Can J Anesth/J Can Anesth (2012) 59:416–423
DOI 10.1007/s12630-011-9661-9

SPECIAL ARTICLE

Bedside ultrasound assessment of gastric content: an observational study

Évaluation échographique du contenu gastrique au chevet du patient: une étude observationnelle

Javier Cubillos, MD · Cyrus Tse, BSc · Vincent W. S. Chan, MD · Anahi Perlas, MD

Received: 13 October 2011 / Accepted: 20 December 2011 / Published online: 4 January 2012

Abstract

Purpose *There is a growing interest in the use of bedside ultrasonography to assess gastric content and volume. It has been suggested that the gastric antrum in particular can be assessed reliably by sonography. The aim of this observational study was to provide a qualitative description of the sonographic characteristics of the gastric antrum when the stomach is empty and following the ingestion of clear fluid, milk, and solid content.*

Clinical features *Six healthy volunteers were examined on four different occasions (24 scanning sessions): following a period of eight hours of fast and following ingestion of 200 mL of apple juice, 200 mL of 2% milk, and a standard solid meal (sandwich and apple juice). Examinations were performed following a standardized scanning protocol by two clinical anesthesiologists with previous experience in gastric sonography. For each type of gastric content, the sonographic characteristics of the antrum and its content are described and illustrated with figures.*

Conclusions *Bedside sonography can determine the nature of gastric content (nil, clear fluid, thick fluid/solid). This qualitative information by itself may be useful to assess risk of aspiration, particularly in situations when prandial status is unknown or uncertain.*

Résumé

Objectif *L'utilisation de l'échographie au chevet du patient pour évaluer le volume et le contenu gastrique suscitent un intérêt croissant. Certains auteurs ont suggéré que l'antre gastrique, en particulier, peut être évalué de façon fiable par échographie. Le but de cette étude observationnelle est de fournir une description qualitative des caractéristiques échographiques de l'antre gastrique d'un estomac vide et après ingestion d'un liquide limpide, de lait et d'un contenu solide.*

Caractéristiques cliniques *Six volontaires en bonne santé ont été examinés à quatre occasions différentes (24 séances d'échographie): après un jeûne de huit heures, après l'ingestion de 200 mL de jus de pomme, de 200 mL de lait à 2 % et après un repas consistant standard (sandwich et jus de pomme). Les échographies ont été réalisées selon un protocole d'examen standardisé par deux anesthésiologistes cliniques ayant une expérience acquise en échographie gastrique. Les caractéristiques échographiques de l'antre et de son contenu sont décrites et illustrées par des figures pour chaque type de contenu gastrique.*

Conclusions *L'échographie au chevet du patient peut déterminer la nature du contenu gastrique (absence, liquide limpide, liquide épais/contenu solide). Cette information qualitative peut, en soi, être utile pour l'évaluation du risque d'aspiration bronchique, en particulier dans les cas où on ne sait pas avec certitude si l'estomac est vide.*

J. Cubillos, MD · C. Tse, BSc · V. W. S. Chan, MD
Department of Anesthesia, Toronto Western Hospital, University of Toronto, Toronto, ON, Canada

A. Perlas, MD (✉)
Department of Anesthesia, Toronto Western Hospital, University Health Network, McLaughlin Pavilion 2-405, 399 Bathurst St, Toronto, ON M5T 2S8, Canada
e-mail: anahi.perlas@uhn.on.ca

A. Perlas, MD
Department of Anesthesia, University of Toronto, Toronto, ON, Canada

Pulmonary aspiration of gastric content is a major anesthetic-related complication which may result in significant morbidity and mortality.[1-4] The volume, nature (fluid *vs* particulate or solid matter), and acidity of the aspirate are thought to be associated with patient outcomes.[5,6] Current prevention strategies rely mostly on recommended fasting periods.[7] However, several underlying medical conditions can predispose patients to significant gastric content at the time of anesthetic induction despite appropriate fasting intervals.[8,9] Clinical assessment of aspiration risk is currently limited due to the lack of a noninvasive validated diagnostic tool to evaluate gastric content. There is a growing interest in the use of bedside ultrasound as a noninvasive portable tool to assess gastric content and volume at the bedside.[10-12] We have previously reported that ultrasonography can provide both qualitative and quantitative information about gastric content which could be useful to the clinician in determining aspiration risk at the bedside.[12] Several authors have suggested that the gastric antrum is particularly amenable to sonographic examination since it has a reliable location and can be identified readily using standard internal anatomical landmarks.[4,12-14]

The purpose of this qualitative study was to provide a systematic description of the sonographic appearance of the gastric antrum in the "empty" (fasted) state, and following ingestion of clear fluids, milk, and a solid meal.

Methods

Following institutional Research Ethics Board approval and written informed consent, six healthy volunteers [age 34 (7) yr, height 166 (10) cm, weight 77 (8) kg, body mass index 27 (2.3) $kg \cdot cm^{-2}$] each underwent four focused gastric sonographic examinations (24 scanning sessions in total). The small number of subjects was a convenience sample size. Based on our previous experience of gastric sonography, it is our view that qualitative findings are consistent among subjects for a given type of content, and thus six subjects would be representative of the general healthy population for the purpose of this descriptive study. Inclusion criteria were subjects aged 18-80 yr, height > 150 cm, weight 50-110 kg, and body mass index < 40 $kg \cdot cm^{-2}$. Exclusion criteria included a history of upper gastrointestinal disorders, including gastroesophageal reflux disease, hiatus hernia, gastroesophageal cancer, or upper gastrointestinal surgery. A small stipend was provided to study subjects to cover travelling and parking expenses. Subjects were examined at the Toronto Western Hospital, Toronto, ON, during April to June 2011. Examinations were performed with the subjects placed in the right lateral decubitus position, and particular attention was given to the gastric antrum. This patient position was chosen for its greater sensitivity to detect small amounts of fluid compared with supine examinations, as fluid and semi-fluid gastric content moves towards the more dependent antrum.[11,12,15,16] Additionally, in the right lateral position, air content is displaced away from the antrum towards the more proximal body and fundus. This optimizes scanning conditions by limiting sound attenuation due to intraluminal air.

Each volunteer was scanned on four different occasions: a) "empty stomach", after fasting for all intake for eight hours; b) five minutes after ingestion of 200 mL of apple juice; c) five minutes after ingesting 200 mL of 2% milk; and d) following a solid meal (sandwich and apple juice) at two time intervals (at 5 min and 90 min). Empty stomachs in healthy individuals often have a small baseline volume of gastric secretions (up to 1.6 $mL \cdot kg^{-1}$).[17] Subjects were asked to ingest 200 mL of clear fluid and milk, as this volume was chosen to be higher than the upper limit of a normal baseline fasting volume. A two-dimensional ultrasound assessment was performed using either a portable General Electric Logiq e unit (GE Healthcare, Mississauga, ON, Canada) or a Philips CX50 unit (Philips Healthcare, Andover, MA, USA) with a low-frequency (2-5 MHz) curved array transducer or a high-frequency (8-13 MHz) linear array transducer, as appropriate. The scanning protocol was adapted from previous studies by our group and performed in collaboration with a certified sonographer and a radiologist who specializes in abdominal ultrasound.[12,17] Examinations were performed and interpreted by two co-authors, both clinical anesthesiologists with a previous experience of 50 and 200 gastric examinations, respectively. The body, antrum, and pylorus were identified sequentially starting at the left subcostal margin and moving in a fan-like manner from the left towards the right subcostal area (Fig. 1). For reasons mentioned previously, the focus of this article is on the descriptions and images of the antrum[4-6]; therefore, a quantitative assessment of gastric volume was not performed since it is outside the scope of this descriptive study. Sonographic methods to determine gastric volume are described elsewhere.[12,17,18]

Results

In all 24 examinations, the gastric antrum was located successfully in the epigastric area, slightly to the right of the abdominal midline between the left lobe of the liver anteriorly and the body of the pancreas posteriorly (Figs 2A, 2B). The abdominal aorta and/or the inferior vena cava, superior mesenteric artery, and splenic vein were used as additional useful landmarks (Figs 2A, 2B).[7] The gastric antrum and its contents were examined

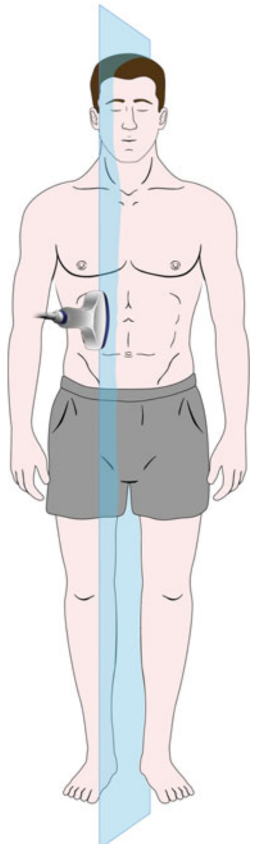

Fig. 1 Sagittal/parasagittal scanning plane for gastric assessment

preferentially in a sagittal scanning plane, while an axial plane was used to locate the antropyloric duodenal transition (Figs 3, 4A, 4B). The pylorus has a thicker muscular wall than the antrum. Peristaltic contractions were often appreciated both in the antrum and pylorus, particularly in the non-empty states. All images were obtained between peristaltic contractions.

The empty antrum

The “empty” antrum appeared collapsed and “flat” with the anterior and posterior walls very close to each other or round to ovoid in shape resembling a “bull’s eye” target (Fig. 5). In the “empty” state, the walls of the stomach appeared relatively thick (Figs 6A, 6B). A high-frequency linear probe gave detailed definition of the five distinctive gastric wall layers described previously (Fig. 7). The five layers, from inner to outer gastric wall surface, include: 1) mucosal/lumen interface (thin echogenic line), 2) muscularis mucosae (hypoechoic), 3) submucosa (hyperechoic), 4) muscularis propria (hypoechoic, usually the thickest gastric wall layer), and 5) serosa (thin, hyperechoic).

Clear fluid

Following ingestion of 200 mL of apple juice, the antrum appeared distended with a round shape, thin gastric walls, and hypoechoic fluid content (Figs 8A, 8B). Immediately following fluid ingestion, multiple gas “bubbles” appeared as punctuate hyperechoic areas within the hypoechoic fluid, mimicking a “starry night” appearance (Fig. 8A). With the subjects in the right lateral decubitus position, the antral content became homogeneously hypoechoic within a few

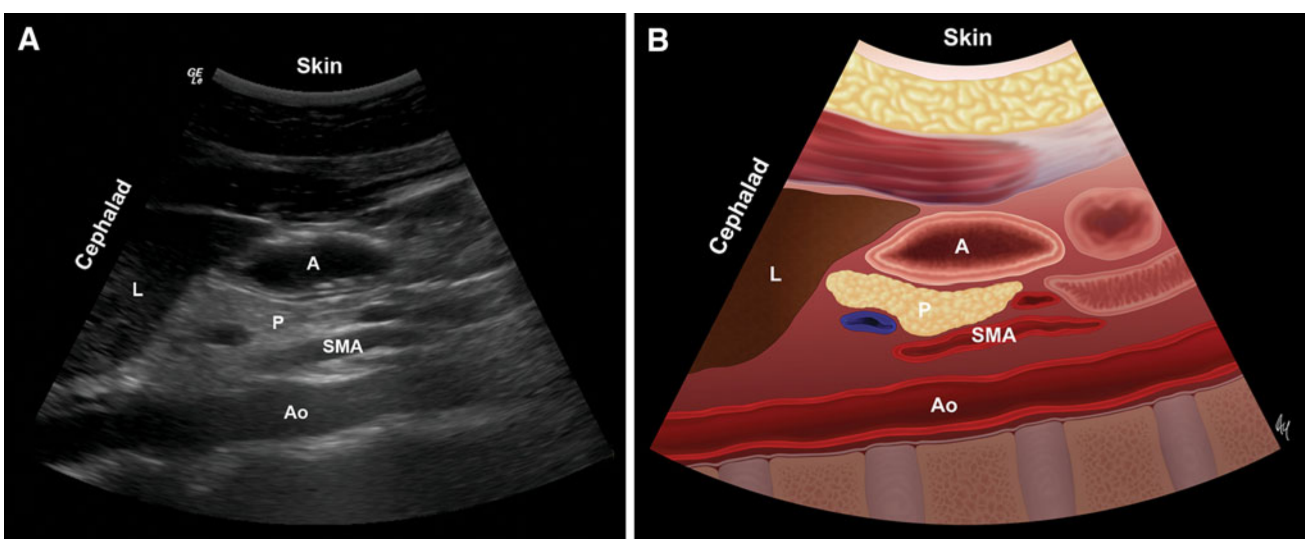

Fig. 2 **A** Sagittal sonogram of the gastric antrum. A = antrum; L = liver; P = pancreas; SMA = superior mesenteric artery; Ao = aorta. **B** Schematic representation of sagittal sonoanatomy. A = antrum; L = liver; P = pancreas; SMA = superior mesenteric artery; Ao = aorta

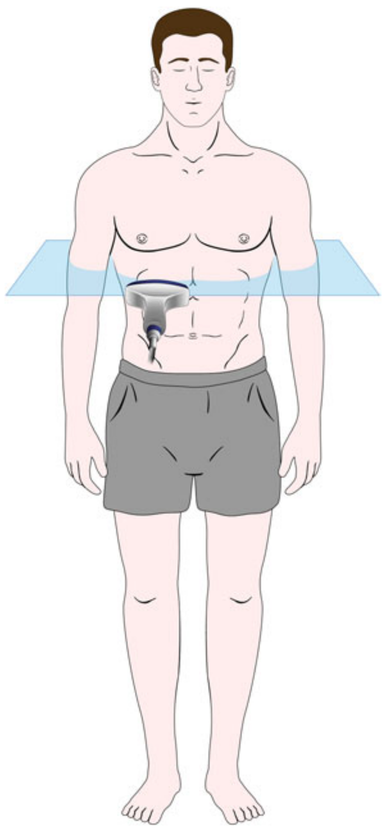

Fig. 3 Axial scanning plane for gastric assessment

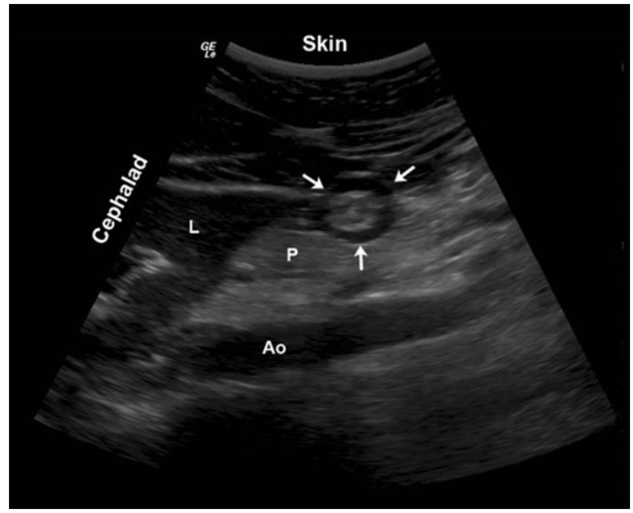

Fig. 5 Sagittal sonogram of the empty antrum resembling a "bull's eye" target (arrowheads). L = liver; P = pancreas; Ao = aorta

minutes of ingestion in all subjects as the gas bubbles presumably moved proximally towards the body and the fundus.

Milk

Following ingestion of 200 mL of 2% milk, the antrum appeared round and distended. Its content, however, differed substantially from clear fluid, appearing with increased echogenicity in all subjects (Fig. 9).

Solid content

Immediately following ingestion of the solid meal, a hyperechoic linear area was seen in four subjects along the mucosa of the anterior wall of the antrum. Several "ring-

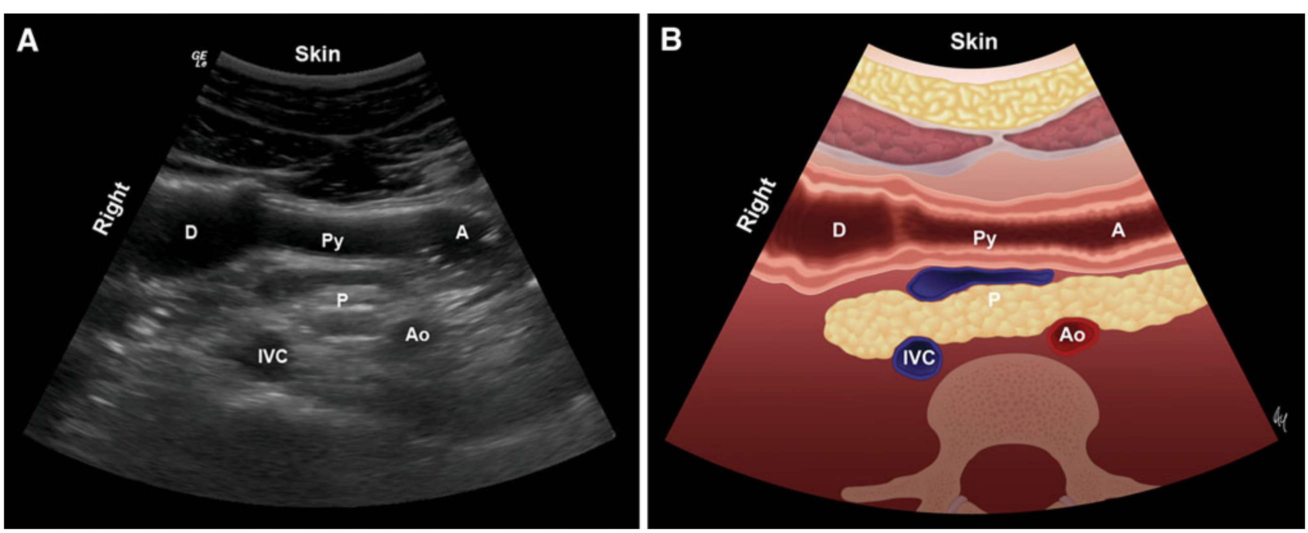

Fig. 4 **A** Axial ultrasound image of the gastric antrum. A = antrum; P = pancreas; D = duodenum; Py = pylorus; IVC = inferior vena cava; Ao = aorta. **B** Schematic representation of axial sonoanatomy. A = antrum; P = pancreas; D = duodenum; Py = pylorus; IVC = inferior vena cava; Ao = aorta

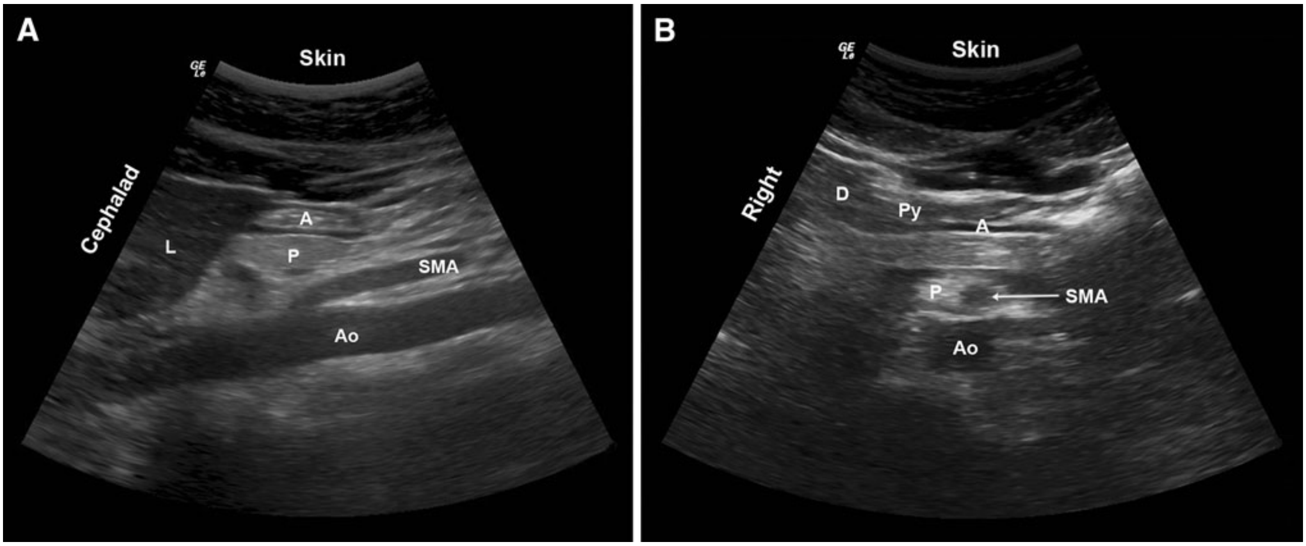

Fig. 6 **A** Sagittal sonogram of the empty antrum with a flat appearance. A = antrum; L = liver; P = pancreas; SMA = superior mesenteric artery; Ao = aorta. **B** Axial sonogram of the empty antrum. A = antrum; Py = pylorus; D = duodenum; P = pancreas; SMA = superior mesenteric artery; Ao = aorta

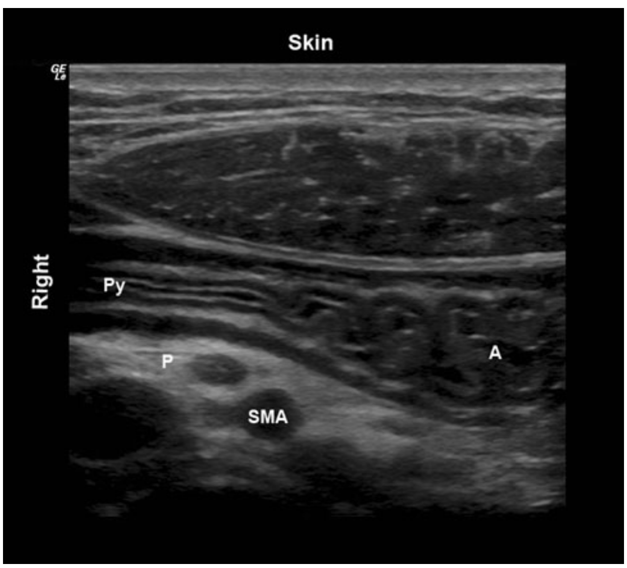

Fig. 7 Axial sonogram of the empty antrum using a linear high-frequency transducer, allowing identification of five gastric wall layers. A = antrum; Py = pylorus; P = pancreas; SMA = superior mesenteric artery

down" artifacts along the mucosal-air interface gave the antrum a "frosted glass" appearance, impairing visualization of deeper structures (Fig. 10A). After 90 min, the solid gastric content acquired a more homogeneous character, appearing of intermediate echogenicity and allowing visualization of more posterior structures (Figs 10B and 10C), presumably as food bolus was mixed with gastric juices and the air was displaced. The appearance of solid gastric content was similar in all six subjects after 90 min.

Discussion

We have systematically described the sonographic characteristics of the gastric antrum in the fasting state and following ingestion of different types of contents (clear fluid, milk, and solid) in healthy human volunteers.

To date, the clinical applications of gastric sonography have been limited. Ultrasound has been used to evaluate gastric wall lesions[19,20] and changes in gastric volume during accommodation and emptying of the stomach.[21,22] Sequential sonographic evaluation of the gastric antrum can be used to study time for gastric emptying, and it correlates well with scintigraphic evaluation, the current gold standard.[23-27]

In anesthesiology and acute care medicine, there is a growing interest in bedside evaluation of gastric "fullness" to assess pulmonary aspiration risk. Patients with a compromised level of consciousness, either due to acute illness or medically induced by the administration of sedatives or anesthetics, have limited ability to protect their upper airway and lungs from aspiration of gastrointestinal contents; therefore, they are at risk of pulmonary aspiration syndrome in the presence of gastric content.[1-4] Severe aspiration pneumonia requiring mechanical ventilatory support ensues in up to one-third of patients with a mortality of 5%, representing up to 9% of all anesthesia-related deaths.[28,29] The severity of the resulting respiratory compromise is thought to be related to both the volume and nature of the aspirate, with particulate matter carrying the highest risk.[29-31] Real-time ultrasonography is a very attractive bedside imaging tool. It is increasingly available

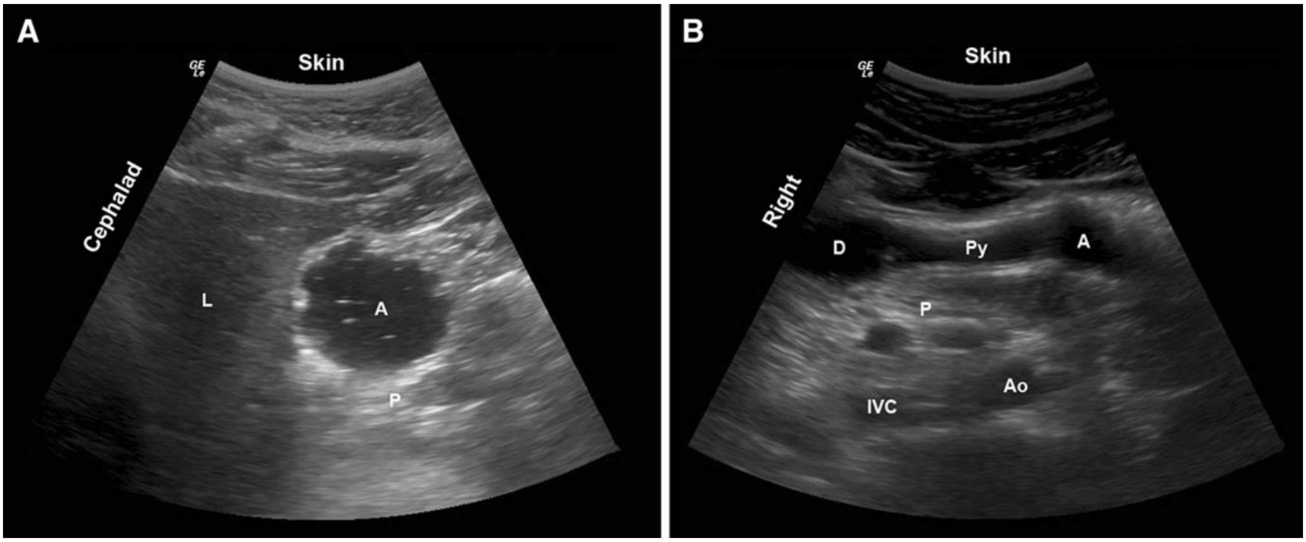

Fig. 8 **A** Sagittal sonogram of the gastric antrum immediately following ingestion of 200 mL of clear fluid ("starry night" appearance) A = antrum; L = liver; P = pancreas. **B** Axial sonogram of the antrum five minutes after ingestion of 200 mL of fluid. A = antrum; D = duodenum; Py = pylorus; P = pancreas; Ao= aorta; IVC = inferior vena cava

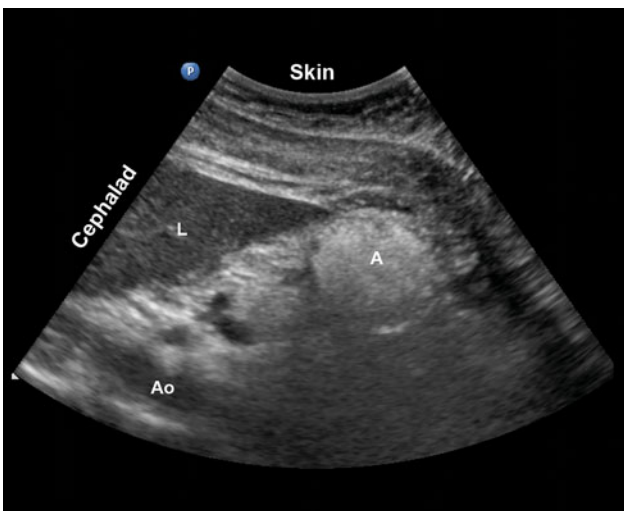

Fig. 9 Sagittal sonogram of the antrum five minutes after ingestion of 200 mL of milk. A = antrum; L = liver; Ao = aorta

in acute care environments, and it is portable and non-invasive.

Currently, clinical decisions regarding surgical timing and airway management choices are based on the *assumption* that a particular patient has either an "empty stomach" or a "full stomach" according to the time elapsed since the last meal. However, gastric emptying times vary significantly depending on pre-existing conditions, and fasting guidelines do not guarantee an "empty stomach" in patients with underlying gastric dysmotility of any etiology. Furthermore, patients presenting for urgent surgical procedures are usually not fasted, or they may have significant gastric content despite long periods of fasting. Whenever prandial status is unclear or unknown, a focused gastric sonogram performed at the bedside may be very helpful to assess aspiration risk more effectively. In such cases, if a gastric sonogram confirms thick fluid or solid content, this is unequivocally a high-risk situation for aspiration regardless of the exact volume. On the other hand, if a gastric sonogram reveals an empty stomach, this is clearly a low-risk situation for aspiration. The sonographic diagnosis of "empty stomach" is a *qualitative* one, and no volume assessment is required. Finally, if gastric sonography shows clear fluid content, then a *quantitative volume assessment* (as previously described by Perlas or Bouvet) can help differentiate a low-volume status (similar to baseline physiologic gastric content) *vs* a high-volume status (higher than baseline gastric volume).[12,17,18]

One limitation to sonographic gastric examination is that it is often difficult to image the entire organ, with the fundus being the most challenging section.[12] Consequently, gastric sonography is usually limited to the body, antrum, and pyloric regions. In addition, some patient factors may potentially increase technical difficulty, including marked obesity, pregnancy, previous abdominal surgery, atypical anatomy, or air insufflation of the stomach.

Additional research is needed for further delineation of the role of a qualitative gastric sonographic examination in determining aspiration risk, as well as how best to combine both qualitative and quantitative information to prevent pulmonary aspiration and its impact on patient morbidity and mortality.

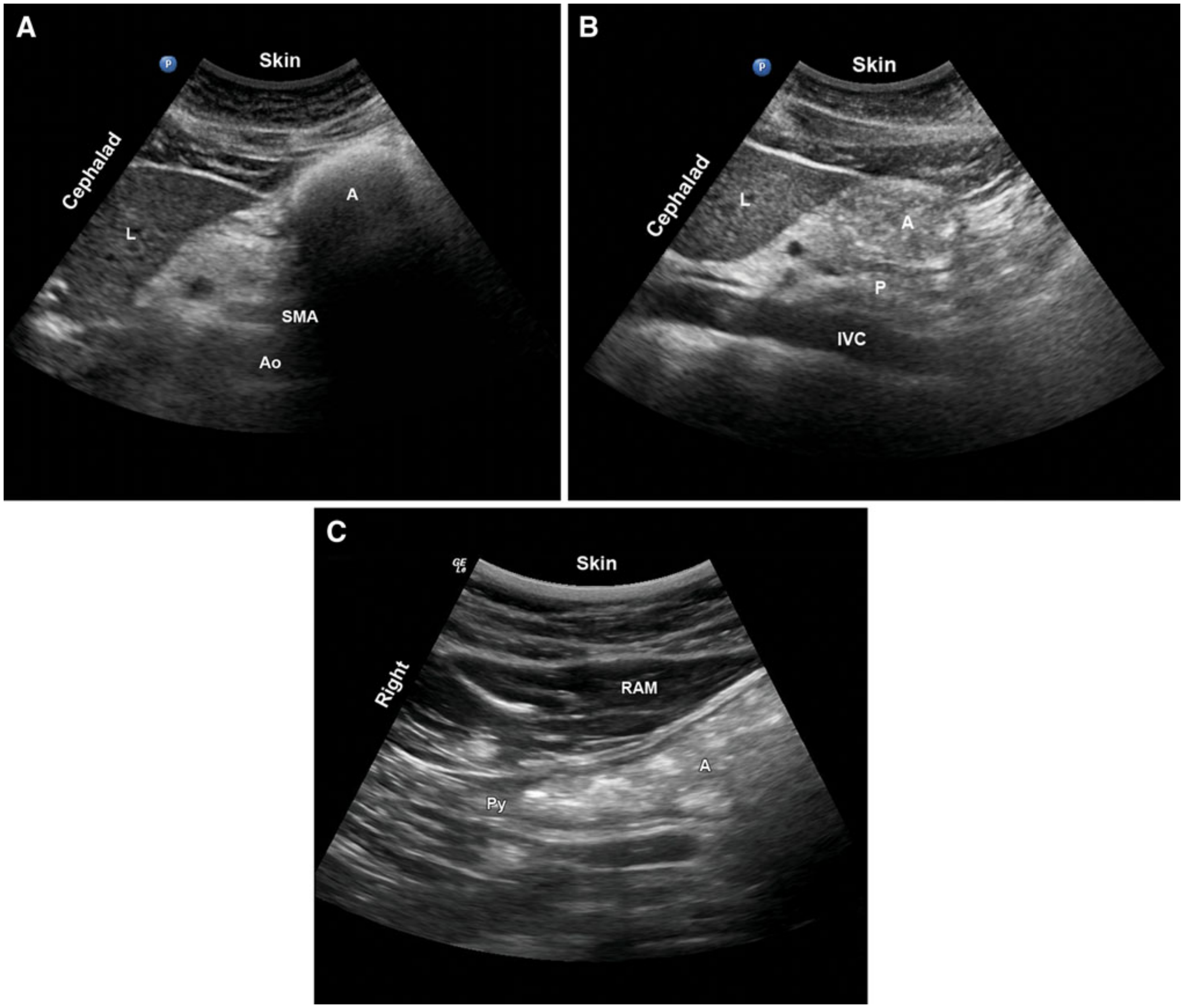

Fig. 10 **A** Sagittal sonogram of the gastric antrum ("frosted glass" appearance) five minutes after ingestion of a solid meal. A = antrum; L = Liver; SMA = superior mesenteric artery; Ao = aorta. **B** Sagittal sonogram of the gastric antrum with hyperechoic content 90 min after ingestion of a solid meal. A = antrum; L = liver; P = pancreas; IVC = inferior vena cava. **C** Axial sonogram of the gastric antrum with solid content 90 min after ingestion of a solid meal. A = antrum; Py = pylorus; RAM = rectus abdominis muscle

Acknowledgement The authors gratefully acknowledge the assistance of Adrian Yen (medical illustrator) with Figures 1, 2B, 3, and 4B.

Competing interests Dr. Vincent Chan receives research and material support from Philips Inc., General Electric Inc., and SonoSite Inc. None of the other authors has financial or other potential competing interests related to this article.

Author contributions *Javier Cubillos* participated in the ultrasound examinations and image interpretation, and he wrote the first draft of the manuscript, collaborated with the illustrator to design Figures 1, 2B, 3, and 4B. *Cyrus Tse* organized the logistics of the scanning sessions, he obtained all study data, recorded and stored images, and formatted the images according to journal requirements. *Vincent Chan* critically revised the original protocol, and critically revised the manuscript. *Anahi Perlas* conceived and designed the study, obtained Research Ethics Board approval, participated in the ultrasound examinations, and critically revised the manuscript.

References

1. *Schwartz DE*, *Matthay MA*, *Cohen NH*. Death and other complications of emergency airway management in critically ill adults. A prospective investigation of 297 tracheal intubations. Anesthesiology 1995; 82: 367-76.
2. *Ng A*, *Smith G*. Gastroesophageal reflux and aspiration of gastric contents in anesthetic practice. Anesth Analg 2001; 93: 494-513.
3. *Neelakanta G*, *Chikyarappa A*. A review of patients with pulmonary aspiration of gastric contents during anesthesia reported to the Departmental Quality Assurance Committee. J Clin Anesth 2006; 18: 102-7.

4. *Green SM*, *Krauss B*. Pulmonary aspiration risk during emergency department procedural sedation – an examination of the role of fasting and sedation depth. Acad Emerg Med 2002; 9: 35-42.
5. *Raidoo DM*, *Roche DA*, *Brock-Utne JG*, *Marszalek A*, *Engelbrecht HE*. Critical volume for pulmonary acid aspiration: reappraisal in a primate model. Br J Anaesth 1990; 65: 248-50.
6. *James CF*, *Modell JH*, *Gibbs CP*, *Kuck EJ*, *Ruiz BC*. Pulmonary aspiration – effects of volume and pH in the rat. Anesth Analg 1984; 63: 665-8.
7. *American Society of Anesthesiologists Committee*. Practice guidelines for preoperative fasting and the use of pharmacologic agents to reduce the risk of pulmonary aspiration: application to healthy patients undergoing elective procedures: an updated report by the American Society of Anesthesiologists Committee on Standards and Practice Parameters Anesthesiology 2011; 114: 495-511
8. *Kinni ME*, *Stout MM*. Aspiration pneumonitis: predisposing conditions and prevention. J Oral Maxillofac Surg 1986; 44: 378-84.
9. *Zaloga GP*. Aspiration-related illnesses: definitions and diagnosis. JPEN J Parenter Enteral Nutr 2002; 26: S2-8.
10. *Carp H*, *Jayaram A*, *Stoll M*. Ultrasound examination of the stomach contents of parturients. Anesth Analg 1992; 74: 683-7.
11. *Hveem K*, *Hausken T*, *Berstad A*. Ultrasonographic assessment of fasting liquid content in the human stomach. Scand J Gastroenterol 1994; 29: 786-9.
12. *Perlas A*, *Chan VW*, *Lupu CM*, *Mitsakakis N*, *Hanbidge A*. Ultrasound assessment of gastric content and volume. Anesthesiology 2009; 111: 82-9.
13. *Koenig SJ, Lakticova V, Mayo PH.* Utility of ultrasonography for detection of gastric fluid during urgent endotracheal intubation. Intensive Care Med. 2011; 37: 627-31
14. *Jacoby J*, *Smith G*, *Eberhardt M*, *Heller M*. Bedside ultrasound to determine prandial status. Am J Emerg Med 2003; 21: 216-9.
15. *Kubli M*, *Scrutton MJ*, *Seed PT*, *O'Sullivan G*. An evaluation of isotonic 'sport drinks' during labor. Anesth Analg 2002; 94: 404-8.
16. *Spahn TW*, *Wessels A*, *Grobe-Thie W*, *Mueller MK*. Assessment of pre-gastroscopy fasting period using ultrasonography. Dig Dis Sci 2009; 54: 621-6.
17. *Perlas A*, *Davis L*, *Khan M*, *Mitsakakis N*, *Chan VW*. Gastric sonography in the fasted surgical patient: a prospective descriptive study. Anesth Analg 2011; 113: 93-7.
18. *Bouvet L*, *Miquel A*, *Chassard D*, *Boselli E*, *Allaouchiche B*, *Benhamou D*. Could a single standardized ultrasonographic measurement of antral area be of interest for assessing gastric contents? A preliminary report. Eur J Anaesthesiol 2009; 26: 1015-9.
19. *Hata J*, *Haruma K*, *Manabe N*, *et al*. Chapter 16: Gastric cancer. In: Maconi G, Bianchi Porro G, editors. Ultrasound of the Gastrointestinal Tract. Medical Radiology Diagnostic Imaging series. Berlin: Springer-Verlag; 2007 .
20. *Ishigami S*, *Yoshinaka H*, *Sakamoto F*, *et al*. Preoperative assessment of the depth of early gastric cancer invasion by transabdominal ultrasound sonography (TUS): a comparison with endoscopic ultrasound sonography (EUS). Hepatogastroenterology 2004; 51: 1202-5.
21. *Gilja OH*, *Hatlebakk JG*, *Odegaard S*, *et al*. Advanced imaging and visualization in gastrointestinal disorders. World J Gastroenterol 2007; 13: 1408-21.
22. *Schulze K*. Imaging and modelling of digestion in the stomach and the duodenum. Neurogastroenterol Motil 2006; 18: 172-83.
23. *Bolondi L*, *Bortolotti M*, *Santi V*, *Calletti T*, *Gaiani S*, *Labo G*. Measurement of gastric emptying time by real-time ultrasonography. Gastroenterology 1985; 89: 752-9.
24. *Hveem K*, *Jones KL*, *Chatterton BE*, *Horowitz M*. Scintigraphic measurement of gastric emptying and ultrasonographic assessment of antral area: relation to appetite. Gut 1996; 38: 816-21.
25. *Darwiche G*, *Bjorgell O*, *Thorsson O*, *Almer LO*. Correlation between simultaneous scintigraphic and ultrasonographic measurements of gastric emptying in patients with type 1 diabetes mellitus. J Ultrasound Med 2003; 22: 459-66.
26. *Gilja OH*, *Lunding J*, *Hausken T*, *Gregersen H*. Gastric accommodation assessed by ultrasonography. World J Gastroenterol 2006; 12: 2825-9.
27. *Haruma K*, *Kusunoki H*, *Manabe N*, *et al*. Real-time assessment of gastroduodenal motility by ultrasonography. Digestion 2008; 77(Suppl 1): 48-51.
28. *Shime N*, *Ono A*, *Chihara E*, *Tanaka Y*. Current status of pulmonary aspiration associated with general anesthesia: a nationwide survey in Japan (Japanese). Masui 2005; 54: 1177-85.
29. *Lienhart A*, *Auroy Y*, *Pequignot F*, *et al*. Survey of anesthesia-related mortality in France. Anesthesiology 2006; 105: 1087-97.
30. *Marik PE*. Aspiration pneumonitis and aspiration pneumonia. N Engl J Med 2001; 344: 665-71.
31. *Apfela CC*, *Roewer N*. Ways to prevent and treat pulmonary aspiration of gastric contents. Curr Opin Anaesthesiol 2005; 18: 157-62.