HIGH BODY MASS INDEX IS STRONGLY CORRELATED WITH DECREASED IMAGE QUALITY IN FOCUSED BEDSIDE ECHOCARDIOGRAPHY

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Abstract—Background: There is a well-established relationship between obesity, as measured by body mass index (BMI), and overall health risk. The presence of body fat is a known limitation to ultrasound, but it is unknown whether any decrease in quality due to obesity limits the interpretability of focused bedside echocardiography (FBE). Objectives: To correlate obesity, as measured by BMI, with image quality and interpretability of (FBE) performed by an emergency physician. Methods: We conducted a prospective observational study in a convenience sample of adults presenting to two academic emergency departments (EDs) and a bariatric surgery outpatient clinic. Twenty patients were enrolled in each of three BMI categories, <30, 30–39, and ≥40 kg/m². FBE was performed in multiple views in two positions. Images were rated for ability to discern the pericardial myocardial interface (PMI) and the endocardial border of the left ventricle (ELV). Results: There were 23 males and 37 females enrolled. The median age was 49 years and the median BMI was 35.6 kg/m². There was a significant difference in the percentage of technically limited examinations between BMI categories for both PMI and ELV. There was an overall negative linear correlation between BMI and image quality for both PMI and ELV. Conclusion: There was an overall decrease in the quality of focused bedside echocardiographic images as BMI increases. This relationship exists for visualization of both the PMI and the ELV. Emergency physicians should be aware of the potential limitations of focused bedside echocardiography in this patient population. © 2016 Elsevier Inc.

Keywords—ultrasound; echocardiography; emergency; point-of-care; obesity; body mass index

INTRODUCTION

Obesity is a significant and growing health problem in the United States. There has been a steady increase in the prevalence of obesity in the American population over the last 25 years. In 2007, 33.8% of adults in the United States were obese and 68% were overweight, as determined by body mass index (BMI) (1). BMI is the most widely accepted measure of obesity in adults (2). BMI is strongly correlated with the percentage of body fat, although it does not, by itself, distinguish fat from lean tissue (3). According to the World Health Organization, BMI ≥25 kg/m² is considered overweight, >30 kg/m² obese, and >40 kg/m² morbidly obese (4). There is a well-established relationship between obesity and overall health risk, both in terms of general mortality and as an independent risk factor for a variety of diseases such as diabetes, atherosclerosis, coronary artery disease, and congestive heart failure (2).

Ultrasound energy is markedly attenuated (i.e., decreased due to absorption and scattering) by subcutaneous fat, and as a result, the presence of adipose tissue can...
significantly limit the ability to obtain high-quality ultrasound images (Figures 1 and 2) [5]. Several techniques may be used to overcome this effect, including the use of a lower-frequency transducer (because low-frequency sound waves penetrate further into the body), repositioning the patient (to bring structures of interest closer to the skin surface), and increasing the pressure of the transducer on the body [2]. Additionally, tissue harmonic imaging, in which the ultrasound machine incorporates higher-frequency harmonic waves returning to the transducer, has been shown to improve image quality in certain ultrasound applications [6]. However, it is challenging to predict which individual obese patient will have limited quality images in which ultrasound application [2].

Focused bedside echocardiography (FBE) performed by emergency physicians (EPs) is a common application of ultrasound that has become integral to the practice of emergency medicine [7]. Early emergency medicine research demonstrated the utility and reliability of FBE to determine the presence or absence of pericardial effusion [8]. More recently, Moore et al. and others have demonstrated that EPs with specific training are able to evaluate left ventricular systolic function with high reliability as compared to experienced cardiologists [9,10]. In addition to assisting in the diagnosis of heart failure, assessment of left ventricular function can often help distinguish between cardiac and other etiologies of undifferentiated hypotension or shock [11].

Because obese patients are at higher risk for cardiac disease, the degree to which obesity limits ultrasound imaging of the heart is important to elucidate. Published studies from the emergency medicine and obstetric literature demonstrate varying findings as to the degree to which obesity limits the interpretability of ultrasound images [12–15]. To date, there has been no research investigating the impact of obesity on FBE performed by EPs. Although subcutaneous fat is known to limit the quality of ultrasound images in general, the amount of image degradation specific to cardiac ultrasound is unclear. Moreover, because FBE aims to answer focused questions, the degree to which any decrease in image quality actually limits the interpretability of this limited type of evaluation is also unknown.

Our study aimed to correlate obesity, as measured by BMI, with image quality and interpretability of FBE performed by emergency physicians. Specifically, we sought to determine whether there is any particular BMI measure above which image quality rapidly decreases, whether obesity affects both the evaluation of the pericardium and visualization of the endocardial border of the left ventricle, and the degree to which patient positioning may overcome these limitations.

**MATERIALS AND METHODS**

This was a prospective observational study conducted at two academic emergency departments (EDs) with a combined annual patient volume of 190,000, and an affiliated bariatric surgery outpatient clinic. Institutional Review Board approval was obtained. A convenience sample of patients ages 18 years and up was enrolled. To avoid interference with ED care and possible harm, patients with abnormal vital signs, significant pain, and inability to lie flat were excluded. Patients unable to stand and walk to a scale placed in the patient care area were also excluded because an accurate BMI could not be calculated at the time of enrollment. In addition, patients with a chief complaint related to the cardiac or pulmonary systems, any foreign material in the chest wall such as breast implants, or inability to read or understand a written English consent were excluded. Subject consent took place at the time of enrollment.
Enrolled subjects underwent FBE by the emergency ultrasound fellowship-trained primary investigator (SDS) with a Sonosite M-Turbo (Sonosite, Bothell, WA) ultrasound machine. A P21x 5-1 MHz phased array transducer was utilized on the cardiac setting, and tissue harmonic imaging was employed. The heart was imaged in three views: the parasternal long-axis view (PLA), the parasternal short-axis view (PSA), and the subxiphoid (SX) view. The PLA and PSA views were first obtained in the left lateral decubitus position; the patient was then placed in the supine position, where the SX view was obtained and the PLA and PSA views were repeated. A 6-s video clip was recorded for each of these views, resulting in five clips per patient. The patients’ height and weight were measured, and BMI was calculated.

Twenty patients were enrolled in each BMI category (<30, 30–39, and ≥40 kg/m²). The study was powered to detect a 40% difference in the frequency of technically limited studies between BMI categories. Clips were reviewed by an emergency ultrasound fellowship-trained, registered diagnostic cardiac sonographer-certified EP with 7 years of experience (TS). The reviewer was blinded to the BMI and other demographics of the patient as well as to patient positioning for each clip. The image quality of the video clips was assessed with respect to two aspects of the cardiac evaluation: the pericardial/myocardial interface (PMI) (where a pericardial effusion would be found) and the visualization of the endocardial border of the left ventricle (ELV) throughout the cardiac cycle (as used in the evaluation of left ventricular ejection fraction). These parameters were chosen to reflect the most essential aspects of FBE as might be performed by an EP; the images were not evaluated for enlargement of the right ventricle, regional wall motion abnormalities, or valvular dysfunction.

For each of these two parameters, the quality of each clip was rated on a scale from 1–5, based on the American College of Emergency Physicians “Emergency Ultrasound Standard Reporting Guidelines” (Table 1), which our department also currently uses for quality assurance of ultrasound examinations (16). A score of 1 or 2 was considered inadequate for evaluation of the relevant structures. For each position (supine or left lateral decubitus), at least two of the views had to be adequate (a score of 3 or higher), or the study was deemed to be a “technically limited study” (TLS). TLS studies are considered to have image quality too poor to be interpreted for the relevant diagnosis or used for patient care decision-making.

Descriptive statistics were used to analyze and present the demographic data. Chi-squared analysis was used to calculate the difference in percentage of TLS studies between BMI groups. Because BMI is a continuous variable, a Spearman’s rho calculation was used to determine the overall degree of correlation between BMI and sonographic image quality and interpretability.

### RESULTS

There were 23 males and 37 females enrolled. The median age was 49 years and the median BMI was 35.6 kg/m². There was a significant difference in the percentage of TLS examinations (image quality score 1 or 2) between BMI categories for both PMI and ELV. For PMI, there were 10% TLS in the BMI <30 category, 10% in the BMI 30–39 category, and 50% in the BMI ≥40 category ($p = 0.0069$). For ELV there were 10% TLS in the BMI <30 category, 25% in the BMI 30–39 category, and 55% in the BMI ≥40 category ($p = 0.0107$). The percentage of studies that were TLS by sex and patient position are presented in Table 2.

Additionally, there was an overall negative linear correlation between BMI and image quality for PMI ($r = -0.65$, $p < 0.0001$) and ELV ($r = -0.60$, $p < 0.0001$) (Figures 3 and 4). Similar significant negative correlations were observed for both patient positions, and across both sexes (Table 3).

### DISCUSSION

Because obese patients are generally at higher risk for cardiac disease, the ability to perform FBE may be particularly relevant to this patient population. Our findings in this study of a single operator’s ability to perform FBE on ED and clinic patients suggest that there is an overall decrease in the quality of FBE images as BMI increases, for both the visualization of the pericardial/myocardial interface and the endocardial border of the left ventricle. In addition, there seems to be an abrupt decrease in the

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**Table 1. Image Quality Rating Scale (16).**

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>No recognizable structures</td>
</tr>
<tr>
<td>2</td>
<td>Minimally recognizable structures but insufficient for diagnosis</td>
</tr>
<tr>
<td>3</td>
<td>Recognizable structures but with some technical limitations with the minimal image criteria met for diagnosis</td>
</tr>
<tr>
<td>4</td>
<td>All structures imaged well with the minimal criteria met and diagnosis easily supported</td>
</tr>
<tr>
<td>5</td>
<td>All structures imaged with excellent image quality, minimal criteria met, and diagnosis completely supported</td>
</tr>
</tbody>
</table>
percentage of technically adequate scans above a BMI of 40 kg/m².

Although it may be intuitive that it is more difficult to obtain adequate images in an obese patient, any experienced sonographer will recall instances in which an obese patient was found to have excellent sonographic windows, allowing adequate images to be obtained easily, as well as the converse situation in which it was very difficult to obtain adequate images in an average or underweight patient. It is evident that there are other anatomical and technical factors besides the presence of subcutaneous fat that determine the ability to obtain adequate ultrasound images in any given patient.

Previous research on obesity in ultrasound has focused primarily on obstetrical and procedural applications (12,13,17,18). Several studies have demonstrated that maternal obesity, as measured by BMI, limits visualization of fetal anatomy and increases the rate of suboptimal studies (12,13). Obesity was also cited as a limiting factor in one study looking at emergency physician bedside assessment of the abdominal aorta (14). Conversely, other ultrasound applications, such as the evaluation of the gallbladder for signs of cholecystitis, seem to be less severely limited by even morbid obesity (15). These varying findings add further ambiguity to our current understanding of the ways in which obesity limits image interpretability.

One study conducted in an outpatient echocardiography laboratory examined the impact of obesity, as measured by BMI, with various echocardiographic findings (19). The investigators found a significantly higher proportion of “poor” quality echocardiographic studies and an increased use of ultrasound contrast in the obese patients as compared to patients with a BMI <25 kg/m², yet the overall ability to estimate left ventricular ejection fraction did not differ between these patient groups.

![Figure 3. Correlation of ultrasound image quality and body mass index for pericardial myocardial interface. PMI = pericardial myocardial interface.](image-url)
However, this study has limited applicability to our own, as the examinations were performed by echocardiography technicians rather than physicians, and employed ultrasound contrast, rarely utilized in the ED setting.

The most notable finding of our study is that even given the limited, specific nature of the FBE examination, the percentage of technically limited images was significantly higher in the overweight and obese groups. We suspect that more difficult aspects of echocardiography, such as evaluation of the valves or aortic outflow tract, comparison of the ventricular size, or the ability to detect subtle pathologic findings would be just as limited in this population, if not more so. Another important and somewhat surprising finding is that the correlation between image quality and BMI was similar for both patient positions; left lateral decubitus positioning, which is commonly used to attempt to improve cardiac windows, did not seem to have a significant mitigating effect on the decrease in image quality with high BMI.

Our study demonstrates the potential limitations of FBE in obese patients. Understanding and anticipating these limitations can allow the sonographer to take steps to optimize the quality of the scan. Even once the best possible images are obtained, the EP should be careful when interpreting these images and acknowledge that they may not provide enough information to make an accurate diagnosis. Further research is necessary to determine the effects of obesity in other ultrasound applications, as well as to investigate what may be done to reduce or overcome the effects of increased BMI on ultrasound image quality.

**Limitations**

This study had several important limitations. First, a single, relatively experienced sonographer performed all of the studies. Although this was intended to minimize the variable of operator dependence, the results may not be generalizable to a more novice or more experienced sonographer. It is also possible that the sonographer’s skill improved over the course of the study, as he gained experience in performing ultrasound on obese patients. Similarly, the studies were reviewed by a single, blinded reviewer, which could also have introduced bias. Second, the sonographer was not blinded to patient body habitus. Although height and weight measurements and the BMI calculation were performed after the ultrasound examination was completed, the sonographer could likely estimate these parameters while interacting with the patient. Being aware of the patient’s habitus, the sonographer could theoretically have changed the degree of effort or amount of

| Table 3. Correlations Between BMI and Image Quality |
|---------------------------------|-----------------|----------------|
| Group                          | r Value         | p Value        |
| PMI                            |                 |                |
| Overall                        | −0.65           | <0.00001       |
| LLD                            | −0.53           | <0.0001        |
| Supine                         | −0.53           | <0.0001        |
| Male                           | −0.61           | <0.0001        |
| Female                         | −0.61           | <0.0001        |
| ELV                            |                 |                |
| Overall                        | −0.60           | <0.0001        |
| LLD                            | −0.47           | <0.0001        |
| Supine                         | −0.51           | <0.0001        |
| Male                           | −0.57           | 0.0075         |
| Female                         | −0.62           | <0.0001        |

BMI = body mass index; PMI = pericardial myocardial interface; LLD = left lateral decubitus position; ELV = endocardial border of the left ventricle.
time spent on the study between different groups. The durations of the examinations were not recorded. Third, patients were included from two different clinical settings, the ED and an outpatient clinic. Because the ED patients selected for the study were clinically stable, ambulatory patients, the two groups were presumed to be relatively similar except for their average BMI. However, there may have been other factors such as time constraints, availability of space, or other characteristics of the encounter that differed between the two groups. Fourth, the results likely do not reflect a more acutely ill ED or intensive care population, in which the ability to perform adequate FBE may be more critical. Lastly, a single sonographer read all of the studies. Any resulting bias is likely limited, however, by the fact that this investigator was blinded to BMI and all other patient demographics. Additionally, a strict and specific grading criterion was utilized.

CONCLUSIONS

In this study of FBE performed by a single experienced operator, there was an overall decrease in the quality of FBE images as BMI increased for both the visualization of the pericardial/myocardial interface and the endocardial border of the left ventricle. A marked decrease in image quality was found above a BMI of 40. There is no significant difference in this finding between males and females, or between the supine and left lateral decubitus positions. Emergency physicians should be aware of the potential limitations of FBE in this patient population.

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REFERENCES

ARTICLE SUMMARY

1. Why is this topic important?
   Obesity is a significant and growing health problem in the United States, and focused bedside echocardiography (FBE) is an ultrasound application that has become integral to the practice of emergency medicine.

2. What does this study attempt to show?
   Obesity as measured by body mass index (BMI) may correlate with decreased image quality of FBE.

3. What are the key findings?
   BMI was found to have a strong negative correlation with image quality of FBE for evaluation of the pericardial interface and the endocardial border of the left ventricle, with a markedly higher percentage of technically limited studies in the BMI >40 kg/m² group.

4. How is patient care impacted?
   Clinicians should be aware of the limitations of FBE in obese patients; they may take steps to optimize the quality of the examination and should be cautious when interpreting findings of FBE in this population.