Sensitivity and Specificity of Gastric Ultrasonography in Determination of Gastric Contents

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Perioperative pulmonary aspiration (PPA) is a major cause of morbidity and mortality. During anesthesia, airway reflexes become depressed, placing patients at risk of PPA. Gastric ultrasonography (GUS) can be used to qualitatively differentiate between solids, liquids, and empty gastric contents. The purpose of this study was to determine the sensitivity and specificity of GUS in identifying gastric contents after participants were randomly assigned to consume 1 donut, drink 360 mL of water, or remain fasted (n=60 each group). Ultrasonography was performed by a blinded scanner, and qualitative findings were recorded by 2 sonography examiners and the primary scanner. Findings from the water group included a sensitivity of 95% to 100% and specificity of 87.5% to 90% for identification of liquids. Interrater reliability results yielded an intraclass correlation coefficient (ICC)=.781 for the solid group; ICC=.950 for the fluid group; and ICC=.761 for the fasted group. Statistically significant differences were found for the effect that body mass index classifications had on sensitivity and specificity of GUS for predicting gastric content. Results of this study demonstrated that GUS is highly sensitive, specific, and reliable with low false-positive and false-negative rates in the identification of fluid gastric content.

Keywords: Diagnostic accuracy, gastric content, gastric ultrasonography, pulmonary aspiration, sensitivity and specificity.

During anesthesia, airway reflexes become depressed, placing patients at risk of intraoperative pulmonary aspiration. Aspiration of gastric contents can cause chemical pneumonitis characterized by bronchospasm, hypoxemia, and atelectasis. In serious cases, epithelial degeneration, interstitial and alveolar edema, and hemorrhage into air spaces can rapidly progress to acute respiratory distress syndrome. Researchers have found that proper assessment of aspiration risk may aid in preventing pulmonary aspiration by improving the choice of anesthetic technique that anesthesia providers make for patients.\(^1\)\(^-\)\(^3\)

It has also been found that despite fasting, patients may present with a full stomach.\(^3\)\(^,\)\(^4\)

Sonographic imaging allows for real-time assessment of gastric contents and may be a useful aspiration risk assessment adjunct to traditional nothing-by-mouth fasting status. Brightness-mode (B-mode) ultrasonography (grayscale) is used to identify the 4 to 5 concentric layers of the gut signature\(^5\) (Figure 1). The layers should alternate in appearance between hyperechoic and hypoechoic.\(^5\) The muscular components of the gut wall (muscularis mucosa and muscularis propria) are those that appear hypoechoic.\(^5\) Routine cross-sectional sonographic imaging can depict the gut signature as anything from full depiction of all the layers to a target or bull’s-eye appearance\(^5\) (Figure 2).

Different approaches to gastric ultrasonography (GUS) have been used to assess quality and quantity of gastric contents.\(^6\) One approach used in previous studies was to examine the cross-sectional area of the antrum to quantitatively evaluate fluid contents.\(^7\)\(^-\)\(^15\) A second approach uses a grading system (Grades 0, 1, and 2)\(^13\) to qualitatively evaluate fluid contents by assessment of the gastric antrum in the supine and right lateral decubitus position.\(^10\)\(^,\)\(^13\)\(^,\)\(^16\) A third approach (and the one used in this study) includes an assessment of the gastric antrum to qualitatively differentiate between solids, clear liquids, and empty gastric contents.\(^8\)\(^,\)\(^13\)\(^,\)\(^17\) Anatomical landmarks (liver, abdominal aorta, pancreas, inferior vena cava [IVC]) are used to locate the gastric antrum for direct visualization of gastric contents. Gastric contents are then differentiated based on visualization of a collapsed antrum (empty stomach), an expanded antrum and a hypoechoic finding (liquids in the stomach), or an expanded antrum and a hyperechoic finding (solids in the stomach). This approach may be a useful tool to determine gastric content and guide anesthetic induction technique and intraoperative anesthesia management, and to determine if surgical delay or cancellation is warranted.
Researchers have only recently begun examining the sensitivity and specificity of GUS to identify gastric content using the direct visualization approach. Sensitivity is the probability of correctly identifying the presence of a disease when the disease does actually exist. Specificity is the probability of correctly identifying the absence of a disease when the disease does not actually exist. Sensitivity has been found to be high in beginning studies using the direct visualization approach, whereas specificity results are mixed. The primary outcome of this study was to evaluate the diagnostic accuracy of GUS in identifying presence, absence, and type of gastric contents using the direct visualization approach. Diagnostic accuracy is defined as the sensitivity and specificity of GUS for allowing the determination of gastric contents including solids, liquids, or an empty stomach. A secondary outcome of this study included examining the impact of body mass index (BMI) on correct identification (assessment) of gastric contents. Primary research questions included the following:

1. What is the sensitivity and specificity of GUS in identifying presence (including type) and absence of gastric contents?

2. What are the false-positive and false-negative rates in identifying presence (including type) and absence of gastric contents?

Methods
- Participants. After institutional review board approval, the convenience sample consisting of sonography and nurse anesthesia students was recruited to participate. The sample size was determined by reviewing prior studies examining sensitivity and specificity for determining the type of gastric contents using similar methods. Inclusion criteria included the ability to understand the study protocol; age 19 to 85 years; and willingness to consume 1 donut or 360 mL of water, and appropriately fast for a minimum of 8 hours. Exclusion criteria included pregnancy, previous gastric or esophageal surgery, known upper gastrointestinal tract abnormalities, diabetes, hepatic impairment, or neurologic disorders. After participant recruitment, study scans were scheduled, instructions and additional study information were sent to participants, and participants were instructed to remain fasted from solids, liquids, and chewing gum for a minimum of 8 hours before their scheduled study scan time.

- Procedures. Informed consent was obtained on arrival the day of the scheduled study. Participants were randomly assigned to 3 equal-sized groups: (1) remain fasted, (2) consume 1 donut, and (3) consume 360 mL of water. Gastric ultrasonography was performed by scanner A (a doctor of nurse anesthesia practice student) in the sonography laboratory. The GUS scans began 1 to 10 minutes after participant randomization and ingestion according to the assigned group, and the scanner was blinded to the participant’s randomization. The primary outcomes of sensitivity, specificity, false-positive rates, and false-negative rates were evaluated by comparing a participant’s randomization status (solid/liquid/empty) to the scanner and examiners’ qualitative assessment of “empty,” “solid,” or “liquid” as identified during GUS evaluation. Clear liquids were defined as a hypoechoic finding within the stomach (antrum). Solids were defined as a hyperechoic finding within the stomach (antrum). Empty was defined as a collapsed antrum with no visible content.

For GUS the Epiq 5 Diamond Select ultrasound machine (Philips) with a low-frequency C6-2 curvilinear array transducer on the abdominal setting was used. Participants were initially scanned in the supine position followed by the right lateral decubitus position. To ensure consistency between participants, the researchers used the following procedure. The gastric antrum was best visualized with the curvilinear transducer placed in the midline sagittal plane in the epigastric region and

![Figure 1. Concentric Layers of Bowel](image1)

**Figure 1. Concentric Layers of Bowel**
Abbreviations: BMI, body mass index; IVC, inferior vena cava; Panc, pancreas.

![Figure 2. Target or “Bulls-Eye”Appearance](image2)

**Figure 2. Target or “Bulls-Eye” Appearance**
Abbreviation: Panc, pancreas.
by sweeping the transducer from left to right between costal margins to identify key landmarks (liver, abdominal aorta, pancreas, and IVC) and the gastric antrum. Consistent with prior literature, the antrum was typically viewed with the liver located cephalad and the pancreas, IVC, and aorta located posteriorly.

After location of the gastric antrum, a qualitative assessment of gastric contents was made as follows: (1) empty (collapsed antrum), (2) clear liquids (hypoechoic finding), or (3) solids (hyperechoic finding).

Two still images and cines (live motion images) were acquired in each position (4 total images) between peristaltic contractions and stored on the main hard drive of the ultrasound machine. After completion of each participant's scan, all images were exported to a picture archiving computer system (Core Studycast) and deleted from the main hard drive of the machine.

After ultrasound completion, the 2 stored images and 2 stored cines (supine and right lateral decubitus positions) were retrieved from the picture archiving system by 2 sonography experts (examiner A and examiner B) to evaluate gastric contents as described previously. The sonography experts did not participate in live scanning.

**Data Analysis.** SPSS Version 21 was used for data analysis. Participant demographic information, including sex, age, fasting time, scan time, and BMI, was evaluated using frequency distributions. The nonparametric Kruskal-Wallis test was used to evaluate group differences in age, fasting time, BMI, and scan time. A nonparametric Fisher exact test was used to evaluate randomized group differences (solid/liquid/empty) based on participant weight category (underweight, normal/healthy, overweight, or obese). The Mann-Whitney (U) test was used to further identify group differences within variables that were found to be significant.

The primary outcome of sensitivity was evaluated by examining the probability of correctly identifying a participant's randomized condition (donut, water, fasted). Specificity was evaluated by examining the probability of correctly identifying that a participant's randomized condition (donut, water, fasted) was not present. The nonparametric Fisher exact test was used to evaluate the secondary outcome of effect of BMI weight categories (underweight, normal/healthy, overweight, or obese) on correct assessments of the scanner and examiners. The Fisher exact and Kruskal-Wallis statistical tests are nonparametric, and therefore no methods to assess normality of data were used.

**Table 1. Demographic Information**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total sample (N=60)</th>
<th>Solids (n=20)</th>
<th>Liquids (n=20)</th>
<th>Fasted (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>Mean (SD)=26.25 (5.3) Mean (SD)=25.65 (4.78) Mean (SD)=26.7 (4.87) Mean (SD)=26.37 (6.56)</td>
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<tr>
<td>Median=27.0</td>
<td>Mean rank=29</td>
<td>Mean rank=31.6</td>
<td>Mean rank=29.37</td>
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<tr>
<td>$\chi^2=269$ (df=2), $P=0.874$</td>
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<td></td>
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<tr>
<td>Fasting time, h</td>
<td>Mean (SD)=9.95 (1.4) Mean (SD)=9.48 (1.437) Mean (SD)=10.13 (1.39) Mean (SD)=10.13 (1.321)</td>
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<tr>
<td>Median=10.0</td>
<td>Mean rank=23.85</td>
<td>Mean rank=33.23</td>
<td>Mean rank=33.08</td>
<td></td>
</tr>
<tr>
<td>$\chi^2=2.83$ (df=2), $P=0.243$</td>
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<td></td>
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<tr>
<td>Body mass index, kg/m²</td>
<td>Mean (SD)=24.47 (4.7) Mean (SD)=24.08 (4.3) Mean (SD)=23.38 (3.78) Mean (SD)=26.107 (1.304)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median=23.17</td>
<td>Mean rank=28.53</td>
<td>Mean rank=27.08</td>
<td>Mean rank=34.63</td>
<td></td>
</tr>
<tr>
<td>$\chi^2=2.11$ (df=2), $P=0.348$</td>
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<td></td>
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</tr>
<tr>
<td>Scan time, min</td>
<td>Mean=3.71 (1.87)</td>
<td>Mean (SD)=4.25 (2.197) Mean (SD)=2.83 (1.12) Mean (SD)=4.05 (1.92)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median=3.0</td>
<td>Mean rank=35.28</td>
<td>Mean rank=21.5</td>
<td>Mean rank=33.39</td>
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</tr>
<tr>
<td>$\chi^2=7.9$ (df=2), $P=0.019^b$</td>
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</tbody>
</table>

**Table 2. Demographic Characteristics According to Body Mass Index (BMI) Categories**

<table>
<thead>
<tr>
<th>Group</th>
<th>BMI obese (n=11), No. (%)</th>
<th>BMI overweight (n=11), No. (%)</th>
<th>BMI normal/healthy (n=37), No. (%)</th>
<th>BMI underweight (n=1), No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids (n=20)</td>
<td>2/20 (10)</td>
<td>6/20 (30)</td>
<td>11/20 (55)</td>
<td>1/20 (5)</td>
</tr>
<tr>
<td>Liquids (n=20)</td>
<td>3/20 (15)</td>
<td>2/20 (10)</td>
<td>15/20 (75)</td>
<td>0/20 (0)</td>
</tr>
<tr>
<td>Fasted (n=20)</td>
<td>6/20 (30)</td>
<td>3/20 (15)</td>
<td>11/20 (55)</td>
<td>0/20 (0)</td>
</tr>
</tbody>
</table>

$^a$Kruskal-Wallace test was used to analyze differences between groups. Age, fasting time, and body mass index were found to be nonsignificant.

$^b$Significant ($P<.05$).

$^c$Mann-Whitney test was used to further identify group differences within the scan time variable. Statistically significant differences were noted between the solids/liquids group and the liquids/fasted group.
Results
Forty-two healthy volunteers were recruited to participate in the study. Eighteen of the 42 participants were randomly selected to different groups twice with 2 weeks between scans to attain a total of 60 randomized GUS scans. Participants’ BMIs were categorized into underweight (BMI<18.5 kg/m$^2$), normal/healthy weight (BMI=18.5-24.9 kg/m$^2$), overweight (BMI=25-29.9 kg/m$^2$), and obese (BMI ≥ 30 kg/m$^2$).

Demographic information is presented in Tables 1 and 2. There were no differences between groups in age, fasting time, or the continuous BMI variable. The fasted group’s mean BMI (26.107 kg/m$^2$) was noted to be higher compared with that of the solid group (donut; 24.08 kg/m$^2$) and liquid group (23.375 kg/m$^2$); however, no differences were found between groups using the nonparametric Kruskal-Wallis test. Total scan times were found to be different between the liquid and solid group ($U=101$, $P=0.006$) and the liquid and fasted group ($U=119$, $P=0.04$). Mean scan times were less for the liquid (2.83 minutes) compared with the fasted (4.05 minutes) and solid groups (4.25 minutes; see Table 1).

• Primary Outcomes. Sensitivity, specificity, false positives, and false negatives were evaluated according to each randomized group (solid, liquid, or fasted) and researcher evaluating the GUS scans (scanner A, examiner A, and examiner B). See Table 3 for results. The sensitivity was higher for all 3 researchers for liquids (95%-100%) compared with fasted (45%-75%) and solids (45%-60%). Specificity was similar for all 3 researchers for liquids (87.5%-90%), solids (80%-90%), and fasted (80%-87.5%). Interrater reliability between the researchers (scanner A and examiners A and B) was assessed using intraclass correlation coefficients (ICC) with absolute agreement for overall correct assessments. Findings included liquids ICC=0.950, solids ICC=0.781, and empty ICC=0.761.

• Secondary Outcome. Table 4 shows the effect of BMI weight categories (underweight, normal/healthy, overweight, obese) on the accuracy of correct assessments of scanners and examiners. Because the BMI category for underweight included 1 participant, it was not included in the analysis. Statistically significant differences were found between BMI weight categories of obese, overweight, and normal/healthy for all researchers (scanner A, examiner A, and examiner B). The highest percentage of correct assessments by researchers (75.7%-83.8%) was found in the normal/healthy weight group. For examiner A and B, as weight categories increased from normal/healthy (BMI=18.5-24.9 kg/m$^2$) to overweight (BMI=25-29.9 kg/m$^2$) and obese (BMI=30 kg/m$^2$ and over), the percentage of correct assessments decreased, respectively.

Discussion
Anesthesia places patients at risk of pulmonary aspiration.1–3 Current recommendations for preoperative fasting include abstaining from clear fluids for 2 hours, solid meals for 6 hours, and meals high in fat for 8 hours.23 These guidelines are only practical for elective surgical patients and may not be as useful for comorbidities that decrease gastric emptying or increase production of gastric secretions. Gastric ultrasonography is a noninvasive assessment of gastric contents that may be useful in these circumstances.

• Accuracy: Sensitivity and Specificity. Establishing the accuracy of GUS assessment of gastric contents is an important first step in determining its efficacy for anesthesia practice. Accuracy is the amount of agreement between a measured value and a true value.18 Accuracy is established using parameters of sensitivity, specificity, false-positive rates, and false-negative rates. See Table 5 for definitions and examples.

This study evaluated the accuracy of GUS when participants ingested 360 mL of clear fluid or 1 donut, or remained fasted for 8 hours or more. Sensitivity (95%-100%) and specificity (87.5%-90%) were found to be high for liquids. This finding is consistent with prior studies evaluating accuracy of GUS for identification
of liquid contents. The ICC was found to be 0.95 between 3 raters (1 doctor of nurse anesthesia practice student and 2 sonography experts) for our study. This is consistent with the interrater reliability results of Kruisselbrink et al (ICC of 0.8) in which one of the raters was also a sonography expert. To our knowledge, no studies have compared solids (without a liquid component), liquids, and empty as we did in this study.

Participants were randomized to a solid group in other studies examining GUS accuracy. However, the solid groups in prior studies consisted of a mixed consumption of solids and fluids, making it easier to differentiate between substances. Mackenzie et al compared water vs water plus a 50-g carbohydrate combination and found a sensitivity of 92% and specificity of 85%. Kruisselbrink et al also compared fluids (250 mL of apple juice) to a fluid plus solid mixture (coffee/muffin) and found higher sensitivity and specificity compared with our study. The study by Kruisselbrink et al also evaluated participants in the fasted state before randomization and excluded those where a baseline empty state was not seen. Our results may indicate that identifying solids and fluids, making it easier to differentiate.

Sensitivity (45%-75%) was also found to be lower for the fasted group. Our results are consistent with those of a prior study examining a cohort of 538 participants who were in the fasted state. The prior study found that 6.2% of individuals were identified as having a full stomach when actually in a fasted state. Our study’s finding of 0.8) in which one of the raters was also a sonography expert. To our knowledge, no studies have compared solids (without a liquid component), liquids, and empty as we did in this study.

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Examples of false-positive and false-negative results are included in Table 5. The importance of this cannot be overstated. An example of a false negative (also thought of as a “miss”) occurs when an individual is determined by GUS to be in a nothing-by-mouth state when that person has actually consumed water or solids. The anesthetic ramifications are that an individual would be identified as fasting, leading to proceeding with a normal induction and a risk of aspiration. An example of a false positive (also thought of as “false alarms”) is when an individual is believed to have a full stomach per GUS findings when that person has actually fasted. The ramifications of this depend on the scenario and could include proceeding with rapid sequence induction, use of succinylcholine, and evolution of an unable-to-ventilate scenario, for example. An additional scenario is unnecessarily proceeding with case cancellation (if the stomach is incorrectly identified as full), resulting in inconvenience to the patient and surgeon, as well as increased operational costs due to wasting of surgical supplies.

### Impact of BMI on Accuracy

The present study found that BMI may have an effect on GUS accuracy. Gastric ultrasonography may be more accurate in healthy/normal-weight participants (75.7%-83.8%) compared with

<table>
<thead>
<tr>
<th>Researcher</th>
<th>BMI (≥30) Obese (n=11)</th>
<th>BMI (25-29.9) Overweight (n=11)</th>
<th>BMI (18.5-24.9) Normal/healthy (n=37)</th>
<th>P value&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scanner A: Correct assessments, No. (%)</td>
<td>7/11 (63.6)</td>
<td>6/11 (54.5)</td>
<td>31/37 (83.8)</td>
<td>≤.001&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Examiner A: Correct assessments, No. (%)</td>
<td>4/11 (36.4)</td>
<td>7/11 (63.6)</td>
<td>30/37 (81.1)</td>
<td>.002&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Examiner B: Correct assessments, No. (%)</td>
<td>5/11 (45.5)</td>
<td>8/11 (72.7)</td>
<td>28/37 (75.7)</td>
<td>.005&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Table 4. Effect of Body Mass Index (BMI) on Accuracy of Correct Assessments

Fisher exact test was used to evaluate differences in correct assessments between BMI categories (kg/m²) of obese, overweight, and normal/healthy. Underweight category was not included in the analysis because there was only one participant.

Significant (P<.05).
overweight (54.5%-72.7%) or obese (36.4%-63.6%) participants. The higher the BMI weight category, the lower the accuracy of all researchers for correct assessment of gastric content. These differences were found to be statistically significant. For normal/healthy-weight participants, the researchers had the highest overall accuracy and for obese participants had the lowest overall accuracy. These results are consistent with those of a prior study finding that higher weight was associated with reduced accuracy in pregnant females after 32 weeks’ gestation.

It is important to note, however, that like our study, most studies evaluating GUS accuracy exclude the pregnant population. No prior studies have examined the impact of BMI weight categories on GUS accuracy for identification of gastric contents in the nonpregnant population.

Body mass index may have an impact on the size of the antrum, as well as having an attenuation effect on sound propagation. Brahee et al noted that physicians routinely commented that the quality of ultrasound images for obese patients (BMI $\geq 30$ kg/m$^2$) was severely reduced. Image quality is believed to be diminished due to attenuation, or weakening, of a sound wave as it propagates through tissue. The transducer frequency used for a patient with a normal BMI would be inadequate to penetrate through tissue of patients with a higher BMI. See Figure 1 (low BMI) and Figure 4 (high BMI) in which the same transducer was used for images produced from individuals with different BMIs. Differences in the amount of adipose tissue present in the anterior abdominal area can be seen. The adipose tissue itself may interfere with scanning if it is thickest in this region. In our study, sensitivity and specificity of the obese weight category were lowest, indicating that BMI may affect accuracy.

The right lateral decubitus body position aids in the assessment of the pylorus for the exact purpose of repositioning adipose tissue and air within the body. If fluid is present, it may likely move to the more dependent portion of the stomach, making the antrum/pylorus easier to identify. We found in our study that capturing a cine loop was more helpful in identifying contents compared with a still image. A cine loop is a display of numerous static images that allow for demonstration of the active bowel.

There are limitations to this study. The scanner was a doctor of nurse anesthesia practice student. The scanner did have formal didactic training in ultrasound principles and had used ultrasound imaging techniques in the clinical setting in 139 clinical cases according to records from a student tracking system (Typhon, Typhon Group). However, experiences were limited in GUS. Prestudy GUS examinations numbered 15. A prior study of 6 anesthesiologists found that there may be a learning curve to GUS requiring approximately 24 to 33 scans to achieve 90% to 95% success rates following a teaching interven-

<table>
<thead>
<tr>
<th>Test</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>Probability of correctly identifying a condition that exists. It is the probability that a test is positive when the condition is known to exist.</td>
<td>• Probability of correctly identifying solids by GUS when a donut was consumed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Probability of correctly identifying liquids by GUS when water was consumed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Probability of correctly identifying an empty stomach when the stomach is truly empty.</td>
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<tr>
<td></td>
<td></td>
<td>• Positive test and positive disease.</td>
</tr>
<tr>
<td>Specificity</td>
<td>Probability of correctly identifying that a condition does not exist.</td>
<td>• Probability of correctly identifying the absence of a donut when water has been consumed or a person has an empty stomach.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Probability of correctly identifying the absence of water when a donut has been consumed or a person has an empty stomach.</td>
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<tr>
<td></td>
<td></td>
<td>• Probability of correctly identifying the absence of gastric contents by GUS when a person consumed a donut or water.</td>
</tr>
<tr>
<td>False negative</td>
<td>Probability of not identifying a condition when the condition actually does exist.</td>
<td>• Negative test and negative disease.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• “Misses”</td>
</tr>
<tr>
<td>False positive</td>
<td>Probability of identifying that a condition does exist when a condition does not actually exist.</td>
<td>• Probability of identifying an empty stomach by GUS when a donut was actually consumed.</td>
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<tr>
<td></td>
<td></td>
<td>• Negative test and positive disease.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• “False alarms”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Probability of identifying a donut by GUS when an empty stomach is the reality.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Positive test and negative disease.</td>
</tr>
</tbody>
</table>

Table 5. Statistical Measures of Accuracy and Examples

Abbreviation: GUS, gastric ultrasonography.
Similar to other studies, our study did find high reliability when examining ICC between the student registered nurse anesthetist and 2 expert sonographers. The sonography experts also noted that it was more difficult to evaluate still images and short cine loops compared with real-time scans. Real-time imaging allows for a more complete scan and the ability to explore tissue in relation to other abdominal structures.

Effects on the BMI categories of weight may have been influenced by rescanning of participants and inadequate sample sizes. Rescanning of participants was not included in the original design of the study and may have affected study results. The sample size may have been inadequate to account for the effects of BMI categories of weight. The original design of the study included a continuous BMI variable. The analysis for this study indicates that BMI weight category may have an effect on accuracy. Future studies are needed to control for the effect of BMI weight categories on GUS assessment and must include an adequately powered study with a higher sample size.

The unknown baseline gastric content of participants was also a limitation. Participants were assumed to have empty stomachs after fasting, and baseline GUS contents were not assessed before randomization. It is possible that excess baseline gastric sections (>1.5 mL/kg or >100 mL) and/or residual undigested food may have affected results for the fasted group. A retrospective review of scans from 8 participants who were randomized to the fasted group showed they were scored by all examiners as liquid or solid. Examiners noted that several of these scans appeared to be of mixed gastric contents (liquid and solids). A possible explanation for this is baseline gastric sections and/or residual undigested food. These findings may have led to lower sensitivity and specificity findings for the fasted group.

Finally, the application to clinical point-of-care testing must be considered. In this research study an Epiq 5 Ultrasound System with a curved array transducer (C6-2) and a general abdominal preset was used. This transducer is designed for clear image generation and deeper penetration to visualize structures located within the abdominal cavity. In clinical practice, the machine used most often for point-of-care testing is the Fujifilm SonoSite. The Fujifilm SonoSite is designed for more superficial structures and uses a linear array transducer. The SonoSite does offer a curved array transducer that can be used for scanning in the abdominal cavity and that is recommended to improve image clarity for abdominal organs. In the event that only a linear transducer is available, clarity of deep abdominal structures may be reduced.

In conclusion, this study demonstrated that GUS is highly sensitive, specific, and reliable with low false-positive and false-negative rates in the identification of liquid gastric content. Gastric ultrasonography was more accurate in allowing the correct identification of gastric content in normal/healthy-weight participants compared with higher weight categories. In this study, GUS demonstrated that there is a high rate of false positives and false negatives for the empty and solid states.

REFERENCES

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