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Sagittal Abdominal Diameter is a Better Predictor than Body Mass Index for Duration of Laparoscopic Left Colectomy

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Abstract

Background Visceral obesity (VO) increases technical difficulty in laparoscopic surgery. The body mass index (BMI) does not always correlate to intra-abdominal fat distribution. Our hypothesis was that simple anthropometric measures that reflect VO, could predict technical difficulty in laparoscopic colorectal surgery, as reflected by the operative time, more accurately than the BMI.

Methods Charts of all consecutive patients who underwent laparoscopic left colon resection in our institution between 2007 and 2010 were reviewed retrospectively. On a preoperative CT scan, anthropometric measures were taken on an axial plane at the L4–L5 level. Demographic, operative and anthropometric CT measures were correlated with the operative time. Logistic regression analysis was performed to assess the value of anthropometric CT measures or BMI to predict the duration of the colectomy.

Results 121 patients with elective left colon resection for benign (56%) or malignant disease (44%) were included. There were 74 sigmoid resections (61%), 21 left hemicolectomies (17%) and 26 low anterior resections (22%). A longer sagittal abdominal diameter ($\geq$24.8 cm) was significantly associated with longer corrected operative time (248 vs. 228 min, $p = 0.043$). In multivariate analysis, greater sagittal abdominal diameter, sagittal internal diameter and abdominal perimeter were significantly associated with longer operative time. No significant association was found for the BMI neither in univariate nor in multivariate analysis.

Conclusions This study suggests that simple linear measures taken on a CT scan, such as sagittal abdominal diameter, sagittal internal diameter and abdominal perimeter, may predict longer operative time in laparoscopic left colonic resections more accurately than BMI.

Introduction

Laparoscopy is becoming the preferred approach for colorectal resection for both benign and malignant diseases, leading to better outcomes compared with laparotomy in terms of bowel function, postoperative pain, surgical site infection (SSI) and length of hospital stay [1–5]. Obesity, defined as a body mass index (BMI) $\geq$30 kg/m^2, is known to increase technical difficulty of laparoscopic colectomy

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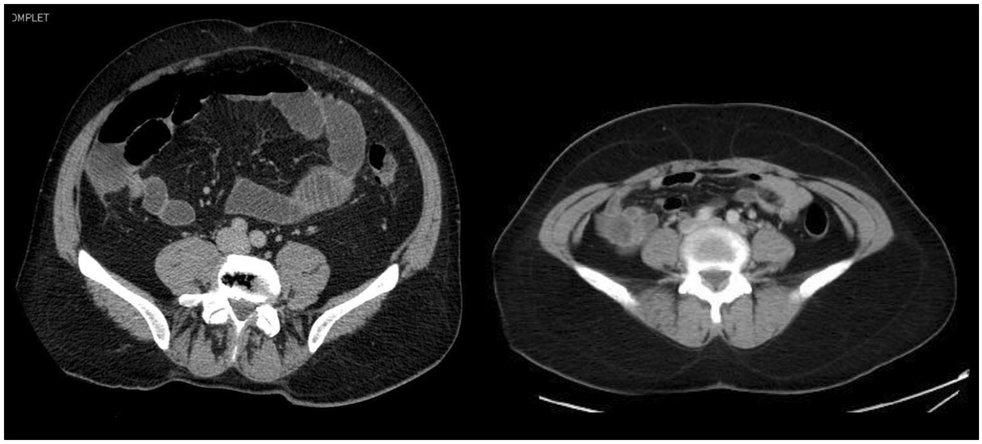

Fig. 1 For an identical BMI, adipose tissue can either locate in the intra-abdominal cavity, along the mesentery (*left*), or in the subcutaneous tissue (*right*)

and is associated with an increased number of trocars, operative time (OpT) and conversion rate [6–12]. Several authors have reported an increased risk for SSI in obese subjects, especially after open procedures [8, 11, 13–15], but others suggest that the benefit of laparoscopy in colorectal surgery may be maximal in obese patients [7, 9, 10, 16].

On the other hand, distribution of body fat is variable and depends on gender, age and ethnicity. It may predominate inside the abdominal cavity, in the subcutaneous tissue (Fig. 1), or in both sites. In the field of internal medicine, it is accepted that these two types of obesity have a distinct association with metabolic disease and cardiovascular risk. After adjustment for BMI, excessive visceral adipose tissue accumulation or visceral obesity (VO) is more closely correlated with the development of metabolic risk factors than subcutaneous tissue accumulation [17]. VO is firmly associated with the risk of developing hypertension, dyslipidemia and diabetes, and is an independent risk factor for cardiovascular disease and stroke [18].

The most accurate method to measure VO is a CT scan-based calculation of intra-abdominal fat [19, 20]. However, this method, besides the need for CT scan with the associated radiation and costs, is time consuming and requires complex software image processing. Simple anthropometric measures, such as sagittal abdominal diameter (SAD), abdominal perimeter or waist-to-hip ratio, are also strongly correlated with VO [19, 21, 22]. They are therefore frequently used in common clinical practice to measure VO and the correlated cardiovascular risk.

In the field of abdominal surgery, intuitively, most surgeons think that it is easier to operate on an obese patient whose adipose tissue is predominantly subcutaneous rather than intra-abdominal. But this difference in fat distribution is not reflected by the BMI. We hypothesized that simple anthropometric measures taken on a CT scan, that reflect VO, can predict technical difficulty in laparoscopic colorectal surgery better than the BMI. In the absence of an objective measurement tool for technical difficulty, we used for our correlation analysis surrogate markers of difficulty, such as duration of surgery, intraoperative complications, conversion and postoperative morbidity.

Material and methods

Patients and data collection

All patients undergoing elective laparoscopic left colorectal surgery in our institution between January 2007 and December 2010 were considered for inclusion. Exclusion criteria were the absence of preoperative abdominal CT scan, emergency surgery, non-resectional procedures, natural orifice specimen extraction and single incision surgery.

Patient data were retrospectively analyzed from electronic charts. Two authors (BB and DaC) performed all CT measures on Carestream Vue PACS (version 11.3, Carestream Health, USA), on a CT scan done within 6 months prior to surgery. They were unaware of the surgical outcomes or OpTs. If more than one examination was available, the closest to the date of surgery was used. The L4–L5 level was determined on a sagittal reconstruction image and the linked cross-sectional image at L4–L5 was used to perform all measurements (Fig. 2). We defined six measurements: (1) abdominal perimeter (Perim), measured at the skin level; (2) SAD, measured on a vertical midline from skin-to-skin without taking in account the umbilical fold; (3) sagittal internal diameter (S-int), measured on a vertical midline from the anterior wall of the vertebra to the internal surface of the abdominal wall; (4) transverse external diameter (T-ext), measured on a horizontal line passing through the vena cava and aorta from skin-to-skin;

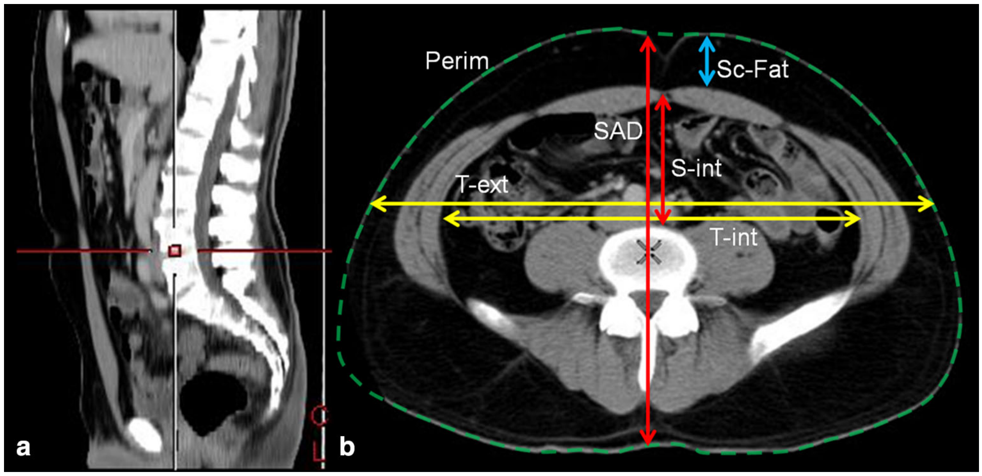

Fig. 2 Localization of the L4–L5 level (**a**), linked cross-sectional image (**b**). Sagittal abdominal diameter (SAD), sagittal internal diameter (S-int), transverse external diameter (T-ext), transverse internal diameter (T-int), abdominal perimeter (Perim), subcutaneous fat (Sc-fat)

(5) transverse internal diameter (T-int), measured on a horizontal line passing through the vena cava and aorta from one side of the internal surface of the abdominal wall to the other; (6) subcutaneous fat (Sc-fat), measured on a vertical line right next to the umbilical fold, from skin to the anterior surface of the abdominal wall.

Surgical procedures were most frequently performed by a chief resident under the direct supervision of one of the six surgeons, either an attending surgeon or an experienced chief resident with complete training in laparoscopic colorectal surgery. The number of trocars used (three to five) and the approach (medial-to-lateral or lateral-to-medial) depended on local status and surgeon preferences. Intra-abdominal adhesions were classified based on the operative report as absent, minor or major. Splenic flexure takedown was defined as complete distal transverse colon mobilization with colo-epiploic dissection. There were no hand-assisted laparoscopic procedures. Conversion to laparotomy was defined as any abdominal incision larger than the incision needed to remove the surgical specimen, motivated by intraoperative technical difficulties or complications. Operative time (OpT) was calculated from skin incision to last skin suture. For patients undergoing combined procedures, we subtracted the duration of the additional procedure as specified on the operating room documents. Postoperative morbidity and mortality were recorded according to a validated classification of surgical complications [23]. Length of hospital stay was calculated from day of entry to discharge. The study was approved by the local ethics committee.

Statistical analysis

For each anthropometric CT measure and for BMI, patients were divided into two groups according to the median. OpT between groups were compared using unpaired two-tailed *t* tests or one-factor analysis of variance (ANOVA) according to the distribution of categorical variables. Linear correlation was performed between predictive continuous variables (anthropometric CT measures and BMI) and OpT. Logistic regression was performed for multivariate analysis to assess the value of anthropometric CT measures and BMI to predict OpT. All preoperative variables achieving statistical significance at a 0.1 level in the linear correlation analysis were considered for the multivariate analysis. Correlation coefficients were calculated. All tests were two sided. For all tests, statistical significance was defined as $p < 0.05$. Statistical analysis was performed on JMP version 8.2 software (SAS Institute, Cary, NC).

Results

Patient characteristics and surgery outcomes

The study included 121 patients (48 women, 73 men). Median BMI was 25.4 kg/m^2 (range 16.7–48.6). Patient population characteristics are shown in Table 1 and operative data in Table 2. Mean (±SD) OpT was 246.8 min ± 67.4. Twenty-six (21.5%) laparoscopic procedures were converted for the following reasons: the presence of adhesions and insufficient exposure in 15 cases; iatrogenic lesion of the urinary tract in 3 (2 bladder, 1 ureter); necessity for "en bloc" resection (small bowel, abdominal wall) in 2; uncontrollable bleeding in 2 (pelvis, spleen); impossibility of tumor localization in 1; iatrogenic laceration of the rectum in 1; the presence of a pelvic abscess with abdominal contamination in 1; and respiratory failure due to the pneumoperitoneum in 1.

Table 1 Patient characteristics

	Patients ($n = 121$)
Age (years) [median (range)]	64 (31–87)
Gender	
Male	73 (60%)
Female	48 (40%)
BMI (kg/m^2) [median (range)]	25.4 (16.7–48.6)
Anthropometric CT measures (cm) [median (range)]	
SAD	24.8 (15.8–36.2)
S-int	10.2 (4.4–18.3)
T-ext	32.7 (25.6–42.3)
T-int	25.1 (20.1–35)
Perim	98.1 (71.9–128)
Sc-fat	2.1 (0.8–5)
ASA score (%)	
1	7 (6)
2	86 (71)
3	28 (23)
Diagnosis (%)	
Benign disease	68 (56)
Malignancy	53 (44)
Previous abdominal surgery	62 (51)
Preoperative radiotherapy	12 (10)

Anthropometric CT measures: sagittal abdominal diameter (SAD), sagittal internal diameter (S-int), transverse external diameter (T-ext), transverse internal diameter (T-int), abdominal perimeter (Perim), subcutaneous fat (Sc-fat)

Table 2 Operative data and postoperative outcomes

	Patients ($n = 121$)	Operative time [mean (SD)]	p value
Type of resection			0.02
Sigmoidectomy	74 (61 %)	227 (55.7)	
Left hemicolectomy	21 (17 %)	236 (58.9)	
Low anterior resection	26 (22 %)	266 (67.6)	
Adhesions			0.23
Absent		237.9 (60.8)	
Minor		229.3 (60.8)	
Major		258.8 (58.7)	
Splenic flexure takedown			0.02
Yes	84 (69 %)	245.1 (60.1)	
No	37 (31 %)	216.2 (57.4)	
Conversion			0.01
Yes	26 (21 %)	229.0 (57.4)	
No	95 (79 %)	268.3 (63.9)	

Overall morbidity rate was 22.3 %. Minor-to-moderate (grade I–II) complications occurred in 15 (12.4 %) patients, 7 (5.8 %) had grade III complications and 5 (4.1 %) grade IV. One (0.8 %) patient died from respiratory failure following postoperative pneumonia. Median length of hospital stay was 8 days (range 4–60).

Intraoperative characteristics that influenced significantly mean OpT were type of resection, splenic flexure takedown and need for conversion (Table 2). Colectomy took longer in men than in women, but this was not statistically significant (244.2 ± 62.8 vs. 224.3 ± 54.9 min, $p = 0.09$). Indication for colectomy did not influence OpT (benign disease, 234 ± 58.8 min vs. neoplasia, 241 ± 63.2 min, $p = 0.519$).

Correlations body measures: operative time, univariate analysis

Operative time was longer for patients in the group with higher value for all types of measures, but the difference was statistically significant for SAD only (SAD $\geq$ 24.8 cm: 248.1 min ± 56.5 vs. SAD < 24.8 cm: 225.5 min ± 62.7, $p = 0.04$) (Fig. 3). Similarly, there was a statistically significant linear correlation between OpT and SAD ($p = 0.01$), S-int ($p = 0.03$) and Perim ($p = 0.02$), but not for for BMI ($p = 0.054$) (Table 3).

Correlations body measures: operative times, multivariate analysis

In logistic regression analysis, when controlling for splenic flexure takedown, SAD ($r^2 = 0.107$, $p = 0.01$), S-int ($r^2 = 0.116$, $p = 0.02$) and Perim ($r^2 = 0.123$, $p = 0.01$) were significant predictors of OpT, but not BMI

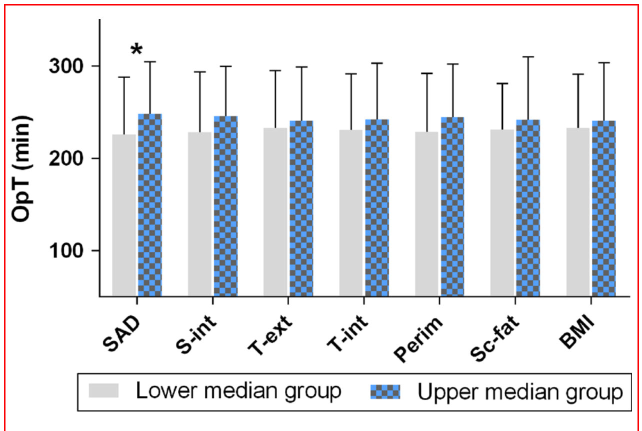

Fig. 3 Operative time (OpT). Anthropometric CT measures: sagittal abdominal diameter (SAD), sagittal internal diameter (S-int), transverse external diameter (T-ext), transverse internal diameter (T-int), abdominal perimeter (Perim), subcutaneous fat (Sc-fat). * significant

Table 3 Linear correlation of BMI and anthropometric CT measures, to operative time

	r^2	p value
BMI	0.03 (+)	>0.05
SAD	0.06 (+)	0.01
S-int	0.04 (+)	0.03
T-ext	0.03 (+)	0.27
T-int	0.01 (+)	0.23
Perim	0.04 (+)	0.02
Sc-fat	0.00	0.18

Anthropometric CT measures: sagittal abdominal diameter (SAD), sagittal internal diameter (S-int), transverse external diameter (T-ext), transverse internal diameter (T-int), abdominal perimeter (Perim), subcutaneous fat (Sc-fat)

Table 4 Multivariate analysis of predictive factors of operative time

	r^2	p value
Splenic flexure takedown		
BMI	0.075	0.07
SAD	0.107	0.01
S-int	0.116	0.02
Perim	0.123	0.01
Type of resection		
BMI	0.096	0.06
SAD	0.136	<0.01
S-int	0.093	0.02
Perim	0.092	0.02

BMI and anthropometric CT measures were controlled for splenic flexure takedown and type of resection. Anthropometric CT measures: sagittal abdominal diameter (SAD), sagittal internal diameter (S-int), abdominal perimeter (Perim)

($r^2 = 0.075$, $p = 0.07$). When controlling for the type of resection, SAD ($r^2 = 0.136$, $p < 0.01$), S-int ($r^2 = 0.093$, $p = 0.02$) and Perim ($r^2 = 0.092$, $p = 0.02$) were also significant predictors of OpT, but not BMI ($r^2 = 0.096$, $p = 0.06$) (Table 4).

Correlations to morbidity

Neither BMI nor CT anthropometric measures were correlated with conversion or postoperative complications (Table 5).

Discussion

The interest of our present study was to observe a statistically significant correlation between the duration of laparoscopic colon resection and the patient's SAD, abdominal perimeter (Perim) and sagittal internal diameter

Table 5 Conversion and postoperative complications

	Conversion			Postoperative complications		
	Yes	No	p value	Yes	No	p value
BMI (kg/m^2)	25.5	25.2	0.74	25.4	25.4	0.71
Anthropometric CT measures (cm)						
SAD	25	24.1	0.82	24.45	24.9	0.89
S-int	10.2	10.1	0.91	10.3	10.2	0.59
T-ext	32.7	33.8	0.36	32.45	32.6	1.00
T-int	25	25.3	0.28	25.5	25	0.22
Perim	98.3	96.2	0.87	99.6	98	0.97
Sc-fat	2.3	1.7	0.21	1.8	2.1	0.23

Anthropometric CT measures: sagittal abdominal diameter (SAD), sagittal internal diameter (S-int), transverse external diameter (T-ext), transverse internal diameter (T-int), abdominal perimeter (Perim), subcutaneous fat (Sc-fat)

(S-int), but not with the BMI. Our measures were made based on a single axial CT scan image, but the two measures that showed the best correlation to OpT (SAD and Perim) can also be easily taken at the patient's bedside.

In colorectal surgery, few studies have evaluated the effect of VO on surgical outcomes. Operative times in viscerally obese patients were found to be longer in several reports [24–27]. Unlike our own report, Kang, in a retrospective study including 231 patients with laparoscopic total mesorectal excision, showed that abdominal volumetric fat parameters and BMI were equally correlated with operative time; operative times were longer for obese patients, either defined by BMI or by volumetric abdominal fat. They found that VO predicted a higher rate of conversion, whereas BMI did not [28]. Tsujinaka found an increase in overall morbidity and wound infection rates in viscerally obese patients, but no correlation between these outcomes and BMI [24]. Ishii found increased overall complication rates following laparoscopic colorectal surgery in patients with VO. No difference was found when the same patients were classified according to BMI [27]. Clark suggested that abdominal fat accumulation was associated with an increased risk of tumor recurrence following multimodal therapy in rectal cancer surgery [29]. In all of the above-mentioned studies, measures of VO were made with complex CT scan-based image processing of intra-abdominal fat. In our opinion, while such measures apply for clinical research, they are hardly applicable in daily clinical practice.

To our knowledge, only few studies used simple measures of VO to predict outcomes after laparoscopic colorectal surgery. Recently, a large multicenter prospective European trial involving 1,349 patients assessed the value of the waist-to-hip ratio compared to BMI regarding the outcomes in elective colorectal surgery. In this study, the waist-to-hip ratio was found to be an independent predictive factor for intraoperative complications, conversion and postoperative complications, whereas BMI was not. In this study, which included both open and laparoscopic procedures, the authors did not report any data on operative duration [30]. Nitori measured waist circumference in 98 patients and compared the outcomes of laparoscopic colectomy for the obese and non-obese patients, defined either according to BMI or waist circumference. Their results suggested that VO was correlated with an increased risk of postoperative pulmonary complications. Operative time for colon resections tended to be longer in VO patients, although the correlation was not statistically significant [31].

In our present study, we observed increased operative times in viscerally obese patients as reflected by SAD and Perim, but no significant correlations with the conversion rate or with postoperative complications. This may be due to a type II error due to the relatively small sample size in our study. Another hypothesis is that surgeon may put more effort and attention to achieve the procedure without complications in patients with more intra-abdominal fat, at a price of a prolonged operative time.

Operative morbidity is clinically more relevant than the operative time, but longer operative times may suggest intraoperative technical difficulties. Thus, predicting difficulty of a laparoscopic procedure is useful and allows appropriate patient selection for teaching operations, operative program planning and stratification of patients in clinical trials.

This said that several limitations need to be addressed. It is a retrospective study with a rather limited number of patients. The absence of correlation between BMI and surgical outcomes in our study could be due to a type II error. In order to create homogeneous groups of patients and allow for standardized measurements, we excluded patients who did not have a preoperative CT scan and patients operated on emergency, as in such cases, abdominal volume often depends on distention due to ileus or peritonitis, rather than visceral fat accumulation. We controlled for some factors known to influence duration of surgery, such as type of procedure, splenic flexure takedown, the presence of adhesions and conversion, but we were unable to take into account several other important factors. In particular, operations were performed by surgeons with different levels of experience and this may have introduced some bias.

In conclusion, despite above-mentioned limitations, our study suggests that SAD, S-int and Perim may predict operative duration and perhaps also operative difficulty in laparoscopic colectomy more accurately than BMI. The measures, that reflect VO, were calculated on standard CT scan and could also be easily taken at patient's bedside. Such measures could be useful for risk-stratification in clinical studies and preoperative planning. However, these findings should be validated in future prospective studies.

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