The presence of gastric content before induction of general anesthesia is the primary modifiable risk factor in the prevention of pulmonary aspiration. The purpose of this project was to determine if ultrasonography could be routinely used to measure gastric content and assign aspiration risk in patients undergoing general anesthesia. Preoperative gastric ultrasonography was performed in a convenience sample of 100 patients. A group of Certified Registered Nurse Anesthetists, anesthesia residents, and anesthesiologists were asked their plan for airway management before and after receiving the results of the patients’ gastric ultrasonogram, to determine if the scan would alter the plan. In 14% of patients scanned, solid gastric content was observed, 7% had clear liquids present, and 79% had an empty stomach. Of the patients with clear liquids present, 3 had substantial (> 100 mL) gastric content despite following fasting guidelines. Overall, there was a 9% change in airway management from standard induction: 6% changed to modified rapid sequence intubation (no ventilation, no cricoid pressure), and 3% changed to rapid sequence intubation with cricoid pressure. The number of changes to the airway management plan and identification of several patients with substantial gastric content demonstrate the value of preoperative gastric ultrasonography in airway management decision making.

Keywords: Anesthesia, gastric content, pulmonary aspiration, ultrasonography.

The American Society of Anesthesiologists (ASA) has established fasting guidelines for healthy patients undergoing elective surgery to reduce the risk of pulmonary aspiration during induction of anesthesia and manipulation of a patient's airway. These guidelines state that before induction of anesthesia a patient should fast for 8 hours following a full meal, 6 hours following a light meal or nonhuman milk, and 2 hours following clear liquids. The goal of patient fasting before surgery is an empty stomach on induction of anesthesia. During induction of general anesthesia (GA), protective airway reflexes are purposefully abolished to allow for placement of an airway device. Esophageal sphincter relaxation also occurs, and if gastric content is present, it can travel retrograde up the esophagus and into the patient's unprotected airway and lungs—a process known as pulmonary aspiration. Aspiration can produce inflammation and infection in the pulmonary parenchyma, resulting in ventilation/perfusion mismatch, hypoxemia, and the need for mechanical ventilation with supplemental oxygen.

Data from the fourth National Audit Project (NAP4) collected on all airway complications in the United Kingdom from 2009 to 2010 cited aspiration as the most significant cause of airway-related mortality. Adherence to the ASA fasting guidelines has not been shown to be effective for reducing gastric contents in patients with comorbidities that delay gastric emptying, including increased intracranial pressure, hiatal hernia, renal failure, obesity, gastrointestinal tract obstruction, gastroesophageal reflux disease and diabetes mellitus. Furthermore, some patients simply do not abide by preoperative fasting instructions.

Anesthesia providers base aspiration risk primarily on the presence of patient risk factors. Once the subjective relative risk of aspiration is determined, the anesthesia provider selects a plan for airway management that is appropriate for the estimated level of risk. However, there remains a great deal of variability among anesthesia providers regarding the use of aspiration risk factors, particularly gastric content, to inform decisions about the method of airway management during induction of GA. Indeed, as noted in the NAP4 study, providers frequently failed to modify their airway management technique to fit the identified risk level based on patient risk factors obtained from their preoperative evaluation. This may be due to providers' uncertainty about the association between the preoperative fasting guidelines and the actual gastric contents at the time of anesthesia induction in the presence or absence of risk factors.

Although the overall incidence of aspiration is es-
Estimated to be 1:2,000 to 1:3,000 anesthetics, when it occurs, the results are often clinically and economically catastrophic. Several sources report that the frequency of aspiration during GA is likely higher due to underreporting. Of the patients who aspirate, 47% experience aspiration pneumonitis and 17% require mechanical ventilation. Aspiration incidents have large financial implications for hospitals because the average overall cost for any patient requiring mechanical ventilation in an intensive care unit is $47,158.

One potential solution for reducing the uncertainty associated with estimating the nature and volume of a patient’s preoperative gastric content and assigning a relative risk level for aspiration, before determining an appropriate airway management method, would be to use an objective method to more accurately estimate a patient’s gastric content. Bedside ultrasonography has been established as a valid and reliable objective method for the measurement of gastric content. At our institution there was no standardized departmental protocol to assess aspiration risk before induction of GA and manipulation of the patient’s airway. Therefore, each provider had to make decisions about gastric content, aspiration risk, and airway management in the context of the uncertainty regarding the use of the ASA preoperative fasting guidelines, patient comorbidities, and the fasting self-report. The application of gastric ultrasonography as an objective, quantitative method to assess gastric content preoperatively could be a valuable method to better define a patient’s actual aspiration risk and most appropriate method of airway management. Decreasing the risk of patient aspiration through the use of gastric ultrasonography has the potential to improve patient safety and to decrease costs of aspiration complications in the healthcare system. The primary purpose of this quality improvement (QI) project was to determine if gastric ultrasonography could be recommended for routine use in the preoperative setting at our institution as an objective method to determine gastric content and aspiration risk.

**Literature Review**

Current literature suggests that following the established ASA preoperative fasting guidelines does not ensure that a patient’s surgical journey begins with an empty stomach. Additionally, patients could be dishonest, confused about, or simply unable to recall compliance to the fasting instructions they received sometimes days or weeks before a procedure. A clear liquid gastric volume of 1.5 mL/kg or less (or approximately 100 mL in the average adult) is considered normal in fasted patients because of baseline gastric secretion. Solid gastric content, however, should not be present in fasted patients. Of patients scheduled for elective surgery, 5% have clinically significant gastric content (> 1.5 mL/kg of liquid or solid food) even when fasting guidelines are followed. In this 5% of patients, obesity, diabetes, and preoperative opioids are factors strongly predictive of a full stomach. Renal failure is another significant predictor of a full stomach because 17% of patients with renal failure present with a full stomach after following fasting guidelines.

The use of gastric ultrasonography to assess gastric content and assign potential aspiration risk has been shown to result in provider changes in airway management technique. Through the use of gastric ultrasonography, providers can accurately distinguish between solids, transparent liquids, and nontransparent liquids present in the stomach. Distinguishing the volume of gastric content is important because the presence of a large volume places the patient at a higher risk of aspiration and necessitates conservative airway management or surgical delay. Conservative airway management consists of induction techniques designed to prevent pulmonary aspiration, including placing a nasogastric tube to empty the stomach before induction of anesthesia; rapid sequence induction (RSI) with cricoid pressure to avoid mask ventilation, which can inflate the stomach; and placing a cuffed endotracheal tube. In addition to determining the nature of gastric content, a mathematical model has been developed that enables calculation of gastric volume present using measurements taken during ultrasonographic assessment. This mathematical model is also highly accurate for obese patients, defined as having a body mass index (BMI) above 35 kg/m².

Ultrasonography measurements of gastric volume determined by different raters under the same conditions correlate very closely, and measurements made by the same rater under the same conditions are in nearly perfect agreement. The maximum difference in the measurements of gastric content between raters has been determined to be 13%, which is within a clinically acceptable margin of error. Preoperative gastric ultrasonography assessment has the potential to alter airway management on a case-by-case basis. Alakkad et al demonstrated that the use of ultrasonography resulted in a change in airway management or surgery start time 71% of the time in patients who did not follow fasting guidelines. In their study, surgical procedures for patients with solid gastric content or more than 1.5 mL/kg of liquid gastric content were delayed. Patients found to have 1.5 mL/kg or less of clear liquid gastric content were managed using conservative airway techniques designed to reduce the chance of aspiration, rather than rescheduling the procedure. Some patients were found to have empty stomachs following ultrasonography and were able to undergo a standard induction without special aspiration-related airway considerations. Gagey et al noted that providers could avoid performing RSI in 88.2% of infants undergoing pyloromyotomy after use of gastric ultrasonography showed clinically insignificant gastric content.
Methods

- **Project Design.** This project was performed at a university medical center in the Southeastern United States. The project was evaluated by the governing institutional review board and determined not to be human subjects’ research. Anesthesia providers were asked to complete a survey to enumerate the criteria they used to estimate a patient’s aspiration risk and determine the induction airway management method. Following survey administration, a convenience sample of patients presenting for surgery under GA had their gastric content determined using ultrasonography by a single member of the project team. The result of the ultrasonographic determination of gastric content was made available to the anesthesia provider after he or she had evaluated the patient and determined the aspiration risk and airway management plan. Any change in aspiration risk assessment and airway management plan as a result of having the ultrasonographic assessment of gastric content information was documented. Providers for whom the patient’s ultrasonographic information about gastric content was made available were surveyed to determine the value of having this information available to them to make airway management decisions before induction.

- **Provider Survey of Aspiration Risk Assessment and Airway Management Practices.** Before implementation of the project, an educational session was provided to 28 Certified Registered Nurse Anesthetists (CRNAs) describing the project. A paper survey was administered at this session to determine which criteria CRNAs at this facility use to evaluate patients’ aspiration risk level and to decide on an airway management technique in patients undergoing GA. Additionally, a summary of the project and the survey were emailed to anesthesia residents, fellows, and attending physicians. They were asked to complete the survey and return it via email.

- **Ultrasonographic Determination of Gastric Content.** A convenience sample of 100 adult patients, aged 18 years or older, who were not pregnant, had a BMI less than 40 kg/m², and were scheduled to undergo any elective procedure under GA were included in the project. Exclusion criteria included the following: (1) patients less than 18 years of age; (2) patients undergoing only monitored anesthesia care or regional anesthesia techniques and sedation; and (3) patients who had prior gastric surgery or a gastric tumor, both of which can obscure the results of the ultrasonography assessment.16 Patient demographic information was recorded along with the time required to perform the ultrasonogram. All scans were performed by a single member of the project team trained to perform gastric ultrasonography.

Patients having GA who met the inclusion criteria were randomly approached during several periods of data collection over 2 weeks and asked to voluntarily agree to have their abdominal area scanned as a part of a project to more accurately determine their gastric content and make decisions about their anesthesia care. If the patient agreed, that individual was placed supine just before the surgical procedure, and a curved-array, low-frequency transducer probe (2-6 MHz; SonoSite M-Turbo Ultrasound, Model P07662-06) was placed over the patient’s epigastric area in the sagittal plane. The gastric antrum was identified in the supine position, and the patient was then asked to assume the right lateral decubitus position. In this position, the gastric antrum is located to the right of the abdominal midline, and gravity causes the stomach contents to shift into the gastric antrum. The nature of the gastric content was then determined based on appearance as solid, liquid, or empty.

If the content was liquid, the ultrasound image was temporarily frozen and the anterior-posterior (AP) diameter and cranial-caudal (CC) diameter of the antrum was measured from serosa to serosa in-between peristaltic contractions, using the caliper method.22 The antral cross-sectional area (CSA) in the right lateral decubitus position was calculated in centimeters squared using the following formula: Antral CSA = AP diameter (cm) × CC diameter (cm) × \( \pi /4 \). The volume of liquid was then quantified using this mathematical model: Volume (mL) = 27.0 + (14.6 × Right-lateral CSA – (1.28 × Patient age in years).22 The nature of the gastric content and the volume were documented on a data collection sheet.

- **Provider Assessment of Aspiration Risk and Airway Management Plan.** Following each anesthesia provider’s assessment of the preoperatively scanned patient, the provider was queried regarding his or her assessment of the patient’s aspiration risk and plan for airway management. The results of the ultrasonogram were then made available to the provider, who was asked if his or her plan for airway management would change based on the ultrasonography information. The response was documented on a data collection sheet.

- **Provider Survey of Value of Gastric Ultrasonography.** Following completion of 100 patient gastric ultrasonography procedures, a survey was emailed to CRNAs, anesthesia residents, fellows, and attending physicians to gather their opinion of the value of the ultrasonographic determination of gastric content in assessing patient aspiration risk and deciding on an induction airway management method.

- **Data Analysis.** Descriptive statistics were used to summarize the preintervention provider aspiration risk assessment and airway management practices, provider types, and the patient demographics. The number and percentage of the provider types and patients are reported as categorical variables, whereas the mean and standard deviation are provided for normally distributed continuous measures. The percentage of patients for whom the provider changed the management plan (change in airway device or induction technique) for the patient after...
reviewing the results of the ultrasonogram is reported. Number and percentages were used to describe responses to the survey items measuring provider opinion of the added value of the use of ultrasonography to make decisions about aspiration risk and airway management.

Results

• Provider Survey of Aspiration Risk Assessment and Airway Management Practices. A total of 50 anesthesia providers responded to the initial survey on aspiration risk assessment and airway management practices. Twenty-eight of the 50 responses were gathered from paper surveys distributed at the CRNA education session, and 22 of the 50 responses were gathered via email from the physician staff including anesthesia residents, fellows, and attending physicians. A full stomach, pregnancy, and emergency surgery were given as the top 3 risk factors for aspiration during the induction of anesthesia and main indications to use an RSI.

• Ultrasonographic Determination of Gastric Content. Gastric ultrasonography was performed in 101 patients to determine gastric content. The gastric antrum could not be visualized in 1 patient, and that person was excluded, for a total of 100 patients. Two patients who were approached refused to be scanned. Of the total patients who underwent ultrasonography, 98 had elective surgical procedures scheduled, and 2 had urgent cases. The mean patient age was 55.4 years with a standard deviation of 16.4 years (Table). Of the 100 patients scanned, 14% had solid gastric content, 7% had clear liquid gastric content, and 79% were found to have no gastric content. Of the 7 patients with liquid gastric content, 3 patients had more than 100 mL of clear liquid. The average time to complete the gastric ultrasonogram, including verbal consent, was 3 minutes 35 seconds.

• Provider Assessment of Aspiration Risk and Airway Management Plan. Of the anesthesia providers who received the results of the gastric ultrasonogram after evaluating the patient, (66%) were CRNAs, (21%) were anesthesia residents, and (13%) were anesthesia attending physicians. Overall, there was a 9% change (9/100) in the planned airway management technique by the anesthesia providers after considering the gastric ultrasonography results. This included a 6% change from a standard induction technique to a modified RSI (no ventilation, no cricoid pressure) and a 3% change from a standard induction technique to an RSI with cricoid pressure.

• Provider Survey of the Value of Gastric Ultrasonography. Thirty-four responses were gathered from the survey regarding anesthesia provider opinion of the value of determining aspiration risk by assessing gastric content via ultrasonography. Of the 34 responders, 25 (73.5%) believed that preoperative gastric ultrasonography should be routine in certain situations. Over half of those 25 responders specified that situations in which preoperative gastric ultrasonography should be routine include unclear nothing-by-mouth status, trauma/emergency cases, and pregnant patients. Twenty-four (92%) of 26 providers who answered the question responded that the addition of a preoperative gastric ultrasonogram would not delay their patient assessment or start of surgery. A total of 28 (82.3%) of the 34 providers who responded to the survey were interested in learning how to use ultrasonography to assess gastric content (Figure).

Discussion

The addition of preoperative gastric ultrasonography assessment resulted in identification of gastric content in some patients that would not have been identified through traditional subjective methods. This resulted in a change in providers’ airway management decisions for a considerable number of these patients. Therefore, use of ultrasonography to objectively measure gastric content before induction of GA provided essential insight into assessing aspiration risk and determining an appropriate method of airway management.

A substantial percentage of the sample had gastric content, with 14% having solid material and 7% having

<table>
<thead>
<tr>
<th>Demographic characteristic</th>
<th>Percent of patients(^a)</th>
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<tbody>
<tr>
<td>Age, y, mean (SD)</td>
<td>55 (16)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
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<tr>
<td>Female</td>
<td>61</td>
</tr>
<tr>
<td>Male</td>
<td>39</td>
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<tr>
<td>Body mass index (BMI) category, kg/m(^2)</td>
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<tr>
<td>Underweight (BMI &lt; 18.5)</td>
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<tr>
<td>Normal (BMI 18.5-24.9)</td>
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<tr>
<td>Overweight (BMI 25.0-29.9)</td>
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<tr>
<td>Obese (BMI &gt; 30)</td>
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<td>Comorbidities</td>
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<td>Hypertension</td>
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<td>Hepatitis</td>
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<tr>
<td>Preoperative opioid use</td>
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<tr>
<td>Chronic obstructive pulmonary disease</td>
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</table>

\(^a\)Except for age.
clear liquid. In all 14 patients with solid gastric content, the content was found to be preoperative oral medication and a small amount of liquid consumed to swallow the medication. These patients would theoretically be at a higher risk of aspiration, but most anesthesia providers treat the administration of preoperative oral medications as an insignificant risk factor. Several providers changed their airway management plan because of the presence of preoperative medications in the stomach, but other providers chose to proceed as planned. This may be due to the lack of definitive guidance on this issue in the literature.

Three patients had greater than 100 mL of clear fluid gastric content that would not have been identified without ultrasonography assessment. This finding prompted 2 anesthesia providers to change their induction airway management plan. The changes were from a standard induction to a modified RSI and an RSI with cricoid pressure. It is interesting to note that all 3 of these patients were having colorectal surgical procedures and were managed with an Enhanced Recovery After Surgery (ERAS) protocol. Participation in the ERAS protocol includes consuming a 240-mL (8-oz) carbohydrate drink 2 hours before surgery. Despite consuming the fluid 2 hours before having their stomachs scanned and falling well within the limits of the ASA fasting guidelines (clear liquids 2 hours before a procedure), these patients still had a large amount of fluid remaining in their stomachs.

Although there were no changes in the airway management devices employed by the providers as a result of having the ultrasonographic information, it is important to note that 85% of the patients scanned were already assigned to the most conservative airway device (an endotracheal tube) before the provider had access to the ultrasonography assessment. This is an unusually high proportion of patients with conservative airway management. Many procedures today are performed with regional anesthesia and sedation or with a laryngeal mask airway (LMA). These approaches leave the patient with an unprotected airway and more vulnerable to pulmonary aspiration. If procedures that could have been performed with an LMA and sedation had been more prevalent in our convenience sample, there would likely have been more changes in airway management plans because the provider comfort level with use of an LMA in the presence of gastric content would have been expected to be lower.

There were several limitations to this departmental QI effort. Not all of the anesthesia providers were personally aware of the experience and expertise of the project member performing the ultrasonography assessments, and therefore they were not always willing to incorporate the ultrasonography results into their anesthesia care plan. Furthermore, despite the information sessions and emails regarding the documented validity and reliability of ultrasonographic determination of gastric content and what is considered a “significant” amount of gastric content, some providers chose not to avail themselves of the available information. Therefore, some providers who cared for patients in the convenience sample remained unfamiliar with this information.

The total cost of performing 100 gastric ultrasonograms, with an average of 3 minutes 35 seconds per scan and averaging CRNAs’ and anesthesiologists’ mean salaries,\textsuperscript{23,24} equates to approximately $628 of provider time. Alternatively, if any of the 9 patients (9%) who had sufficient gastric content to compel anesthesia providers to change their airway management plan had not been identified and had aspirated, treating the aspiration with mechanical ventilation would cost, on average, $47,158 per event.\textsuperscript{7} Clearly there is a large potential cost benefit for making airway management decisions based on preoperative gastric ultrasonography assessment with respect to a single incident of unidentified gastric content resulting in pulmonary aspiration on induction or emergence.

The results of this project suggest several areas that would benefit from further inquiry. An important question is whether the recommendation allowing clear liquids up to 2 hours before induction of anesthesia is a sufficient time limit for patients undergoing colorectal surgery who receive a carbohydrate drink. The patients with the largest volume of gastric content were all members of this group, which highlights a potential shortcoming in the fasting guidelines for this popula-
tion. Another QI opportunity lies in conducting a similar evaluation of gastric content in a patient population undergoing sedation or GA for which an LMA is the airway management device of choice. Anesthesia providers would be expected to have a lower tolerance level for gastric content when the airway management plan includes an LMA. In this scenario providers would likely get more value out of a preoperative gastric ultrasonography assessment in making airway management decisions because of an unsecured airway. Finally, the provider responses to the survey suggest there are clear situations for which an RSI, and therefore use of an endotracheal tube, are indicated. However, they also noted that there are situations (unclear nothing-by-mouth status, trauma/emergency procedures, and pregnant patients) in which the use of gastric ultrasonography should be a routine part of the decision-making process to determine the appropriate airway management method. This result advocates for educating anesthesia providers regarding the value of gastric ultrasonography for objectively identifying gastric content in preoperative patients and the need for instruction in its use in the operating room setting.

Conclusion
The ability to use ultrasonography to objectively determine gastric content, particularly in a specific subset of patients, is a skill that should be in every anesthesia provider’s toolbox. In a convenience sample of patients at our institution who followed fasting guidelines, the addition of gastric ultrasonography assessment added important information that would not have been obtained from traditional subjective evaluation methods. The 9% change in airway management method and identification of 3 patients who were managed with an ERAS protocol with clinically significant gastric content demonstrates the value that gastric ultrasonography brings to preoperative patient evaluation and patient safety.

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