Body Mass Index is a Poor Predictor of Bedside Appendix Ultrasound Success or Accuracy

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Introduction: The objective of this study was to determine whether there is a relationship between body mass index (BMI) and success or accuracy rate of bedside ultrasound (BUS) for the diagnosis of appendicitis.

Methods: Patients four years of age and older presenting to the emergency department with suspected appendicitis were eligible. Enrollment was by convenience sampling. After informed consent, BUS was performed by trained emergency physicians who had undergone a minimum of one-hour didactic training on the use of BUS to diagnose appendicitis. We ascertained subject outcomes by a combination of medical record review and telephone follow up. Calculated BMI for adults and children were divided into four categories (underweight, normal, overweight, obese) according to Centers for Disease Control and Prevention classifications.

Results: A total of 125 subjects consented for the study, and 116 of them had adequate image data for final analysis. Seventy (60%) of the subjects were children. Prevalence of appendicitis was 39%. Fifty-two (45%) of the BUS studies were diagnostic (successful). Overall accuracy rate was 75%. Analysis by chi-square test or Mann-Whitney U test did not find any significant correlation between BMI category and BUS success. Similarly, there was no significant correlation between BMI category and BUS accuracy. The same conclusion was reached when children and adults were analyzed separately, or when subjects were dichotomized into underweight/normal and overweight/obese categories.

Conclusion: BMI category alone is a poor predictor of appendix BUS success or accuracy. [West J Emerg Med. 2016;17(4)454-459.]

BACKGROUND
In recent years studies have been published on the use of bedside ultrasound (BUS) to diagnose appendicitis in the emergency department (ED). Its popularity is likely due to the improving ultrasound skills of emergency physicians, as well as the obvious BUS advantages of no ionizing radiation emission, and ease of performance and interpretation at the bedside. Use of ultrasound in suspected appendicitis is also supported by American College of Radiology recommendations, especially in the pediatric population.

Body habitus can be a limiting factor in appendix ultrasound. Several studies have reported decreased ultrasound success rate and accuracy with increasing body mass index (BMI). Nevertheless, such findings are by no means universal. Furthermore, none of the studies was conducted with BUS performed in the ED setting.

The purpose of the current study was to determine whether there is a relationship between BMI and success or accuracy of BUS for the diagnosis of appendicitis.

METHODS
This was a single-site, prospective study on patients...
Children (≤ age 18) (%)
16 (35)
17 (37)
13 (28)
11 (16)

Underweight (<5 %tile)
Normal (5-84.9 %tile)
Overweight (85-94.5 %tile)
Obese (≥95 %tile)

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RESULTS
This study examines the relationship between BMI and BUS success and accuracy. A total of 125 subjects were consented, and 116 had adequate image data for final analysis. (Images on nine subjects failed to transfer to database after recording.) Mean age of the subjects was 20.2 years, and 51% were male. Sixty percent were 18 years of age or younger. Table 1 shows the distribution of subject BMI according to CDC classifications. Prevalence of appendicitis was 39%.

Fifty-two (45%) of the 116 BUS studies were diagnostic (successful). Figure 1 and Table 2 illustrate the BUS success rate according to subject BMI categories.

Among the diagnostic BUS studies, there were 33 true positive, 13 false positive, 6 true negative, and no false negative BUS studies. This corresponds to an overall accuracy of 75%. Figure 2 and Table 3 describe BUS accuracy categorized by BMI.

No obvious trend was observed when BUS success and accuracy was plotted against individual BMI/ BMI percentile in adult and pediatric patients (Figures 3, 4, 5, and 6).

Statistical analysis by chi-square test or Mann-Whitney U did not find any significant correlation between BMI and BUS success and accuracy.

Table 1. Subject body mass index distributions according to Centers for Disease Control and Prevention classifications.

<table>
<thead>
<tr>
<th></th>
<th>Adult (%)</th>
<th>Children (≤ age 18) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight (&lt;18.5)</td>
<td>0 (0)</td>
<td>3 (4)</td>
</tr>
<tr>
<td>Normal (18.5-24.9)</td>
<td>17 (37)</td>
<td>41 (59)</td>
</tr>
<tr>
<td>Overweight (25-29.9)</td>
<td>13 (28)</td>
<td>11 (16)</td>
</tr>
<tr>
<td>Obese (≥30)</td>
<td>16 (35)</td>
<td>15 (21)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Underweight (&lt;5 %tile)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal (5-84.9 %tile)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overweight (85-94.5 %tile)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Obese (≥95 %tile)</td>
</tr>
</tbody>
</table>
Table 2. Beside ultrasound (BUS) success rate categorized by body mass index (BMI).

<table>
<thead>
<tr>
<th>BMI category</th>
<th>BUS success (%)</th>
<th>BUS failure (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>2 (67)</td>
<td>1 (33)</td>
</tr>
<tr>
<td>Normal</td>
<td>28 (48)</td>
<td>30 (52)</td>
</tr>
<tr>
<td>Overweight</td>
<td>10 (42)</td>
<td>14 (58)</td>
</tr>
<tr>
<td>Obese</td>
<td>12 (39)</td>
<td>19 (61)</td>
</tr>
</tbody>
</table>

Figure 1. Bedside ultrasound (BUS) success rate categorized by body mass index.

Table 3. Beside ultrasound (BUS) accuracy categorized by body mass index (BMI).

<table>
<thead>
<tr>
<th>BMI category</th>
<th>BUS accurate (%)</th>
<th>BUS inaccurate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>1 (50)</td>
<td>1 (50)</td>
</tr>
<tr>
<td>Normal</td>
<td>23 (82)</td>
<td>5 (18)</td>
</tr>
<tr>
<td>Overweight</td>
<td>6 (60)</td>
<td>4 (40)</td>
</tr>
<tr>
<td>Obese</td>
<td>9 (75)</td>
<td>3 (25)</td>
</tr>
</tbody>
</table>

Figure 2. Bedside ultrasound (BUS) accuracy rate categorized by body mass index.
category and BUS success rate. Similarly, there was no significant correlation between BMI category and BUS accuracy. We reached the same conclusions when adults and pediatric populations were analyzed separately, or when subjects were dichotomized into underweight/normal and overweight/obese categories.

We also examined the outcome of the 64 subjects whose BUS was non-diagnostic. Twenty-eight of them underwent radiology department-performed ultrasound, with only nine studies interpreted as diagnostic. The overall accuracy of these nine studies (4 positives, 5 negatives) was 67% (2 false positives, 1 false negative). Forty-two of the subjects had abdominal and pelvis computed tomography performed, with an overall accuracy of 98% (1 false positive, no false negative).

**DISCUSSION**

As far as the authors are aware, ours is the first study examining the relationship between BMI and accuracy and success rate of bedside appendix ultrasound performed in the ED setting.

Multiple studies have investigated the relationship between BMI and accuracy and success rate of radiology department-performed appendix ultrasound, and the conclusions have been inconsistent. Josephson et al. found that sensitivity (but not specificity or accuracy) of appendix ultrasound was significantly lower in patients with BMI≥25 compared with those<25. Their findings were echoed in a study by Blebea et al. On the contrary, Keyzer et al. found BMI had no effect on the accuracy or success rate of appendix ultrasound.

![Figure 3. Beside ultrasound (BUS) success rate versus body mass Index (BMI) in adult patients.](image1)

![Figure 4. Beside ultrasound (BUS) accuracy rate versus body mass index (BMI) in adult patients.](image2)
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ultrasound, regardless of the expertise of the performing radiologist.\textsuperscript{12} A recent study by de Oliveira Peixoto came to the same conclusion.\textsuperscript{13}

Similarly, the topic has been researched in pediatric patients with mixed findings. Two studies found that children with BMI \textgreater=85\textsuperscript{th} percentile have lower appendix ultrasound accuracy,\textsuperscript{8,9} and two other studies found that obese children have lower appendix identification rate on ultrasound.\textsuperscript{10,11} Other studies have failed to find any relationship between BMI of children and accuracy\textsuperscript{14,15} or success\textsuperscript{14} of appendix ultrasound. Nevertheless, Abo et al. did observe a trend of decreasing ultrasound sensitivity with increasing BMI in their study of 176 children with suspected appendicitis.\textsuperscript{14}

While it makes intuitive sense that increasing BMI might lead to decreasing appendix ultrasound accuracy and success due to generally poor penetration of the high frequency (5-15MHz) transducer commonly used for the application, it is likely not the sole determining factor. Operator experience, duration of symptoms (hence the degree of inflammatory changes present), ultrasound machine make and model, location of the appendix, and patient cooperation can all affect the outcome of such examination. Although no statistical significant relationship was found, we observed a trend that as BMI increased, appendix ultrasound success and accuracy declined to the degree of approximately 10-20\%. This magnitude of difference parallels those found in previously cited studies, whether statistical significance was found or not.\textsuperscript{8,9,14,15}

**Figure 5.** Beside ultrasound (BUS) success rate versus body mass index (BMI) percentile in pediatric patients.

**Figure 6.** Beside ultrasound (BUS) accuracy rate versus body mass index (BMI) percentile in pediatric patients.
BUS has been found to be moderately sensitive and specific in making the diagnosis of appendicitis. Given the relatively small impact BMI has on its diagnostic accuracy and success rate, and the obvious advantages of no ionizing radiation and potential facilitated clinical decision-making, we believe that BUS should be attempted in all ED patients presenting with suspected appendicitis, regardless of BMI, by clinicians who are trained in the application.

LIMITATIONS
A major limitation of the study was convenience sampling of the subjects, leading to possible selection bias. Nevertheless, nearly half of our included subjects had BMI in the overweight or obese range, which would argue against patient selection according to body habitus by investigators. Investigators were unblinded to the history and clinical examination findings of the subjects. Awareness of these findings, however, is exactly what distinguishes BUS from ultrasound performed by non-clinicians. Hence, we do not consider this a weakness of our study. Our sample size was relatively small, limiting the power of our conclusions, and this was a single-center study. All investigators who performed BUS in our study were ED ultrasound fellows or faculty, with ultrasound experience exceeding that recommended by the American College of Emergency Physicians. Hence, our study findings may not be applicable to operators with different BUS skill levels. Study results might also be different in institutions using different point-of-care ultrasound machines than ours.

CONCLUSION
We failed to demonstrate any significant relationship between body mass index and success or accuracy of bedside appendix ultrasound performed in the emergency department.

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Conflicts of Interest: By the WestJEM article submission agreement, all authors are required to disclose all afflictions, funding sources and financial or management relationships that could be perceived as potential sources of bias. The authors disclosed none.

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REFERENCES