BACKGROUND: Body surface area is a measurement of body size used in clinical settings. Its impact on laparoscopic colorectal surgery has not been previously studied.

OBJECTIVE: The aim of this study was to assess the impact of body surface area on the conversion rate and laparoscopic operative time.

DESIGN: This study was conducted as a retrospective analysis of prospectively collected data.

SETTING: This study was conducted at a single tertiary care institution.

PATIENTS: Nine hundred sixteen consecutive patients operated on between January 2004 and August 2011 were identified from a prospective database.

MAIN OUTCOME MEASURES: Conversion rate and laparoscopic operative time were analyzed related to age, sex, obesity, disease location (colon vs rectum), type of disease (neoplastic vs nonneoplastic), history of previous surgery, and body surface area; body surface area was calculated by the Mosteller formula. Body surface area was analyzed by the use of median and quartile cutoff values (1.6, 1.8, and 2.0). Multivariate models were adjusted for different confounders. Interaction between body surface area and BMI was ruled out.

RESULTS: The conversion rate was 10%. Conversion rates for quartiles 1, 2, 3, and 4 were 4.4%, 8.3%, 12.7%, and 14.8%, p = 0.001. Patients with body surface area ≥1.8 had a higher conversion rate than those with body surface area <1.8 (13.9% vs 5.3%, OR: 2.35 (95% CI: 1.45–3.86; p = 0.0001)). Multivariate analysis showed that body surface area ≥1.8 was associated with conversion (OR: 2.95% CI: 1.1–3.7, p = 0.02) and a longer operative time after adjusting for sex, age, obesity, disease location (rectum vs colon), and type of laparoscopic approach.

LIMITATION: This was a single-institution retrospective study.

CONCLUSION: Body surface area is a predictor for conversion and longer laparoscopic operative time. It should be considered when informing patients, selecting cases in the early learning curve, and assessing standard of care.

KEY WORDS: Laparoscopic colorectal surgery; Body surface area; Conversion; Short-term outcomes; Operative time; Operative difficulties.

Laparoscopic colorectal surgery (LCRS) is becoming the standard treatment for elective colorectal resection. In recent years, LCRS increased from 13.8% in 2007 to 42.6% in 2009 of all colorectal resections.1 This relatively rapid acceptance by the surgical community has evolved as a result of numerous advantages offered to patients, including smaller wounds and better cosmetic results, less pain and postoperative stress, fewer infections, less morbidity, shorter hospitalization, less cost, and a faster recovery with early return to a productive life.1-7 These advantages are particularly appealing to younger patients.2-7 Consequently, there is growing interest in identifying additional factors that can further facilitate and improve this technique.8-10

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advantages are lost when conversion to open surgery is required. Furthermore, conversion has been associated with higher intraoperative blood loss and blood transfusion requirements, a higher postoperative morbidity, and a lower overall and disease-free survival. 8–11 Consequently, the optimal identification of patients with a higher risk of conversion may determine an improvement in postoperative outcomes and a better quality of medical care.

A recent report by Cima et al12 showed that there is no reliable predictive model for conversion. Numerous variables including sex, ASA III–IV classification, obesity, previous abdominal surgeries, low anterior resection, diverticular disease, surgical expertise, and local advanced tumors have been inconsistently associated with conversion to open surgery.7,13–19

Body surface area (BSA) is a measurement of the surface of the human body often used in many clinical settings. The impact of BSA on the grade of difficulty of laparoscopic surgery has not been previously studied. Thus, the main aim of this study was to assess the impact of BSA on the conversion rate during elective LCRS. A secondary aim was to assess its impact on operative time.

METHODS
Patients and Data Collection
A prospectively maintained, practice-specific database was used to identify all patients who underwent laparoscopic colorectal surgery from January 2004 to August 2011 at the Hospital Italiano de Buenos Aires, Argentina. Outcomes were prospectively recorded in an institutional review board-approved database. Data were collected relative to age, sex, height, weight, laparoscopic operative times, type of disease (neoplastic vs nonneoplastic), type of laparoscopic approach (straight vs hand-assisted), disease location (rectum vs colon), and a history of previous abdominal surgery. Indications for surgery included both neoplastic (adenomas and adenocarcinomas) and nonneoplastic (diverticulitis, ulcerative colitis, Crohn’s disease, etc) disease.

Procedures
All patients underwent mechanical bowel preparation with 90 mL of phosphate-based solution or 4 L of polyethylene glycol solution. Antibiotic prophylaxis included a single administration of 750 mg of oral ciprofloxacin and 1000 mg of ornidazole. Low-dose heparin was given by subcutaneous injection until the first postoperative ambulation. All the procedures were performed or supervised by 1 of the 3 staff colorectal surgeons. The surgeon’s decision to convert to open surgery was not based on the patient’s BSA calculation. Straight or hand-assisted laparoscopic approaches were selected based on the individual surgeon’s experience and preference. Both techniques implied intracorporeal colon mobilization and ligation of the main vessels. Dissection was performed by the use of a medial-to-lateral approach. The splenic flexure was taken down, if necessary, to achieve an adequate resection margin and to perform a tension-free anastomosis. An extracorporeal handsewn anastomosis was performed for right colectomy, whereas an intracorporeal double-stapling technique with the use of a circular stapler was performed for left colectomies and anterior resections.

Outcomes and Variable Effects
The main outcome was conversion, and the secondary outcome was laparoscopic operative time. Conversion to an open procedure was defined as lengthening of the incision more than that required for the specimen retrieval. Causes for conversion to open surgery included bleeding, adhesions, and/or technical difficulties.

According to the World Health Organization definition, patients with a BMI ≥30 kg/m² were categorized as obese. Analysis of BMI was performed by using quartiles. BSA was calculated by the Mosteller11 formula as follows: 

\[
\text{BSA (m}^2\text{)} = (\text{height in centimeters} \times \text{weight in kilograms} / 3600)^{1/2}
\]

Because of the lack of previous data assessing the impact of BSA, this variable was categorized by the use of quartiles to report a more clinically useful finding. Consequently, patients were classified as "large" or "nonlarge" by using BSA median values of BSA ≥1.8 (large) or BSA<1.8 (nonlarge).

Statistical Analysis
Data of continuous variables were expressed by the median or mean ± SD. We used the Student t test, the Mann-Whitney U test, or ANOVA for comparing means, when appropriate. Categorical variables were compared with the \(\chi^2\) test. Multivariate analysis by logistic and multiple regressions was used to identify independent variables associated with conversion and operative times. Odd ratios with their 95% CIs were calculated. Multivariate models included variables statistically associated in univariate analysis. To exclude potential bias and interaction, obesity was also included in this model, although it was not associated with the univariate model.

Interaction between BSA and BMI was ruled out by using the likelihood ratio test for interaction between variables. Because of the interaction between weight and/or height and BMI and/or BSA, 2 different multivariate models were run to assess the relative impact of these variables.

Receiver operator curve (ROC) analysis was performed to evaluate the discriminative power of BSA for the prediction of conversion, and the ROC curve area was calculated with its 95% CI.

All statistics were 2-tailed and a \(p\) value of less than 0.05 was deemed significant. Statistical analysis was done
TABLE 1. Demographic characteristics according to conversion to open surgery

<table>
<thead>
<tr>
<th>Nonconverted cases (n = 23)</th>
<th>Converted cases (n = 92)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large (BSA ≥ 1.8 m²) (%)</td>
<td>52.5</td>
<td>76.1</td>
</tr>
<tr>
<td>Mean BSA, m² (SD)</td>
<td>1.81 (0.23)</td>
<td>1.91 (0.20)</td>
</tr>
<tr>
<td>Male sex, %</td>
<td>50.7</td>
<td>74.5</td>
</tr>
<tr>
<td>Mean age, y (SD)</td>
<td>63.4 (15)</td>
<td>64.5 (15.5)</td>
</tr>
<tr>
<td>Mean BMI (SD)</td>
<td>25.9 (4.4)</td>
<td>27.1 (3.6)</td>
</tr>
<tr>
<td>BMI (%)</td>
<td>≥30</td>
<td>16.1</td>
</tr>
<tr>
<td></td>
<td>≥35</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>≥40</td>
<td>0.8</td>
</tr>
<tr>
<td>Mean height, cm (SD)</td>
<td>166.5 (9.5)</td>
<td>169.8 (7.9)</td>
</tr>
<tr>
<td>Mean weight, kg (SD)</td>
<td>72.2 (15.5)</td>
<td>78.4 (14)</td>
</tr>
<tr>
<td>Previous surgeries, %</td>
<td>48.4</td>
<td>44</td>
</tr>
<tr>
<td>Rectum, %</td>
<td>20.3</td>
<td>37</td>
</tr>
<tr>
<td>Neoplasia, %</td>
<td>77.2</td>
<td>76.1</td>
</tr>
<tr>
<td>HALS, %</td>
<td>22.5</td>
<td>13.2</td>
</tr>
</tbody>
</table>

BSA = body surface area; HALS = hand-assisted laparoscopic surgery.

RESULTS

A total of 916 patients (mean age 63.9, range 14–91 years, 53.2% female) were identified. Median BSA was 1.8 m² (range, 1.1–2.5 m²). Men had a significantly higher mean BSA than women (1.96 m² vs 1.64 m², p < 0.001). Converted cases had significantly higher means of height, weight, BMI, and BSA, and significantly higher proportions of male sex, rectal disease, and straight laparoscopy (Table 1). Large and nonlarge patients differed in most of the demographic variables assessed. The expected difference in height found between large and nonlarge patients was not observed when patients were compared according to their BMI (Table 2). The overall conversion rate was 10% (92 cases). Large patients had a significantly higher conversion rate than nonlarge patients (13.9% vs 5.3%, OR: 2.35 (95% CI: 1.45–3.86); p = 0.0003). Conversion rates of BMI and BSA are shown in Figure 1. In univariate analysis, women had a significantly lower conversion rate than men (5.6% vs 14%, p < 0.001). Although large men had a significantly higher conversion rate than large women (15.5% vs 7.3%, p = 0.05), nonlarge men and women had similar conversion rates (Fig. 2). Both obese and nonobese patients had similar conversion rates (11.3% vs 9.8%, p = 0.55).

Among cases undergoing straight laparoscopy, large and nonlarge patients had conversion rates of 14.6% and 6.4%, p < 0.001. Among (hand-assisted laparoscopic surgery procedures, large and nonlarge patients had conversion rates of 10.4% and 2%, p < 0.01.

The primary multivariate analysis model, including BMI and BSA, showed that only the latter was significantly associated with conversion after adjusting for sex, type of surgery, and disease location (Table 3). Because the linear regression analysis between BSA and height showed an r² = 0.58 with a p < 0.0001, we ran a secondary multivariate model replacing BSA and BMI by weight and height. Neither height nor weight were associated with conversion (p = 0.71 and 0.18).

ROC analysis of BSA showed an area under the curve of 0.62 (95% CI: 0.57–0.68) for conversion. BSA >1.8 had a sensitivity and specificity to predict conversion to open surgery of 76% and 48%.

Regarding laparoscopic operative time, after adjusting for sex, disease location, type of laparoscopic approach, weight but not height was associated with longer operative times (regression coefficient = 0.82, p = 0.0001 and regression coefficient = −0.06, p = 0.85). When patients were categorized by BSA and BMI, univariate analysis showed that both obese and large patients were associated with longer operative times than nonobese and nonlarge patients (Fig. 3). However, although categorization by BSA yielded a 25-minute difference, BMI yielded only a 10-minute difference. When analyzed by BSA and BMI quartiles, longer values were found from 50% and 75% (Fig. 4). However, in the multivariate analysis, large patients were statistically associated with longer operative time (p = 0.003) but obesity was not (p = 0.054).

TABLE 2. Demographic characteristics according body surface area and BMI

<table>
<thead>
<tr>
<th></th>
<th>Large (n = 507)</th>
<th>Nonlarge (n = 409)</th>
<th>p</th>
<th>Obese (BMI ≥ 30) (n = 150)</th>
<th>Nonobese (BMI &lt; 30) (n = 766)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age, y (SD)</td>
<td>63.4 (13.8)</td>
<td>64.4 (16.4)</td>
<td>0.35</td>
<td>63.4 (13.2)</td>
<td>63.9 (15.4)</td>
<td>0.85</td>
</tr>
<tr>
<td>Male sex, %</td>
<td>84%</td>
<td>16%</td>
<td>&lt;0.05</td>
<td>21%</td>
<td>79%</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mean height, cm (SD)</td>
<td>172.3 (7.1)</td>
<td>159.9 (6.9)</td>
<td>&lt;0.001</td>
<td>167.5 (9.1)</td>
<td>166.7 (9.3)</td>
<td>0.31</td>
</tr>
<tr>
<td>Mean weight, kg (SD)</td>
<td>83.8 (10.9)</td>
<td>59.5 (7.3)</td>
<td>&lt;0.05</td>
<td>92.5 (12.7)</td>
<td>68.9 (12.7)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mean BSA, m² (SD)</td>
<td>1.99 (0.1)</td>
<td>1.62 (0.1)</td>
<td>&lt;0.05</td>
<td>2.07 (0.2)</td>
<td>1.78 (0.2)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mean BMI (SD)</td>
<td>28.2 (3.7)</td>
<td>23.3 (3.3)</td>
<td>&lt;0.05</td>
<td>32.9 (2.9)</td>
<td>24.7 (3.1)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Previous abdominal surgery, %</td>
<td>40.5</td>
<td>56.2</td>
<td>&lt;0.001</td>
<td>48</td>
<td>48.4</td>
<td>0.92</td>
</tr>
<tr>
<td>Rectum, %</td>
<td>22.9</td>
<td>22.8</td>
<td>0.78</td>
<td>18.7</td>
<td>22.6</td>
<td>0.30</td>
</tr>
<tr>
<td>Neoplasia, %</td>
<td>80.3</td>
<td>73.1</td>
<td>0.009</td>
<td>83.3</td>
<td>75.8</td>
<td>0.04</td>
</tr>
</tbody>
</table>

BSA = body surface area.
**DISCUSSION**

The main finding of this study was that BSA was significantly associated with conversion and longer operative times after adjusting by sex, BMI, disease location (colon vs rectum), and type of laparoscopic approach (straight vs hand-assisted laparoscopy); when sex was categorized by BSA, nonlarge men had a conversion rate similar to those found in nonlarge women and large women. Furthermore, BSA categorization yielded a larger operative time difference than that provided by BMI categorization.

The strength of the study is the large number of consecutive patients accrued over a relatively short period of time and operated on or supervised by colorectal surgeons performing a standardized laparoscopic technique. A weakness of this study is the fact that it cannot be technically considered as a blinded study because of its retrospective design. However, conversion bias is highly unlikely, because our hypothesis had not been raised at the time the procedures were performed; hence, the surgeons were unaware of BSA value. An additional limitation is that the 1.8 cutoff value was based on the median value of our patients, which may likely differ from others. However, this value is similar to that reported by others, and therefore a great variability should not be expected.
The BSA is a simple way to measure body size. Several formulas have been developed over the years with the Mosteller formula gaining support as a standard because it is simple and easily calculated with a hand-held calculator. In addition, online calculation is available at several Web sites. Although BSA is calculated based on the same variables as BMI, it yields a different estimation of body size by the fact that, in the BMI calculation, height is used as a denominator, whereas in the BSA it is the numerator. Accordingly, for the same weight, a tall person has a higher BSA and a lower BMI than a short person. Although BSA is used for several clinical purposes (eg, adjustment of renal clearance, cardiac index, and glucocorticoid dosing), we found no study that assessed its relationship with surgical difficulties. Risk factors for conversion were examined by Marush et al in a multicenter prospective study of 1658 laparoscopic and laparoscopic-assisted colorectal procedures. As in the present series, the mean BMI of those who underwent conversion was significantly higher than of those who did not undergo conversion (26.5 vs 24.9; p < 0.05). Senagore et al retrospectively compared 260 obese (BMI 30) and nonobese patients reporting a significant difference in the conversion rate (23.7% vs 10.9%, p < 0.05). Short-term results of the CLASSIC Trial also showed a higher rate of conversion among obese patients. Although 30.7% of cases lacked BMI data, a clear cutoff was not provided, and multivariate analysis was not performed. In contrast to these studies, Schwandner et al found no significant difference in the conversion rate between 95 obese (BMI ≥ 30) and 494 nonobese patients. This lack of association has also been reported by other authors. A recent comprehensive review by Makino et al analyzed 33 studies and found significantly higher conversion rates in obese patients. The differences observed may be associated with surgical expertise and patient selection criteria.

Several recent studies have focused on novel qualitative fat parameters. Tsujinaka et al analyzed 133 consecutive patients who underwent elective laparoscopic surgery for sigmoid colon cancer. Obesity was defined as BMI ≥ 25 kg/m² or a visceral fat area (calculated by computed tomography) ≥ 130 cm². Although the latter classification was better able to predict wound infection, postoperative complications, and hospital stay, no relationship with the conversion rate was found. More recently, Cecchini et al analyzed 187 consecutive patients who underwent elective colon resection with either an open or laparoscopic technique by the use of CT volumetric analysis. Operative time was correlated with subcutaneous fat storage and BMI in the laparoscopic right colectomy subgroup, but no associations were found with the conversion rate.

Regarding operative time, most of the studies found a relationship with BMI. Mustain et al recently queried American College of Surgeons National Surgical Quality Improvement Program Participant Use Data Files. In an analysis of 9693 patients (30% with BMI ≥ 30) who underwent laparoscopic colectomy, the operative time correlated

---

**TABLE 3.** Univariate and multivariate analysis of variables related to conversion

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate OR (95% CI)</th>
<th>p</th>
<th>Multivariate OR (95% CI)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female vs male</td>
<td>0.4 (0.2–0.6)</td>
<td>0.00004</td>
<td>0.5 (0.3–0.9)</td>
<td>0.04</td>
</tr>
<tr>
<td>BSA &lt;1.8 vs BSA ≥1.8</td>
<td>2.9 (1.7–4.7)</td>
<td>0.00003</td>
<td>1.9 (1.1–3.7)</td>
<td>0.04</td>
</tr>
<tr>
<td>Obese vs nonobese</td>
<td>1.2 (0.7–2.0)</td>
<td>0.56</td>
<td>0.85 (0.5–1.6)</td>
<td>0.62</td>
</tr>
<tr>
<td>Rectum vs colon</td>
<td>2.3 (1.5–3.6)</td>
<td>0.0003</td>
<td>2.2 (1.4–3.5)</td>
<td>0.001</td>
</tr>
<tr>
<td>Neoplasia vs no neoplasia</td>
<td>0.9 (0.6–1.6)</td>
<td>0.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HALS vs Lap</td>
<td>0.5 (0.3–0.9)</td>
<td>0.04</td>
<td>0.6 (0.30–1.10)</td>
<td>0.10</td>
</tr>
<tr>
<td>Previous surgeries (yes vs no)</td>
<td>1.0 (0.6–1.5)</td>
<td>0.91</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BSA = body surface area (Mosteller); HALS = hand-assisted laparoscopic surgery; Lap = straight laparoscopic surgery.

---

**FIGURE 3.** Laparoscopic operative time according to body surface area and BMI.
with BMI class, independent of other variables. Unfortunately, conversion to open surgery data is not available in this current version of the American College of Surgeons National Surgical Quality Improvement Program Participant Use Data Files.

Unlike the BMI, BSA is related to height, and, consequently, BSA may be related more to anthropometric features (e.g., pelvis diameter, location of the splenic flexure) than BMI, which may finally influence conversion. Furthermore, the impact of height in the laparoscopic technique has not been previously assessed. In this series, height and weight had significant association with conversion and longer operative times in univariate analysis. However, in the multivariate model, the only independent association was between weight and operative time. These findings make BSA a novel and excellent anthropometric categorical variable to predict both conversion and longer operative times.

The conversion rate found in this series is within the range reported by other authors with the use of the same definition. Because of lack of previous research on the relationship between BSA and surgical difficulty, we explored its impact by quartiles. This categorization showed an increasing proportion of conversion rates and operative times. Although this kind of categorization is useful, we used a binary cutoff to best delineate results and to facilitate its applicability in clinical practice.

This study provides several appealing and practical findings. First, in the clinical setting, the preoperative estimation of conversion risk may influence the final decision of the surgical approach. Although BSA ≥1.8 is not a contraindication per se for the laparoscopic approach, it may serve to select cases in the early learning curve or in teaching programs to best select patients, thereby avoiding an even further increase in the conversion rate. Moreover, a full informed consent must include the risk of conversion, which is independently influenced by BSA. This predictive factor should not be overlooked and must be considered when patients are informed about short-term outcome after laparoscopic surgery. Second, conversion rate is one of the most important variables when evaluating the performance of a particular surgeon or colorectal unit, and also when determining a standard of care. Because patient characteristics may vary widely among centers, countries, and regions, this factor should be taken into account in this regard. From the research perspective, previous studies assessing factors associated with conversion have not considered this variable. BSA was probably a nonadjusted confounder that explains, in part, the previously reported association between sex and conversion in many series. As shown in this series, sex (one of the most consistent factors previously associated with conversion) is greatly influenced by BSA. Finally, in an era of “Pay for Performance” and “Outcome to Expected Ratios,” there will undoubtedly be increased reliance on risk stratification, and an accurate understanding of surgical difficulty risk factors will become increasingly important.

**CONCLUSION**

BSA is an excellent anthropometric-related categorical variable to predict conversion and longer operative times in patients undergoing elective laparoscopic colorectal surgery. Based on our findings, surgeons and patients can expect that the completion of laparoscopic procedure may be more technically challenging and time consuming in large patients. As an independent predictive variable, it should be considered when informing patients about intraoperative risks and selecting cases in the early learning curve, and when evaluating a colorectal unit’s performance.
ACKNOWLEDGMENT

The authors thank Elektra McDermott for the grammatical correction.

REFERENCES


AUTHOR PLEASE ANSWER ALL QUERIES

AQ1—At the beginning of the introduction, “elective colorectal diseases” has been changed to “elective colorectal resection.” because the surgery, rather than the disease, could be elective. Please confirm.

AQ2—Please explain (Hintze J, 2077, Kaysville, UT).”

AQ3—In most cases, male(s) has been changed to man(men) and female(s) to woman(women) per AMA Manual of Style preference to use specific terminology to refer to person’s age. In this article, all patients are adults, so can be referred to specifically as men and women. Please verify.

AQ4—Please check your figures carefully. Some of the colors may have been changed to reflect journal style/preference and figure text may have been rekeyed. --- Is the word “percentage” correct in the label of the verticle axis in Figure 4. Please change if necessary.

AQ5—Please supply postal code for Buenos Aires in the Correspondence footnote.