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# Waist Circumference Predicts Increased Complications in Rectal Cancer Surgery

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**Abstract**
*Background* The impact of obesity on development of postoperative complications after gastrointestinal surgery remains controversial. This may be due to the fact that obesity has been calculated by body mass index, a measure that does not account for fat distribution. We hypothesized that waist circumference, a measure of central obesity, would better predict complications after high-risk gastrointestinal procedures.
*Methods* Retrospective review of an institutional cancer database identified consecutive cases of men undergoing elective rectal resections. Waist circumference was calculated from preoperative imaging.
*Results* From 2002 to 2009, 152 patients with mean age 65.2±0.75 years and body mass index 28.0±0.43 kg/m$^2$ underwent elective resection of rectal adenoma or carcinoma. Increasing body mass index was not significantly associated with risk of postoperative complications including infection, dehiscence, and reoperation. Greater waist circumference independently predicted increased risk of superficial infections (OR 1.98, 95% CI 1.19–3.30, $p<0.008$) and a significantly greater risk of having one or more postoperative complications (OR 1.56, 95% CI 1.04–2.34, $p<0.034$).
*Conclusions* Waist circumference, a measure of central obesity, is a better predictor of short-term complications than body mass index and can be used to identify patients who may benefit from more aggressive infection control and prevention.

**Keywords** Obesity · Rectal cancer · Complications

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## Introduction

The impact of obesity on development of postoperative complications after gastrointestinal surgery remains controversial. Several studies have shown that obese patients are at greater risk for death and short-term complications including wound infections, venous thrombosis, and anastomotic leaks.[1–3] However, other groups have shown no difference between obese and normal weight individuals or an effect limited primarily to those who are morbidly obese.[4–7] These contradictory findings may be partly explained by the fact that obesity is traditionally measured by BMI, which does not account for fat distribution.[8] By contrast, alternative measures of obesity including waist circumference can be used to measure fat distribution and to distinguish between central and other types of obesity.

Central obesity is an element of the metabolic syndrome and has been associated with changes in insulin regulation and mortality as well as increased incidence of colorectal cancer.[9,10] Central distribution of fat may be relevant for abdominal surgery since adipose tissue tends to be less well vascularized than skin and surrounding stroma. Consequently, having excess fat tissue in the abdominal region should be more likely to increase complications than having the same absolute quantity of fat distributed away from the operative field in the limbs or posterior region.

Several recent papers have looked at the effects of fat distribution by measuring intra-abdominal/visceral fat and subcutaneous fat area. These authors found that in laparoscopic colorectal surgery measuring fat distribution is better than BMI when it comes to predicting postoperative complications.[11–13] However, measuring visceral and subcutaneous fat requires specialized software and is time-consuming. By contrast, waist circumference is a simpler measure that reflects the presence of central obesity and has been associated with increased risk for parastomal hernia following abdominoperineal resection (APR).[14] We hypothesized that waist circumference would be an accurate predictor of other postoperative complications.

## Materials and Methods

After obtaining approval from the Baylor College of Medicine and Veterans Affairs institutional review boards, consecutive patients undergoing rectal surgery from 2002 to 2009 were identified using an institutional database at the Michael E DeBakey Veterans Affairs Hospital. Patients were included in this study if they underwent elective resection for rectal adenoma or adenocarcinoma. Patients were excluded if they had a history of Crohn's disease, underwent emergency surgery, or had surgery purely for palliation. Demographics, comorbidities, surgical data, pathology, and information on complications were obtained from electronic medical records. Complications were defined according to VA National Surgical Quality Improvement Program criteria.[15]

Preoperative CT imaging was reviewed retrospectively to obtain images at mid-waist, defined as the midpoint between the last rib visualized and the top of the iliac crest.[9] Images were manually captured and de-identified prior to measuring circumference. Waist circumference was then measured at the mid-waist level using Photoshop© to determine abdominal circumference. Circumference was measured manually using the magnetic lasso tool within Photoshop© to trace the edge of the skin surface and record distance. To maximize sensitivity and reproducibility, image contrast and brightness were set to maximum in order to highlight differences between skin and surrounding air. Image scale was maintained by defining unit of measurement within Photoshop© based on visual record of the scale ruler from the original image. Abstraction of images and measurements were performed by one author (C.B.) who was blinded to patient outcomes. A second rater (W.B.) was blinded to previous measures of waist circumference and then measured waist circumference in a random sample of 50 patients in order to calculate the intraclass correlation coefficient.

Correlations between continuous variables were assessed using Pearson's correlation coefficient or Kendall's tau depending on normality of data distribution, and categorical variables were assessed using chi-square. The intraclass correlation coefficient was calculated as a two-way mixed effects model with raters classified as random effects. Comparisons of mean length of stay between tertiles of waist circumference and BMI were performed using ANCOVA with age as a covariate and taking the natural log transformation of the length of hospital stay as the dependent variable. Comparison between means was done using planned contrasts with quartile 1 as the reference category. Independent predictors of postoperative complications were calculated using univariable and multiple logistic regression. When adjusting for surgical approach comparing minimally invasive (laparoscopic or hand-assisted laparoscopic) to open surgery, cases were categorized as minimally invasive even when converted to open surgery. Comorbidities were controlled for individually (except for cardiac disease which was denoted as positive if patients had prior surgical or medical intervention for cardiac disease) by entrance into regression models as a dichotomous variable indicating either presence or absence of disease. The presence of effect measure modification was assessed by including a term for multiplicative interaction between obesity measures and variables coding for ethnicity and surgical approach. Model discrimination was assessed using the c-statistic and model fit evaluated using the Hosmer and Lemeshow test. All statistical comparisons were conducted using SPSS version 17 copyright SPSS Inc.

## Results

### Demographics and Comorbidities

From 2002 to 2009, 152 patients underwent elective resection for rectal adenoma or carcinoma under the supervision of 12 surgical attendings at a tertiary care Veterans Affairs hospital. A total of 129 patients (85%) had preoperative imaging available to determine waist circumference. There were no significant differences in age, comorbidities or complication rates between patients with available imaging and those without preoperative CT scans (data not shown). Mean patient age was 65±0.8 years, 98% were male and 93% were either Caucasian or African–American (Table 1). The most common surgeries were low anterior resection (LAR, 66%) and APR (30%), and 95% of cases revealed cancer on final pathology. An open surgical approach was utilized in 72% of cases with the remainder performed using laparoscopic-assisted or hand-assisted laparoscopic surgery. Conversion rate for laparoscopic-assisted and hand-assisted surgery was 23%. The most common comorbidities in this population were hypertension (68%) and diabetes (26%), and there was also a high smoking prevalence as 73% of patients were either current or former smokers.

### Obesity Measurements

Previous studies have shown that measurements of visceral and subcutaneous fat are better predictors of postoperative complications than BMI, but none have evaluated whether increasing waist circumference is associated with overall complication rate or specific complications aside from parastomal hernia.[12–14] Consequently, we evaluated preoperative BMI and waist circumference to determine their association with postoperative complications. BMI was determined from preoperative medical records, and CT imaging was used to quantify waist circumference prior to surgery. Mean BMI was 28±0.43 kg/m$^2$, and mean waist circumference was 108.8±1.3 cm. Intraclass correlation coefficient for measuring waist circumference was assessed on a random sample of 50 cases and was found to be 0.999, indicating a high degree of reproducibility between raters.

**Table 1** Demographics and comorbidities

| | *N* or mean±SEM (*N*=128) | % |
|---|---|---|
| Age (years) | 65.2±0.83 | |
| Race | | |
| Caucasian | 94 | 73 |
| African American | 26 | 20 |
| Other | 8 | 7 |
| Male | 125 | 98 |
| Surgical approach | | |
| Open | 97 | 76 |
| Minimally invasive | 31 | 24 |
| Current or former smoker | 94 | 73 |
| Hypertension | 87 | 68 |
| Diabetes | 33 | 26 |
| Prior cardiac surgery | 11 | 9 |
| Prior PCI | 6 | 5 |
| Surgery performed | | |
| Low anterior resection | 84 | 66 |
| Abdominoperineal resection | 39 | 30 |
| Other | 5 | 4 |

### Complications

During the 30 days following surgery, 55 patients (43%) had one or more postoperative complications (Table 2). The most common complication was superficial wound infection which occurred in 31%, and these infections resulted in wound opening and packing in 15% of patients. Additionally, 11% had an organ space infection and 13% required reoperation for complications. Dehiscence occurred less frequently at 7%, and deep wound infections (5%) or anastomotic leaks (4%) were the least common complications seen.

### Predicting Complications

The univariable relationship between postoperative complications and BMI or waist circumference was assessed using logistic regression. Increasing BMI predicted a significantly greater risk of superficial surgical site infection along with the need for wound opening and packing (Table 3). For each 1 kg/m$^2$ increase in BMI, the odds of having a superficial infection increased 12% and the odds of having the surgical wound opened and packed increased by 9%. Larger BMI was also associated with increased risk for dehiscence and reoperation but neither achieved statistical significance. Overall, increasing BMI predicted significantly greater risk of one or more postoperative complications (HR 1.095, 95% CI 1.025–1.170). Increased waist circumference also predicted significantly increased risk of surgical site infection and need for wound opening as well as increased risk for any postoperative complication. For each 10 cm increase in waist circumference, the odds of infection increased 62% and the odds of having one or more complications increased by 51%. Additionally, greater values for waist circumference predicted a significantly greater risk of dehiscence and showed a trend towards higher risk of reoperation.

To further evaluate the relationship between obesity and risk of overall complication or infection, patients were divided into three groups (tertiles) for waist circumference

**Table 2** Postoperative complications

| Complication | *N* (*N*=128) | % |
|---|---|---|
| Superficial surgical site infection | 40 | 31 |
| Wound opened and packed | 19 | 15 |
| Reoperation | 17 | 13 |
| Organ space infection | 14 | 11 |
| Dehiscence | 9 | 7 |
| Deep surgical site infection | 6 | 5 |
| Anastomotic leak | 5 | 4 |
| Any complication | 55 | 43 |

and BMI. Tertile one represents the reference category and consists of the thinnest individuals while tertile three represents more obese patients. As waist circumference increased from tertile one to tertile three, the chance of having some postoperative complication increased from 28% to 61% ($p<0.009$, Fig. 1a). Similarly, the likelihood of having any postoperative complication increased from 32% in patients with the lowest BMI to 54% in patients in the highest tertile of BMI, but this difference was not significant ($p<0.072$, Fig. 1b). When looking at superficial infections and waist circumference, those with the largest waist circumference developed infections in 46% of cases compared to 14% for the thinnest patients ($p<0.005$, Fig. 1c). Individuals with greater BMI also experienced a significantly greater chance of developing infections when compared to patients in tertile 1 for BMI ($p<0.019$, Fig. 1d).

Since increased operative time and bleeding have been associated with greater risk of complications, we also assessed correlations between these variables and both waist circumference and BMI. Neither BMI ($r=0.007$) nor waist circumference ($r=-0.007$) were significantly correlated with intraoperative bleeding. For operative time, BMI showed a weak positive correlation ($r=0.197$, $p<0.022$) but waist circumference was not significantly correlated with procedure length ($r=0.126$, $p<0.179$).

In order to adjust for potential confounders, multiple logistic regression was used to evaluate whether waist circumference and BMI independently predicted the risk of complications. After adjusting for age, ethnicity, smoking status, comorbidities, operative time, and laparoscopic versus open approach, BMI was associated with an increased risk of postoperative complications but these associations did not reach statistical significance (Table 4). However, waist circumference independently predicted an increased risk of superficial infection as well as a greater risk of encountering one or more postoperative complications. For each 10-cm increase in waist circumference, the odds of infection increased by 98% and odds of having one or more complication increased by 56%. Additionally, waist circumference was associated with an increased risk of dehiscence and reoperation but this did not achieve statistical significance. We also wanted to assess for interaction/effect measure modification between ethnicity and obesity measures as well as surgical approach and these measures. Consequently, the significance of the interaction term between these variables was also assessed and no significant interaction was seen.

Length of Hospital Stay

Given differences in complication rates based on waist circumference, we also wanted to evaluate whether increasing waist circumference or body mass index was associated with prolonged length of hospital stay. Neither waist circumference ($r=0.076$, $p<0.396$) nor body mass index ($r=0.034$, $p<0.679$) significantly correlated with length of stay (Fig. 2a and b). Additionally, differences in length of stay by tertile of waist circumference and BMI were compared after adjusting for age. Once again, length of stay did not significantly differ according to tertile of waist circumference (Fig. 2c, $p<0.447$) or tertile of BMI (Fig. 2d, $p<0.229$).

## Discussion

An important issue in obesity research is determining the best way to actually measure obesity. The medical literature has increasingly made use of waist circumference, waist-to-hip ratio, visceral fat and subcutaneous fat ratios rather than relying solely on BMI.[16,17] This change stems from an evolving understanding of the biology and significance of

**Table 3** Univariable odds ratios for complications

| Complication | Body mass index | | Waist circumference | |
|---|---|---|---|---|
| | Odds ratio | 95% CI | Odds ratio | 95% CI |
| Superficial Surgical Site Infection | 1.12* | 1.04–1.20 | 1.62* | 1.20–2.17 |
| Organ Space Infection | 0.96 | 0.87–1.06 | 0.82 | 0.55–1.22 |
| Wound Opened and Packed | 1.09* | 1.01–1.18 | 1.75* | 1.21–2.54 |
| Dehiscence | 1.06 | 0.96–1.18 | 1.64* | 1.02–2.63 |
| Reoperation | 1.05 | 0.96–1.14 | 1.13 | 0.79–1.61 |
| Any Complication | 1.10* | 1.03–1.18 | 1.51* | 1.15–1.99 |

Odds ratio reflects changes of 1 kg/m$^2$ for BMI and 10 cm for waist circumference

*$p<0.05$

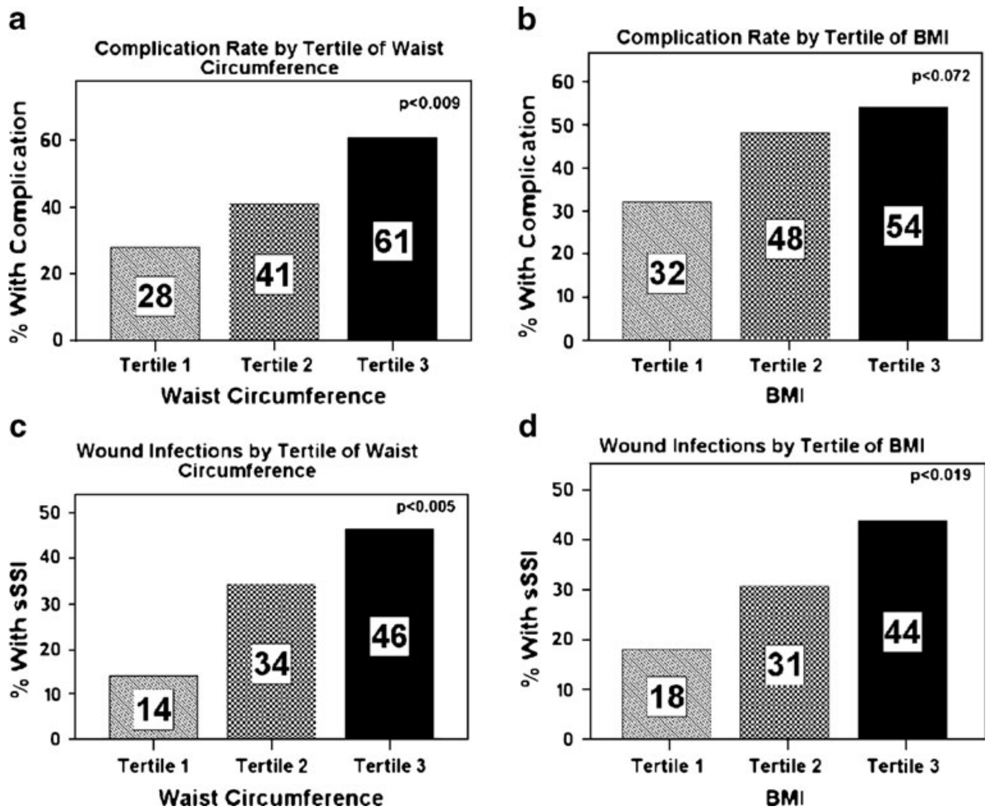


**Fig. 1** Overall complication rate and rate of wound infections increase by tertile of waist circumference and BMI on univariable analysis. (**a**–**b**) Risk of having a postoperative complication increases by tertile of waist circumference (**a**) or BMI (**b**). (**c**–**d**) Risk of superficial surgical site infection increases by tertile of waist circumference (**c**) or BMI (**d**)

different types of adipose tissue and how fat distribution impacts outcomes.[18–20] Central obesity, in particular, is an important element of the metabolic syndrome and correlates strongly with incidence of cardiovascular disease as well as incidence of colorectal cancer.[18,21] Prospective studies have now shown that measuring adipose tissue quantity and distribution in addition to BMI offers valuable information when it comes to predicting medical complications of obesity.[18,22] Consequently, it is important to consider whether these measures have equal value in predicting surgical complications.

Multiple studies have attempted to evaluate obesity using BMI as an indicator, and this has generated mixed results. Merkow et al. used the American College of Surgeons NSQIP to examine 30-day outcomes following resection for colon malignancy.[4] They found that patients who were morbidly obese (BMI≥35 kg/m$^2$) were more than twice as likely as normal weight individuals to develop a surgical site infection and four times as likely to develop a deep wound infection. Other complications including pulmonary embolism and renal failure were also increased in the morbidly obese and the overall odds of having some

**Table 4** Waist circumference predicts postoperative complications on multivariable analysis

| Complication | Body Mass Index | | Waist circumference | |
|---|---|---|---|---|
| | Odds Ratio | 95% CI | Odds Ratio | 95% CI |
| Superficial Surgical Site Infection | 1.70 | 0.75–3.86 | 1.98* | 1.19–3.30 |
| Organ Space Infection | 1.60 | 0.44–5.80 | 0.6 | 0.33–1.07 |
| Wound Opened and Packed | 2.45 | 0.92–6.55 | 1.47 | 0.82–2.62 |
| Dehiscence | 3.82 | 0.55–26.8 | 1.29 | 0.58–2.84 |
| Reoperation | 1.63 | 0.47–5.65 | 1.12 | 0.65–1.94 |
| Any Complication | 1.22 | 0.63–2.34 | 1.56* | 1.04–2.34 |

All odds ratios adjusted for age, ethnicity, smoking, diabetes, hypertension, cardiac disease, operative time, and laparoscopic versus open approach

Odds ratio reflects changes of 1 kg/m$^2$ for BMI and 10 cm for waist circumference

*$p<0.05$

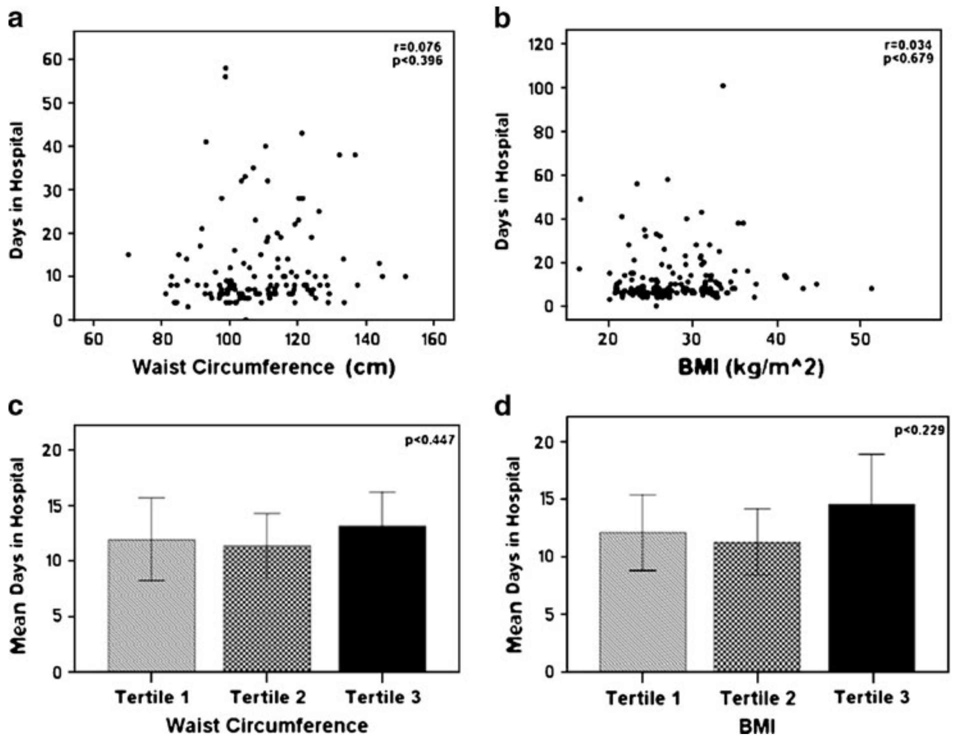


**Fig. 2** Increasing waist circumference and BMI do not predict greater length of hospital stay. Waist circumference (**a**) and BMI (**b**) do not correlate with length of stay. There is no difference in length of stay by tertile of waist circumference (**c**) or BMI (**d**) after adjusting for age

postoperative complication were increased by 75%. By contrast, obese patients with a BMI of 30–34 kg/m$^2$ did not have significantly greater odds of infection when compared to normal weight individuals and their overall complication rate was similar. The authors did note, however that being overweight but not obese was associated with increased odds of perioperative complications. Benoist et al. evaluated 737 patients who underwent elective colorectal resection at their institution over a 7-year period of time and compared those with BMI>27 kg/m$^2$ to those with BMI≤27 kg/m$^2$.[1] After adjusting for other factors, this study did not find a significant difference in postoperative complications between the two groups undergoing rectal surgery. However, operative time was prolonged and mortality rate was increased in obese patients. Similarly, Hawn et al. evaluated the impact of obesity on resource utilization following colectomy and found that obesity was associated with increased operative time but did not predict length of stay.[23] Pikarsky et al. looked specifically at laparoscopic colorectal surgery and found increased risk of complications and conversions to open surgery in obese compared to non-obese patients.[2]

By contrast, several studies have found no difference in morbidity or mortality between obese and non-obese patients. Dindo et al. examined 6,336 consecutive patients undergoing elective general surgery and compared patients with BMI≥30 kg/m$^2$ to those with BMI<30 kg/m$^2$. The authors found no difference in complication rate after adjusting for confounding factors.[5] Schwandner et al. evaluated outcomes in laparoscopic colorectal surgery and found that obesity was not associated with postoperative morbidity or length of stay.[6] Another study looking specifically at laparoscopic rectal surgery also found no difference in mortality or overall morbidity despite prolonged operative time in obese patients.[24] Similarly, Leroy et al. looked at the effect of obesity on outcomes following laparoscopic left colectomy and found no difference in length of stay or postoperative complications.[7] Ballian et al. evaluated short- and long-term outcomes in obese patients undergoing surgery for rectal cancer and saw no difference in morbidity or length of stay, and actually saw improved overall survival.[25]

Since data based on BMI has generated conflicting results, other groups have asked whether measuring fat distribution can predict surgical complications. Ishii et al. used CT imaging to measure visceral fat area in 46 patients undergoing laparoscopic rectal cancer resection and found that visceral obesity was associated with prolonged operative time and increased risk of postoperative complications.[12] Similarly, Tsujinaka et al. found that visceral fat was a better predictor than BMI for wound infection, overall complications rate, and length of stay.[13] Seki et al. also looked at visceral fat as a predictor of technical difficulty in laparoscopic rectal sigmoid resections.[11] The authors found that increased visceral fat area relative to body surface area correlated with increased operative time and delayed resumption of a regular diet, but was not associated with increased complications.

One potential limitation of these newer obesity measurements is that quantification of adipose tissue on CT imaging is time-consuming and often uses specialized software. By contrast, calculating waist circumference ought to be more straightforward and less time-consuming. Additionally, if waist circumference proves to be a useful predictor it can easily be assessed without resorting to radiologic imaging. At least one group evaluated patients who underwent APR and found that waist circumference predicts parastomal hernia, but they did not assess other complications.[14]

Our study evaluated the predictive power of waist circumference in relation to the traditionally used measure of body mass index. On univariable analysis, we found that waist circumference was strongly associated with an increased risk of one or more postoperative complications as well as specific complications including wound infection and dehiscence. Even after adjusting for confounders including age, ethnicity, smoking status, comorbidities, operative time, and surgical approach we found that waist circumference predicted a twofold increase in risk of infection and greater than 50% increase in the odds of encountering one or more postoperative complications. By contrast, BMI was no longer significantly associated with risk of complication after adjusting for confounders. Since operative difficulty has been associated with increased risk of complications we also assessed whether surrogates for difficult surgery (operative time and blood loss) correlated with increasing waist circumference. We found that neither length of procedure nor intraoperative blood loss were significantly correlated with waist circumference, and this suggests that the increased rate of complications observed is not due simply to more difficult operations. The relationship between greater waist circumference and increased risk of complications may be due, at least in part, to greater quantities of adipose tissue in the abdominal region. Since adipose tissue tends to be poorly vascularized, one might expect central obesity to increase the risk of postoperative complications, especially wound infections. Since BMI does not specifically reflect an abdominal or central distribution of fat, this measure may be less sensitive to detecting differences between patients that are relevant for predicting complications.

Despite an increased risk of complications related to enlarging waist circumference, we did not find an associated increase in length of hospital stay. This finding may reflect the benefits of tightly integrated multidisciplinary care in the treatment of cancer patients. Close coordination with social work and case management allows surgical teams to continue care in the outpatient setting using home health agencies and other modalities. Additionally, early detection of infectious complications allows for initiation of antibiotics and wound opening so that patients are able to return home without significant delays.

Potential limitations of our study include its retrospective nature with an associated risk of differential misclassification bias. Additionally, selection bias cannot be ruled out since not all patients had preoperative imaging available for review. However, comparisons between patients with and without CT scans showed no significant differences. Moreover, since this was not a prospective study the timing of preoperative imaging was not standardized and it is conceivable that waist circumference as well as BMI may have fluctuated between time of measurement and time of surgery. Even though dramatic weight loss is not common in colorectal cancer patients, this possibility cannot be completely ruled out. Furthermore, although we attempted to control for relevant confounders, residual confounding cannot be entirely excluded. We are also limited by the single institutional nature of our study. Since all of the patients were part of the VA system, results may not be generalizable to other public or private institutions. At the same time, the vast majority of VA patients are men and it is possible that obesity has different impacts on complication rates depending on gender. Finally, our study has a relatively small sample size which makes it more difficult to determine predictors of complications that occur at low rates. It is also possible that a larger sample would result in smaller confidence intervals so that the trends we observed towards greater risk of dehiscence and reoperation on multivariable analysis would become significant given the larger sample population.

## Conclusion

In spite of its potential weaknesses, our study is the first to demonstrate a link between waist circumference and postoperative complications. More importantly, waist circumference may be a better predictor of complications than BMI which has been the traditional measure of obesity. Since risk adjustment has begun to play an increasingly important role in surgery and may soon play a role in determining reimbursements for care, it is important to build models based on accurate predictors. Currently, no large prospective surgical databases are collecting measures of obesity other than BMI. Consequently, we are forced to rely on BMI and this measure may not accurately reflect what it means to be obese. Indeed, the medical literature has consistently shown the advantage of evaluating obesity measures other than BMI. Our study demonstrates that at least one of these measures, waist circumference, can be a useful predictor of surgical complications. Identification of high-risk patients helps delineate those who would benefit from more aggressive measures to prevent infection and other complications. This measure deserves further study and validation in a larger sample involving multiple patient populations.

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## Discussant

**Dr. Stuart G. Marcus:** Your presentation was excellent with good command of the data, and also you prepared a well-written manuscript. Your data challenges the accuracy of BMI in predicting surgical complications. Measuring waist circumference certainly seems simple. It's reproducible and it makes intuitive sense for patients undergoing abdominal surgery.

Your data joins a growing body of literature, including a paper presented this morning that highlights an important public policy issue. The concern is that surgeons will avoid operating on obese patients that are identified at high risk in order to keep their own quality report card more acceptable with regards to postop infections, readmissions, or returns to the OR, all potential financial disincentives to practitioners and hospitals.

Furthermore, a possible scenario that one could envision is the development of specialized obesity centers for the referral of high-risk obese patients for non-bariatric surgery similar to what we have seen for pancreatic and esophageal surgery.

With this in mind, I have several questions.

Are there strategies that you recommend to mitigate the risk of complications in patients identified preoperatively as being at high risk?

You mentioned some ranges, but where do you propose the cut-off is for waist circumference where we should begin to worry?

Can your results be extrapolated to women, who have a different body habitus than men? And also can they be extrapolated to patients undergoing non-rectal abdominal surgery?

Finally, can you comment on the use of neoadjuvant chemoradiation therapy and ostomies in your patients and how they contributed to your complication rates?

## Closing Discussant

**Dr. Courtney Balentine (Houston, TX):** I'll try to take your first two questions together, since I see them as a little bit linked in terms of where the cut-offs are and then what you can actually do about it.

I think that one of the take-home messages from our data is that the effective waist circumference is relatively linear over the range of values we observed, meaning it kind of keeps getting worse as you add more. So there's not a really good, hard and fast cut-off you can say, this is great, this is bad. It's more if we can bring it back down to the lower end of the spectrum, it tends to be better.

I think extrapolating from the medical literature, we say someone is at increased risk for the metabolic syndrome and bad factors associated with diabetes at about 102 cm, and our average waist circumference was 108 cm. So I think we have, just in terms of the broad categories, quite a bit of room for improvement.

In terms of strategy, one of the nice things about rectal cancer, and again, one of the other reasons we focused on it, is you have sort of this extra time between identification of the patient coming to clinic, the setting up of the preop and neoadjuvant therapy before getting to the surgery. And looking at our population, about 80% of our patients are getting neoadjuvant therapy prior to the surgery. And that gives us a nice window in which we can say, hey, we know that if you can drop 10 cm off your waist between the next month and a half when we get you in from clinic to the OR, it will make a big difference.

At the same time, I think there's good data out there to say extra dosing or increasing the dosing of antibiotics in the OR can have some effect in the high-risk patients. And I think that's something we should probably explore in this group, since they certainly seem to be at risk specifically for infections.

I'm not sure from this data that we can really answer the question yet because there weren't enough women in our group to do a good subset analysis, or to do even a remotely robust test for interaction to figure that out.

One of the things we are looking to do is expand our data set and move into our county hospitals, where there are more females as well as different ethnic minority groups in which we can start getting sort of a broader picture and see how widely applicable this is.

In terms of looking outside of rectal cancer surgery specifically, that's something we are actually kind of in the process of doing now. We are looking at all the colon patients as well as the folks who were operated on purely for benign disease instead of cancer. And we are also sort of collaborating with our pancreatic surgeons at the Elkins Pancreas Center and looking at some of these different measures in the pancreatic patients as well to see if it's equally good at predicting risk in that population.

## Discussant

**Dr. Merril T. Dayton (Buffalo, NY):** I have to stand and just commend the presenter on one of the cleanest presentations I think I've ever seen. I don't know if you noticed, but Dr. Balentine did not use any notes. His presentation was committed to memory. It really enhanced the quality of your presentation.

My first question is a simple one. It's a question about the technique that you used in CT scanning to measure the abdominal girth. Is there a scale on the CT scanner that tells you what the absolute size is relative to what one actually sees?

My second question is, what happens if one sees diastasis or, heaven forbid, an abdominal hernia that increases that girth artificially? Is there a way to factor that in?

The last question is, do you recommend that we have our patients lose weight before we do their surgery, based on your findings here?

## Closing Discussant

**Dr. Courtney Balentine:** For the last question, certainly, I think it's always a good idea, especially given the body habitus of most of the VA patients running through our group, they could all benefit with a little extra exercise and maybe a little thinning down.

In terms of the technique, what we did was took the image directly from the CT at mid waist level, essentially, and then imported it into sort of a preinstalled version of Photoshop, which allows you to sort of scale directly to the scale marker on the CT imaging from the hospital.

Take that, and then you can do it a couple of ways. You can actually sort of have it calculate to a certain extent for you, and you can guide it as well at the same time to kind of confirm it.

And that sort of helped us with the precision of the measurements. One of the things I didn't bring out in the presentation that did make it in the paper is we went back and had an MD PhD student who was rotating through on surgery do, basically, a subset. He took 50 random CTs that I had already scored and did a whole set of calculations on his own to repeat them to see what the intra-class correlation coefficient was. And it was 0.999. So it's about as reproducible as you can get in this sort of setting.

In terms of dealing with hernias or other things that are sort of adding extra space on CT without actually adding to waist circumference, I didn't run across it in this population. I did run across it a few times in the colon group. And I'm struggling internally on how to deal with that, to be honest.

My approach so far has been to try to approximate where the abdominal wall is and come across that as the true measure of circumference and not counting, sort of extruding viscera. Obviously, I'm not sure if that's the best way to do it, but it seemed reasonable that I'm basically measuring where the skin should be if nothing else were there. And that's kind of how I've been approaching it.

## Discussant

**Dr. David Greenblatt (Madison, WI):** We have a lot of larger patients in our hospital, too. And in the really big patients, sometimes you can't even see the circumference of the waist. Was that a problem? And did you lose some super-obese patients because of that?

Number two, there's been several papers have come out on this visceral fat measure. And I'm wondering, have you had a chance to compare head to head your measure, this circumference, with the retro renal visceral fat thing and which is better.

Number three, in your analysis, it appears you treated BMI as a continuous variable. What happened if you tried to do it as a categorical variable barrier with a cut-off of like 30 or 35? Would/did it become significant in that case?

## Closing discussant

**Dr. Courtney Balentine:** Actually, it worked out fairly well for the rectal patients, ironically. No one was so generally obese that I couldn't get a good image at the mid waist level that I was shooting. Where I got into trouble is I wanted to look at a waist-to-hip ratio at the same time and sort of adjust. And at that point, there was a little bit extra fat kind of distributed out over the hips. And for about 10 of those patients, it was cut off. So I didn't end up doing that for these patients.

For some of the colon patients, there were a couple people whose BMI was around the range of 45 to 50. And I just couldn't trust anything that I was getting. It was all folded and shaped around. So that is certainly a limitation of this particular measure.

In going forward, I wouldn't necessarily recommend irradiating people just to get a measure of their waist circumference. I think you put a tape measure around their waist, you get the same useful information. It's just as good. And that's actually something we are looking at exploring prospectively in another study that one of our attendings is doing looking at infections in patients undergoing cancer surgery. He agreed to add that variable for us.

The third question, looking at BMI, how to model it is always something I kind of struggle with when I'm doing it. And I tried it a few different ways in the model. Hard cut-offs in terms of overweight versus obese versus normal weight, tertiles, quartiles. And it seems that no matter how I did it, you kind of saw this nice stepwise trend, which kind of indicated to me there were major peaks and valleys over the range of our data. So I felt fairly comfortable modeling it as a linear continuous variable.

I did it both ways just because I'm paranoid, and the results are pretty much the same. Even if you compared the most obese just to the reference category at the beginning, once you adjust for other factors, the significance kind of starts to fade out of the picture.

The visceral fat, that actually is, ironically, the original hypothesis that I pursued that got me going in this direction. And we found something kind of interesting. We reported the waist circumference data here and the visceral fat at SSO, because we found very different effects.

So when it came to complications, visceral fat, we measured the area at three different levels and took an aggregate average score. We measured the subcutaneous fat and took an aggregate score over three levels, looked at the absolute values of each and how it corresponded to outcomes. We looked at ratios between them and how they corresponded to outcomes.

What we found is, for short-term calculations, visceral and subcutaneous fat seemed to hint at a trend towards more significant complications as the values went up but it wasn't quite significant, whereas waist circumference, we saw, was significant, even after adjusting for other stuff.

The weird part—and I'm still trying to kind of make sense of this internally—is that in terms of long-term survival outcomes, visceral fat and subcutaneous fat seemed to matter, whereas waist circumference shows a trend but it's not quite significant.

So I'm still kind of monkeying around in my head how to explain that. We have some reasons that we are kind of exploring out long term, but it will be about 6 months to a year, I think, before I have enough data to really answer some of our hypotheses for why that turns out to be true.