Annals of surgical oncology 2009;16:1279-86.
42. Thorpe H, Jayne DG, Guillou PJ, Quirke P, Copeland J, Brown JM, Medical Research Council Conventional versus Laparoscopic-Assisted Surgery In Colorectal Cancer Trial G. Patient factors influencing conversion from laparoscopically assisted to open surgery for colorectal cancer. The British journal of surgery 2008;95:199-205.
43. Agha A, Furst A, Iesalnieks I, Fichtner-Feigl S, Ghali N, Krenz D, Anthuber M, Jauch KW, Piso P, Schlitt HJ. Conversion rate in 300 laparoscopic rectal resections and its influence on morbidity and oncological outcome. International journal of colorectal disease 2008;23:409-17.
44. Targarona EM, Balague C, Pernas JC, Martinez C, Berindoague R, Gich I, Trias M. Can we predict immediate outcome after laparoscopic rectal surgery? Multivariate analysis of clinical, anatomic, and pathologic features after 3-dimensional reconstruction of the pelvic anatomy. Annals of surgery 2008;247:642-9.
45. Veenhof AA, Engel AF, van der Peet DL, Sietses C, Meijerink WJ, de Lange-de Klerk ES, Cuesta MA. Technical difficulty grade score for the laparoscopic approach of rectal cancer: a single institution pilot study. International journal of colorectal disease 2008;23:469-75.
46. Schlachta CM, Mamazza J, Gregoire R, Burpee SE, Pace KT, Poulin EC. Predicting conversion in laparoscopic colorectal surgery. Fellowship training may be an advantage. Surgical endoscopy 2003;17:1288-91.
47. Kienle P, Weitz J, Benner A, Herfarth C, Schmidt J. Laparoscopically assisted colectomy and ileoanal pouch procedure with and without protective ileostomy. Surgical endoscopy 2003;17:716-20.
48. Marusch F, Gastinger I, Schneider C, Scheidbach H, Konradt J, Bruch HP, Kohler L, Barlehner E, Kockerling F, Laparoscopic Colorectal Surgery Study G. Importance of conversion for results obtained with laparoscopic colorectal surgery. Diseases of the colon and rectum 2001;44:207-14; discussion 14-6.
49. Schwandner O, Schiedeck TH, Bruch H. The role of conversion in laparoscopic colorectal surgery: Do predictive factors exist? Surgical endoscopy 1999;13:151-6.
50. Pandya S, Murray JJ, Coller JA, Rusin LC. Laparoscopic colectomy: indications for conversion to laparotomy. Archives of surgery 1999;134:471-5.
51. Dean PA, Beart RW, Jr., Nelson H, Elftmann TD, Schlinkert RT. Laparoscopic-assisted segmental colectomy: early Mayo Clinic experience. Mayo Clinic proceedings 1994;69:834-40.
52. Tekkis PP, Senagore AJ, Delaney CP, Fazio VW. Evaluation of the learning curve in laparoscopic colorectal surgery: comparison of right-sided and left-sided resections. Annals of surgery 2005;242:83-91.

53. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health Organization technical report series 2000;894:i-xii, 1-253.
54. Examination Committee of Criteria for 'Obesity Disease' in J, Japan Society for the Study of O. New criteria for 'obesity disease' in Japan. Circulation journal : official journal of the Japanese Circulation Society 2002;66:987-92.
55. Zaidi A, Sharma S. The athlete's heart. British journal of hospital medicine (London, England : 2005) 2011;72:275-81.
56. Schlussel AT, Lustik MB, Johnson EK, Maykel JA, Champagne BJ, Goldberg JE, Steele SR. Do the advantages of a minimally invasive approach remain in complex colorectal procedures? A nationwide comparison. Diseases of the colon and rectum 2015;58:431-43.
57. Bonjer HJ, Hop WC, Nelson H, Sargent DJ, Lacy AM, Castells A, Guillou PJ, Thorpe H, Brown J, Delgado S, Kuhrij E, Haglind E, Pahlman L. Laparoscopically assisted vs open colectomy for colon cancer: a meta-analysis. Archives of surgery 2007;142:298-303.
58. Causey MW, Stoddard D, Johnson EK, Maykel JA, Martin MJ, Rivadeneira D, Steele SR. Laparoscopy impacts outcomes favorably following colectomy for ulcerative colitis: a critical analysis of the ACS-NSQIP database. Surgical endoscopy 2013;27:603-9.
59. Messenger DE, Mihailovic D, MacRae HM, O'Connor BI, Victor JC, McLeod RS. Subtotal colectomy in severe ulcerative and Crohn's colitis: what benefit does the laparoscopic approach confer? Diseases of the colon and rectum 2014;57:1349-57.
60. Lopez-Candales A, Dohi K, Iliescu A, Peterson RC, Edelman K, Bazaz R. An abnormal right ventricular apical angle is indicative of global right ventricular impairment. Echocardiography 2006;23:361-8.
61. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity among adults: United States, 2011-2012. NCHS Data Brief 2013:1-8.
62. He Q, Horlick M, Thornton J, Wang J, Pierson RN, Jr., Heshka S, Gallagher D. Sex and race differences in fat distribution among Asian, African-American, and Caucasian prepubertal children. J Clin Endocrinol Metab 2002;87:2164-70.
63. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004;363:157-63.
64. Bouchard C, Despres JP, Mauriege P. Genetic and nongenetic determinants of regional fat distribution. Endocr Rev 1993;14:72-93.
65. Ishii Y, Hasegawa H, Nishibori H, Watanabe M, Kitajima M. Impact of visceral obesity on surgical outcome after laparoscopic surgery for rectal cancer. The British journal of surgery 2005;92:1261-2.
66. Tokunaga K, Matsuzawa Y, Ishikawa K, Tarui S. A novel technique for the determination of body fat by computed tomography. Int J Obes 1983;7:437-45.
67. Kvist H, Chowdhury B, Sjostrom L, Tylen U, Cederblad A. Adipose tissue volume determination in males by computed tomography and 40K. Int J Obes 1988;12:249-66.
68. Martin-Rodriguez E, Guillen-Grima F, Marti A, Brugos-Larumbe A. Comorbidity associated with obesity in a large population: The APNA study. Obes Res Clin Pract 2015.
69. Pelosi P, Gregoretti C. Perioperative management of obese patients. Best Pract Res Clin Anaesthesiol 2010;24:211-25.
70. Miskovic D, Ni M, Wyles SM, Tekkis P, Hanna GB. Learning curve and case selection in laparoscopic colorectal surgery: systematic review and international multicenter analysis of 4852 cases. Diseases of the colon and rectum 2012;55:1300-10.
71. Bardakcioglu O, Khan A, Aldridge C, Chen J. Growth of laparoscopic colectomy in the United States: analysis of regional and socioeconomic factors over time. Annals of surgery 2013;258:270-4.
72. Celentano V. Need for simulation in laparoscopic colorectal surgery training. World J Gastrointest Surg 2015;7:185-9.
73. Guillou PJ, Quirke P, Thorpe H, Walker J, Jayne DG, Smith AM, Heath RM, Brown JM. Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with

colorectal cancer (MRC CLASICC trial): multicentre, randomised controlled trial. Lancet 2005;365:1718-26.
74. Trastulli S, Cirocchi R, Listorti C, Cavaliere D, Avenia N, Gulla N, Giustozzi G, Sciannameo F, Noya G, Boselli C. Laparoscopic vs open resection for rectal cancer: a meta-analysis of randomized clinical trials. Colorectal disease : the official journal of the Association of Coloproctology of Great Britain and Ireland 2012;14:e277-96.
75. Kehlet H. Fast-track surgery-an update on physiological care principles to enhance recovery. Langenbecks Arch Surg 2011;396:585-90.
76. Basse L, Hjort Jakobsen D, Billesbolle P, Werner M, Kehlet H. A clinical pathway to accelerate recovery after colonic resection. Annals of surgery 2000;232:51-7.
77. Dhruva Rao PK, Howells S, Haray PN. Does an enhanced recovery programme add value to laparoscopic colorectal resections? Int J Colorectal Dis 2015;30:1473-7.
78. Vennix S, Pelzers L, Bouvy N, Beets GL, Pierie JP, Wiggers T, Breukink S. Laparoscopic versus open total mesorectal excision for rectal cancer. Cochrane Database Syst Rev 2014;4:CD005200.
79. Sajid MS, Ahamd A, Miles WF, Baig MK. Systematic review of oncological outcomes following laparoscopic vs open total mesorectal excision. World J Gastrointest Endosc 2014;6:209-19.
80. Efron JE, Uriburu JP, Wexner SD, Pikarsky A, Hamel C, Weiss EG, Nogueras JJ. Restorative proctocolectomy with ileal pouch anal anastomosis in obese patients. Obes Surg 2001;11:246-51.