Original Article

Preoperative gastric point-of-care ultrasound in nonelective surgical procedures in pediatric-aged patients

ABSTRACT

Background: Airway management for nonelective surgical procedures in the setting of trauma, pain, and opioid use can be complicated by the potential for aspiration due to delayed gastric emptying. Point-of-care ultrasound (POCUS) remains a useful tool for evaluating gastric content and volume in various clinical settings. The authors evaluated gastric volume and content in children scheduled for urgent and semi-urgent procedures to assess their aspiration risk.

Methods: After obtaining consent, gastric POCUS was performed in the preoperative holding area for pediatric patients scheduled for both elective and nonelective surgery. Qualitative and quantitative measurements of the gastric antrum were taken, and the risk of gastric aspiration was calculated. Additional data collected included patient demographics, the type of surgery, *nil per os* (NPO) status at the time of surgery, NPO status at the time of injury, and administration of opioids.

Results: The study cohort included 100 patients ranging in age from 3 to 17 years old (mean age 9.2 years). Out of these 100 patients, gastric scanning was successfully conducted in 98 patients. Sixteen of fifty-nine nonelective patients (27%) had received opioids for pain control prior to surgery. Among the 34 patients who had suffered an acute injury, 7 (21%) had been NPO for <8 hours at the time of the injury. Ninety-nine out of hundred patients had been NPO for at least 6 hours at the time of the gastric ultrasound. Based on our gastric ultrasound findings, all patients who were appropriately NPO had either Grade 0 or Grade 1 risk for aspiration, indicating a low risk of aspiration.

Conclusions: The preliminary data show that when patients presenting for nonelective surgery are appropriately NPO, they may have a low risk of aspiration. This information may help guide the choice of anesthetic induction technique, particularly when concerns exist about the safety of a rapid sequence induction. It allows for a more stable and controlled induction of anesthesia.

Key words: Gastric ultrasound, nil per os, point-of-care, ultrasound

Introduction

Pulmonary aspiration of gastric content is a rare but potentially serious complication that can occur during anesthesia and perioperative care. In the pediatric population, the incidence of pulmonary aspiration during the

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perioperative period is estimated to be between 0.02 and 0.1%.[1-4] This complication can have severe consequences, including unplanned hospital admission, prolonged hospital stay, the need for postoperative intensive care unit admission, and postoperative respiratory support such as mechanical ventilation. To prevent pulmonary aspiration, healthcare practitioners adhere to standard *nil per os* (NPO) guidelines that allow sufficient time for gastric emptying. The American Society of Anesthesiologists has widely accepted guidelines in this regard. According to these guidelines, clear liquids should be avoided for at least 2 hours before surgery, breast milk for at least 4 hours, infant formula and nonhuman milk for at least 6 hours, and solid food for at least 8 hours.[5,6]

Other factors can impact gastric emptying, which may render the standard NPO guidelines less effective in determining preoperative fasting status. Gastric emptying can be delayed by factors such as trauma, acute and chronic pain accompanied by opioid use, and medical conditions that affect motility. In cases where there are concerns about the status of gastric contents, a rapid sequence induction (RSI) technique may be employed for emergent, urgent, and semi-urgent procedures, regardless of fasting status, to minimize the risk of aspiration. However, it is important to note that pediatric patients may be at a higher risk for oxygen desaturation and respiratory decompensation during an RSI.[7,8]

Point-of-care ultrasonography (POCUS) has emerged as a valuable tool to evaluate critically ill patients, and it has proven to be effective in assessing gastric contents and volume in various clinical settings. POCUS can aid in identifying patients who are at risk for aspiration, thus guiding the decision to employ an RSI and assisting in determining the most appropriate airway management technique during anesthesia. The objective of the current study was to assess the aspiration risk in pediatric-aged patients scheduled for urgent and semi-urgent procedures by evaluating gastric volume and content using gastric ultrasound.

Methods

The study was approved by the Institutional Review Board at Nationwide Children's Hospital, Columbus, Ohio (STUDY00000480), and it was registered on clinicaltrials.gov (NCT04127331). Prior to the surgical procedures, the research team informed the parent or guardian and the patient about the study in the preoperative holding area. Verbal consent and assent were obtained, when appropriate, from the participants. The inclusion criteria for the study were as follows: patients aged 2–18 years with American Society of Anesthesiologists physical status I-III who were scheduled for a procedure requiring general anesthesia. Elective surgery patients were recruited for the control arm, while urgent and semi-urgent patients were recruited for the study arm. Exclusion criteria included a history of upper gastrointestinal surgery, pregnancy, prisoners, and refusal by the parent or patient. Originally, the research protocol involved both preoperative gastric ultrasound imaging and gallbladder imaging to assess fasting status. However, due to the limited impact of gall bladder imaging on the study hypothesis, the protocol was modified to only include gastric ultrasound assessment. Additionally, enrollment of emergent cases was intended but not feasible due to hospital policy requiring surgical incision within 60 minutes of posting, and the study protocol's potential impact on this time.

Ultrasonographic examination of the gastric antrum: Gastric ultrasound was performed in the preoperative holding area by one of three investigators proficient in Diagnostic POCUS. The Sonosite X-Porte (Sonosite Inc., USA) machine with a low frequency (3–8 MHz) curvilinear probe was used. The ultrasound examination was conducted with the patient in the supine position, followed by the right lateral decubitus (RLD) position. In cases where the RLD position was not feasible, a 45° semi-recumbent position was used to place the patient in the RLD position. The gastric antrum was identified in a sagittal plane between the left lobe of the liver and the pancreas at the level of the descending aorta and superior mesenteric artery [Figures 1 and 2].[9] Qualitative and quantitative measurements of the gastric antrum were recorded. The quantitative exam involved measuring the cross-sectional area (CSA) of the gastric antrum using a free-tracing method along the outer margin corresponding to the serosal layer.[9] Gastric volume was calculated using the following formula: Gastric volume (ml/kg) = $[-7.8 + 0.035 \times \text{CSA (mm}^2) + 0.127 \times \text{age (months)}]$/body weight (kg). The qualitative

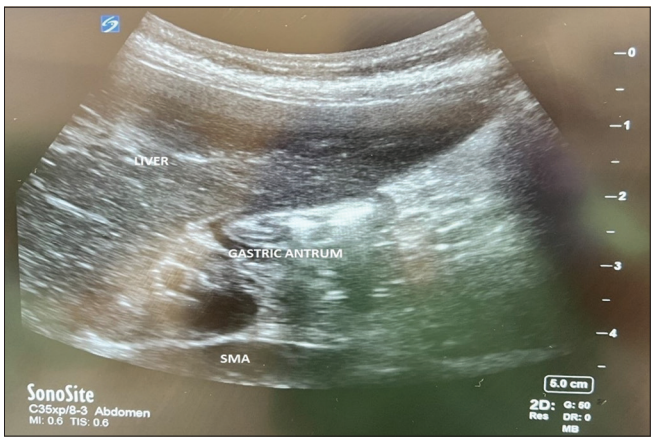

Figure 1: Sonographic image of the gastric antrum of an empty stomach. The antrum appears flat and collapsed, with no visible content (Grade 0); SMA, superior mesenteric artery

and quantitative measurements were categorized using a 3-point grading scale: [10]

Grade 0: No fluid visible in the gastric antrum

Grade 1: Clear fluid visualized with volume <1.5 mL/kg

Grade 2: Clear fluid visualized with volume >1.5 mL/kg

High risk of aspiration was defined as Grade 2 or the presence of any solid or thick liquid during the examination. Demographic data (age, gender, and weight), NPO status at the time of injury, NPO status at time of procedure, preoperative symptoms of pain or nausea and vomiting, administration of opioids, and type of surgery were also recorded.

Statistical Analysis: Continuous data were presented as a mean ± standard deviation or median (interquartile range). Categorical variables were presented as frequencies and percentages. Two-sample *t*-tests or Mann–Whitney *U*-tests were used to compare the continuous data between emergent and urgent cases, while Chi-square or Fisher's Exact tests were used for categorical data comparison. Python (Python Software Foundation, Wilmington, DE) software was used for all statistical analyses. Statistical significance was determined at a *P* value <0.05.

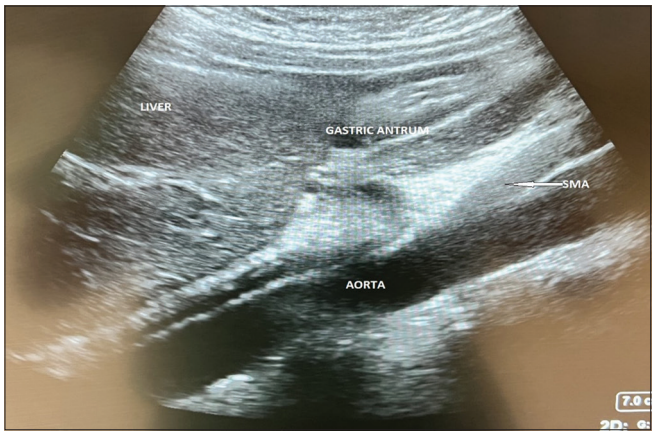

Figure 2: Sonographic image of the gastric antrum of an empty stomach in an additional study patient. Once again, the antrum appears flat and collapsed, with no visible content (Grade 0); SMA, superior mesenteric artery

Results

The study cohort comprised 100 patients scheduled for elective and nonelective procedures, ranging in age from 3 to 17 years (median age: 9.2 years). Among them, there were 41 elective and 59 nonelective procedures, with 32 classified as semi-urgent and 27 as urgent. All patients had ASA physical status of 1 or 2, with 40 female and 60 male patients [Table 1]. Ninety-nine out of hundred patients were NPO for at least 6 hours at the time of surgery. Among the patients scheduled for nonelective procedures, 16 out of 59 patients (27%) had received opioids for pain management before surgery. Of the 34 patients who experienced an acute injury, 7 (21%) had been NPO for <8 hours at the time of the injury. The most common nonelective procedures in the study included laparoscopic appendectomies for both ruptured and nonruptured acute appendicitis, as well as surgical correction of orthopedic injuries.

Using POCUS, 81 patients (81%) were classified as having a Grade 0 aspiration risk, while 16 patients (16%) had a Grade 1 aspiration risk based on the gastric ultrasound findings during the preoperative period, indicating a low risk of aspiration for all patients [Table 2]. Two patients were unable to undergo scanning due to technical reasons. In one patient, colonic shadowing obstructed the view of the gastric antrum, and in another patient, visualization of the stomach was hindered by their body habitus. In one elective surgery patient, evidence of solid food was detected on gastric ultrasound. Upon further inquiry, it was discovered that the patient had eaten that morning and had not observed for NPO. Consequently, the procedure was delayed for 4 hours. A subsequent gastric ultrasound revealed an empty stomach, the surgical procedure was performed as planned. The original research protocol aimed to recruit 300 patients. However, after interim analysis demonstrated a low incidence of aspiration risk, the study was concluded after enrolling 100 patients.

Discussion

Pediatric patients are at a higher risk for oxygen desaturation and respiratory decompensation following the RSI compared

Table 1: Demographic data of the study cohort

	Overall	Elective	Semi-urgent	Urgent	*P*
Number	100	41	32	27	-----
Age (years), mean (SD)	9.2 (4.5)	7.8 (5.3)	9.8 (4.1)	10.6 (3.1)	0.033
Gender, *n* (%); male/female	60/40 (60/40)	24/17 (58.5/41.5)	20/12 (62.5/37.5)	16/11 (59.3/40.7)	0.939
Weight (kg), mean (SD)	41.5 (18.0)	35.5 (16.8)	44.1 (8.0)	47.6 (17.5)	0.014
ASA, median (Q1, Q3)	2.0 (1.0, 2.0)	2.0 (1.0,2.0)	1.0 (1.0,2.0)	2.0 (1.0,2.0)	0.150
BMI, mean (SD)	20.3 (4.2)	19.3 (4.1)	21.3 (4.2)	20.8 (4.0)	0.104

ASA=American Society of Anesthesiologists' Physical Status; SD=standard deviation; BMI=body mass index

Table 2: Additional study data and patient information

	Clinical category	Overall	Elective	Semi-urgent	Urgent	*P*
NPO at the time of injury, *n* (%)	<8 hours	7 (21)	-----	1 (17)	6 (21)	0.701
	>8 hours	27 (79)	-----	5 (83)	22 (79)	
NPO at the time of surgery, *n* (%)	<8 hours	5 (5)	2 (5)	1 (3)	2 (7)	0.534
	>8 hours	95 (95)	39 (95)	31 (97)	25 (93)	
Preoperative opioid administration, *n* (%)	No	84 (84)	41 (100)	27 (84)	16 (59)	<0.001
	Yes	16 (16)	0 (0)	5 (16)	11 (41)	
Aspiration risk Grade, *n* (%)	0	81 (81)	31 (74)	30 (94)	20 (76)	0.257
	1	16 (16)	9 (22)	2 (6)	5 (20)	
	Solid (High risk)	1 (1)	1 (2)	0 (0)	0 (0)	
	Inconclusive	2 (2)	1 (2)	0 (0)	1 (4)	

NPO=*nil per os*; *n*=number

to adult patients. This is due to their higher oxygen consumption to functional residual capacity ratio.[7,8] Gastric ultrasound is a quick and noninvasive procedure that can be performed in real-time at the patient's bedside to assess gastric volume and content, providing real-time information about aspiration risk. Point-of-care gastric ultrasound has been found to have a sensitivity of 1.0 and a specificity of 0.975 in detecting a full stomach and, therefore, a higher aspiration risk.[11] In the current study cohort, we were able to perform scans in <5 minutes in the preoperative holding area of a busy tertiary care operating room on all awake patients without the need for premedication or sedation.

The method of anesthetic induction and airway management techniques may differ between elective and urgent surgical procedures. Factors such as traumatic injury, opioid administration, and intra-abdominal processes may undermine the effectiveness of recommended NPO guidelines in providing an empty stomach, free from aspiration risks during standard induction techniques. These factors may require the placement of intravenous access and RSI in children and adolescents, despite meeting recommended NPO guidelines. However, with the advent of ultrasonography, it may be possible to individually assess patients and determine the suitability of various anesthetic induction techniques based on gastric volume and contents. In our patient cohort, even with confounding factors such as the administration of opioids, an associated traumatic orthopedic injury, pain, or an intra-abdominal process, none of the patients had gastric volumes or contents that would put them at significant risk of aspiration. By using preoperative gastric ultrasound, we could potentially stratify the aspiration risk and choose the optimal anesthetic induction technique for each patient.[12,13] Furthermore, although the study cohort was somewhat limited, our preliminary data suggest that patients who were previously considered at higher risk of aspiration, such as those undergoing urgent procedures, with acute abdominal pathology, recent trauma, pain, and the administration of opioids, may actually have a lower risk of aspiration when appropriately NPO. Thus, a noninvasive method to assess gastric volume and contents in the perioperative setting could potentially change current practices.

Several studies have evaluated gastric content and aspiration risk in children. A study at Couple Enfant Hospital of Grenoble (France) retrospectively analyzed the findings of gastric ultrasound performed in the operating room before the induction of anesthesia in 115 children scheduled for emergency appendectomy.[14] Among the 97 subjects with clear visualization of the gastric antrum, 45 had an empty stomach, 39 had clear liquid visible, and 13 patients had solid food or thick liquid content. However, scanning was not possible in 16 patients due to pain, anxiety, or positioning difficulties. Two patients had noncontributory ultrasound findings. None of the patients with clear liquid on ultrasound scan had volumes greater than 1.5 mL/kg. For the purpose of the study, the authors chose 0.8 ml/kg of gastric volume as the cut-off limit for a theoretical increased aspiration risk. Based on their risk stratification for aspiration, the authors were able to guide their choice of induction and intubation technique according to their gastric ultrasound findings.[14] This study outlines the utility of diagnostic POCUS in enhancing patient safety. In our study, the anesthesiologist involved in the care of the patient was informed of the patient's aspiration risk as well.

Bouvet *et al*.[13] conducted a prospective observational cohort study in 200 children scheduled for elective surgery. The median NPO time for clear liquids was 4 hours, and for solid food and milk, it was 13.5 hours. The gastric ultrasound performed in the operating room prior to the induction of anesthesia revealed that none of the children had solid or thick liquid content in their stomach. Two patients (1%) had a gastric volume >1.25 mL/kg, and one patient (0.5%) had a gastric volume >1.5 mL/kg. A similar prospective observational study performed by Desgranges *et al*.[12]

involved gastric ultrasound assessment of pediatric patients scheduled for elective otolaryngology surgery. All of the 66 patients in the study had a gastric content <1.5 mL/kg with an average gastric volume of 0.28 mL/kg prior to the induction of anesthesia. The results of our study, which included children with fasting times of >6 hours, are comparable to the findings of the above-mentioned studies. However, our patients all had potential additional comorbid features or clinical scenarios which may place them at risk of higher gastric volumes.

Gagey *et al*.[15] conducted a prospective observational cohort study in 130 pediatric patients scheduled for urgent and emergent cases. The gastric ultrasound findings led to a change in management in 67 patients with a transition in 30 patients from a standard induction technique to an RSI and in 37 patients from an RSI to a standard induction.

Our study included trauma patients, patients in acute pain receiving opioids, and those with acute abdominal pathology. Anesthetic induction in these patients has traditionally been carried out using an RSI or modified RSI technique.[16] The findings of our study showed that all of our patients had a minimal risk of aspiration, allowing for a standard induction technique. These findings may assist in the perioperative management of similar patients with associated comorbid conditions. Trauma patients present several challenges in addition to concerns for a full stomach. Some may still have a cervical collar in place as a cervical spine injury may not be able to be ruled out owing to the presence of a distracting injury, or they may have other features that increase the difficulty and challenges of airway management, including the potential for an airway injury. Allowing for a standard induction technique, including inhalational techniques with maintenance of spontaneous ventilation, may be preferable if there are associated clinical concerns. In addition, patients presenting for nonelective surgery may be at risk for hemodynamic instability due to dehydration, acute blood loss, sepsis, or pre-existing cardiopulmonary pathology. A more controlled induction technique may lessen the incidence of hypotension after intubation.

There were several potential limitations to our study. Given the overall low incidence of gastric aspiration during anesthesia, we do not have a large enough cohort of patients to conclusively say that these patients can be considered NPO. However, ultrasound is a quick and noninvasive technique that provides useful information in evaluating these nonelective cases preoperatively in real-time at the patient's bedside. Although we evaluated nonelective surgical patients, none of our subjects met the criteria for a true surgical emergency per our institution guidelines. This means that the patient needed to be on the operating room table within an hour of scheduling the procedure. This was a logistical limitation of the study as we did not ethically believe it feasible to include these patients given the need to discuss the study with the patient and family and obtain consent in the setting of a true surgical emergency. A previous study by Bouvet *et al*.[17] has shown emergency surgery to be an independent risk factor for delayed gastric emptying. Future gastric ultrasound studies in the emergency surgical setting may help us delineate the patient and surgical risk factors for delayed gastric emptying and the extent to which they are at risk of pulmonary aspiration. Finally, many of our scans were performed in the semi-recumbent position: supine with the head of bed elevated at 45°. This was clinically necessary due to acute pain or the presence of invasive lines, drains, or an external fixation device, all of which would have made placing the patient in the RLD position difficult. Bouvet *et al*.[18] had previously shown the utility of the semi-recumbent position in evaluating gastric volumes due to gravitational drainage of gastric content toward the antrum. This was particularly useful for our cohort of nonelective surgical patients with hardware or drains that impede optimal patient positioning. However, there are limited data on the direct correlation between gastric ultrasound findings in the RLD position and the semi-recumbent position.

With these limitations in mind, our preliminary data demonstrate that point-of-care gastric ultrasound can be effectively used to evaluate gastric contents and volume in patients presenting for nonelective surgery. Gastric ultrasound can be performed quickly and in real-time at the patient's bedside, even in the presence of comorbid features. The information obtained may guide the choice of anesthetic induction technique. This may be clinically relevant when there are concerns about the safety and feasibility of performing an RSI. This may also allow for a more stable and controlled induction of anesthesia in this patient population.

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Conflicts of interest
There are no conflicts of interest.

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