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Ultrasound assessment of gastric content and volume

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Editor's key points

- The authors review the literature regarding the use of ultrasound to estimate gastric volume and, thus, aspiration risk.
- Suggestions for clinical usage are provided.

Pulmonary aspiration of gastric content is a serious anaesthetic complication that can lead to significant morbidity and mortality. Aspiration risk assessment is usually based on fasting times. However, fasting guidelines do not apply to urgent or emergent situations and to patients with certain co-morbidities. Gastric content and volume assessment is a new point-of-care ultrasound application that can help determine aspiration risk. This systematic review summarizes the current literature on bedside ultrasound assessment of gastric content and volume relevant to anaesthesia practice. Seventeen articles were identified using predetermined criteria. Studies were classified into those describing the sonographic characteristics of different types of gastric content (empty, clear fluid, solid), and those describing methods for quantitative assessment of gastric volume. A possible algorithm for the clinical application of this new tool is proposed, and areas that require further research are highlighted.

Keywords: antrum; gastric content; pulmonary aspiration; ultrasound

Perioperative aspiration of gastric contents is a rare but serious complication of anaesthesia. The overall incidence in a mixed surgical population ranges between <0.1% and 19% depending on patient and surgical factors and it has not changed in the last few decades.[1–5] Aspiration pneumonia is associated with significant morbidity, including prolonged mechanical ventilation,[6] and carries a risk of mortality as great as 5%. Pulmonary aspiration is involved in up to 9% of all anaesthesia-related deaths.[7 8] One of the main risk factors for aspiration is the presence of gastric content. The critical volume threshold of gastric fluid that by itself increases aspiration risk is controversial, but healthy, fasted patients frequently have residual gastric volumes (GVs) of up to 1.5 ml kg^{-1} without significant aspiration risk.[9–13] Sedation and general anaesthesia depress or impede the physiological mechanisms that protect against aspiration (the tone of the lower oesophageal sphincter and upper airway reflexes).[14 15] Since restriction of fluid and food intake before general anaesthesia is vital for patient safety, anaesthesiology societies have developed guidelines for preoperative fasting.[16 17] For example, current guidelines by the ASA recommend a minimum of 2 h of fasting for clear fluids, 6 h after a light meal (toast and clear fluids), and 8 h after a full meal with high calorie or fat content.[17] However, these guidelines apply only to healthy patients for elective surgery and are not reliable in patients with coexisting diseases that affect gastric emptying or volume, patients in whom airway management might be difficult or in emergency situations.[17] This systematic review summarizes the current state of knowledge on the use of bedside ultrasound to evaluate gastric content and volume as they relate to aspiration risk assessment from the perspective of the clinical anaesthesiologist.

Methods

The recommendations and checklist of the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) were followed to conduct and report this review.[18]

The National Library of Medicine's PubMed, OVID Medline, and EMBASE databases were searched since their date of inception to February 2013 using the following Medical Subject Headings: *gastric ultrasonography* or *gastric ultrasound* or *gastric sonography* and *stomach* or *antrum* were used. The search was restricted to English language articles and human subjects. Two independent reviewers read all citations. Prospective or retrospective experimental studies of portable 2D ultrasonography on human subjects, case series, or observational studies were selected for inclusion if they addressed one or two of the following questions: (i) Can ultrasound determine the nature of gastric content (empty, clear fluid, or thick fluid/solid)?, (ii) Can ultrasound estimate the volume of gastric fluid?, or both. Commentaries, abstracts, letters to the editor, case reports, editorials, and meeting proceedings were excluded. Discrepancies were settled by discussion and consensus. Selected articles underwent full-text review and references were screened for further articles not identified by the searches.

The following data were extracted from each included study: publication year, country of origin, study design, number of subjects and patient characteristics, gastric sections studied (antrum, body, fundus), scanning position, and plane. For quantitative studies, details of mathematical models were extracted (reference standard, correlation coefficient).

Results

Three hundred and ninety-four citations were identified (Fig. 1). Based on title and abstract, 356 were excluded as not meeting inclusion criteria, and five were duplicates. Thirty-three articles were retrieved for full-text review. Of these, 22 publications were excluded (13 studied gastric emptying, three studied gastric motility, and six were on other gastroenterology applications not directly related to aspiration risk assessment). Six additional articles were identified from reference lists. Seventeen articles were included in this review. Eight articles dealt with qualitative assessment (Table 1), seven articles dealt with quantitative assessment (Table 2), and two additional studies were included in both categories. Of the included studies, 41% (n=7) were published before 2000, 18% (n=3) between 2000 and 2009, and the remaining 41% (n=7) in or after 2010. The majority of the studies originated in North America (47%, n=8) and Europe (41%, n=7), whereas 12% (n=2) were from Japan. A total of 533 subjects were included in the qualitative studies and 542 subjects in the quantitative studies. Study populations consisted of healthy volunteers (n=267), pregnant patients (n=73), newborns (n=32), other paediatric patients (n=16), elective adult surgical subjects (n=467), upper gastric endoscopy (n=140), or intensive care patients (n=80). The antrum was evaluated in 82% of the studies, the fundus in 23%, and the gastric body in 35%. Two studies did not specify which section of the stomach was evaluated.

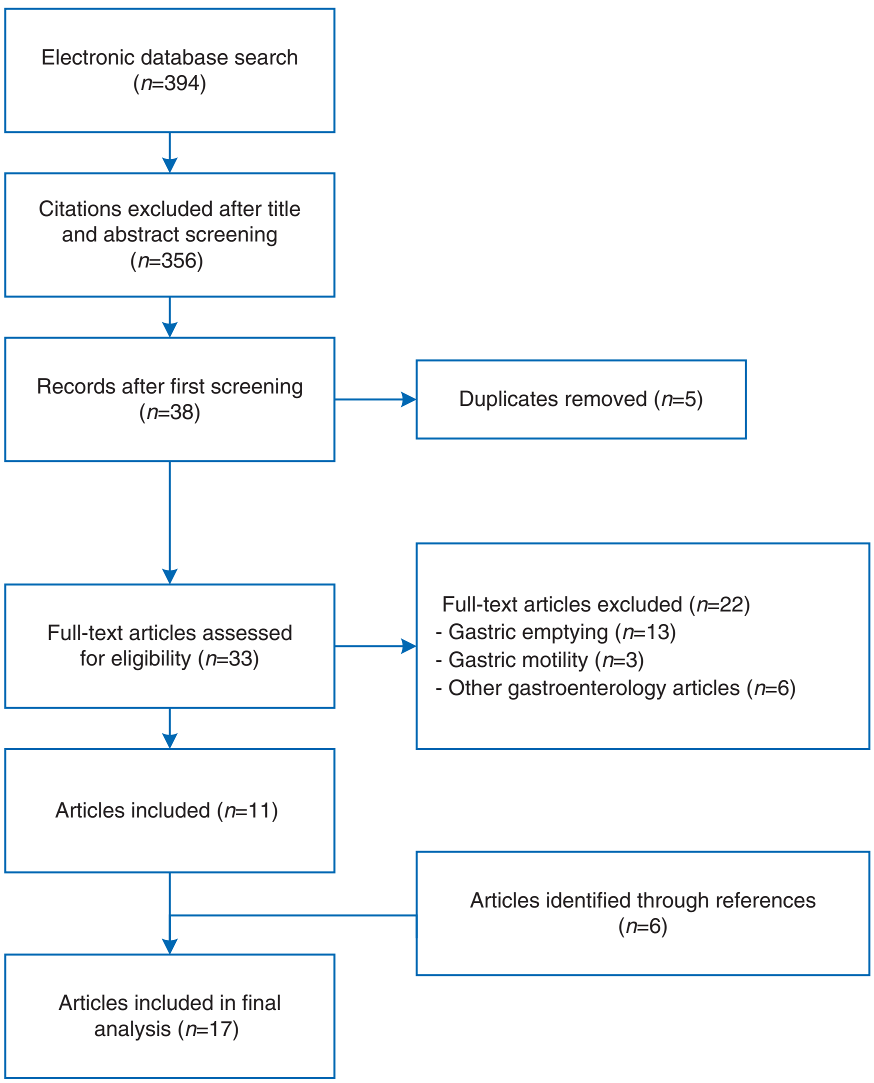

Fig 1 Results.

Table 1 Qualitative studies. *, mean (SD); and °, range

Author	Year	Country	Design	Study population	n	Age (yr)	BMI	Patient position	Gastric section	Scanning plane	Empty	Fluid	Solid
Sijbrandij and Op den Orth[19]	1991	The Netherlands	Pictorial essay	NA	NA	NA	NA	RLD	A/F/B	Oblique left upper quadrant	No	Yes	No
Carp and colleagues[20]	1992	USA	OBS	Females (OB and non-OB)	93	NR	NR	SIT/RLD	A/B	Oblique left upper quadrant	No	Yes	Yes
Jayaram and colleagues[21]	1997	USA	OBS	Females (OB and non-OB)	94	20–40°	20–40°	SIT	A/B	Oblique left upper quadrant	No	Yes	Yes
Jacobyand colleagues[22]	2003	USA	INT blind	Volunteers	20	NR	NR	SUP/RLD	NR	Axial	No	Yes	Yes
Perlas and colleagues[23]	2009	Canada	OBS	Volunteers	18	NR	NR	SUP/RLD	A/B/F	Parasagittal	Yes	Yes	Yes
Bouvet and colleagues[24]	2009	France	INT blind	Volunteers	22	27–51°	21–24°	Semi SIT	A	NR	Yes	Yes	Yes
Sporea and Popescu[25]	2010	Romania	Technical report	NA	NA	NA	NA	NA	A/B/F	Axial/sagittal	Yes	Yes	No
Koenigand colleagues[26]	2011	USA	OBS	ICU patients for urgent intubation	80	20–91°	NR	SUP	B/F	Axial/mid-axillary line	Yes	Yes	Yes
Perlas and colleagues[27]	2011	Canada	OBS	Adult surgical patients	200	51 (16)*	28 (5)*	SUP/RLD	A	Sagittal	Yes	Yes	No
Cubillos and colleagues[28]	2012	Canada	Pictorial essay	Volunteers	6	34 (7)*	27 (2)*	RLD	A	Axial/sagittal	Yes	Yes	Yes

Qualitative gastric sonography: can ultrasound determine the nature of gastric content (empty, clear fluid, or thick fluid/solid)?

Ten articles describe the utility of ultrasound to determine the nature of the gastric content (Table 1).

Scanning technique

The stomach has been imaged with the patient in the supine, sitting, semi-sitting, or right lateral decubitus (RLD) position. The best position depends on the section of the stomach to be imaged and affects sonographic findings. Several studies suggest that the distal parts of the stomach (antrum and body) are better evaluated in a semi-sitting or RLD position.[19–23 27–29] Owing to a gravitational shift, a greater proportion of gastric content will move towards the more dependent areas of the stomach in these two positions. This may be especially important to evaluate gastric content in low-volume states in which gastric fluid may only be visible in a sitting or RLD position.[20 23 27] Scanning technique was similar among different reports whether they studied healthy volunteers or patients. The only exception is a report on critically ill patients in which it may not be feasible to scan in a patient position other than supine.[26]

A curved array low-frequency transducer (2–5 MHz) with standard abdominal settings is most useful in adults. It provides the necessary penetration to identify the relevant anatomic landmarks.[19] A linear high-frequency transducer can be used in leaner or paediatric patients or to obtain detailed images of the gastric wall. The gastric wall is 4–6 mm thick and has a characteristic appearance of five distinct sonographic layers that are best visualized with a high-frequency transducer (e.g. 5–12 MHz) in the fasting state.[19 25 27 28] These layers help differentiate the stomach from other hollow viscus. Starting at the inner surface of the stomach, the first thin hyperechoic layer corresponds to the mucosal–air interface. A second hypoechoic layer is the muscularis mucosa. A third hyperechoic layer corresponds to the submucosa. A fourth hypoechoic layer is most prominent and corresponds to the muscularis propria, whereas a fifth thin hyperechoic layer is the serosa.[19 25 27 28]

Gastric antrum Several studies suggest that the antrum is the gastric region that is most amenable to sonographic examination.[19 23 25 27–29] It is the gastric portion most consistently identified (98–100% of cases).[23 24 30] It is found superficially between the left lobe of the liver anteriorly and the pancreas posteriorly in a sagittal or para-sagittal scanning plane in the epigastrium.[22–25 27 28 31] Important vascular landmarks including both the aorta or inferior vena cava (IVC) and either the superior mesenteric artery or vein have been used to standardize a scanning plane through the antrum.[22–24 27 28] Not only is the antrum highly amenable to ultrasound imaging, its evaluation accurately reflects the content of the entire organ.

Gastric body The body of the stomach may be imaged by sliding the transducer towards the left subcostal margin using an oblique scanning plane.[19–21 23 25 26] In this plane, the

Table 2 Sonographic presentation of the antrum and contents

	Empty	Clear fluid	Milk or suspensions	Solid
Antral shape	Flat, collapsed, or round (bull's eye)	Round, distended	Round, distended	Round, distended
Antral wall	Thick, prominent muscularis propriae	Thin	Thin	Thin
Content	None (grade 0) or small amount of hypoechoic content (grade 1)	Hypoechoic	Hyperechoic	Hyperechoic Heterogeneous (mixed with air)
Peristalsis	None	Present (usually fast waves)	Present	Present (usually slow waves)

anterior wall is consistently identified, extending from the lesser to the greater curvature.[23] However, the presence of air in the body frequently obscures the posterior wall, and it may be more difficult to image a full cross-section of the gastric body.

Gastric fundus The fundus is located in the left upper quadrant of the abdomen, inferior to the diaphragm, anterior to the left kidney, and posterior to the spleen. It is the most challenging section of the stomach to image due to its deep location and the lack of a wide acoustic window due to the rib cage. Two different approaches have been described. A left lateral, intercostal, trans-splenic approach has been reported with limited success.[23 25] Alternatively, a longitudinal scan in the mid-axillary line has been used.[26] Air is commonly found in both the fundus and the body, even in 'empty' stomachs, which hinders visualization of these two sections.[19 23]

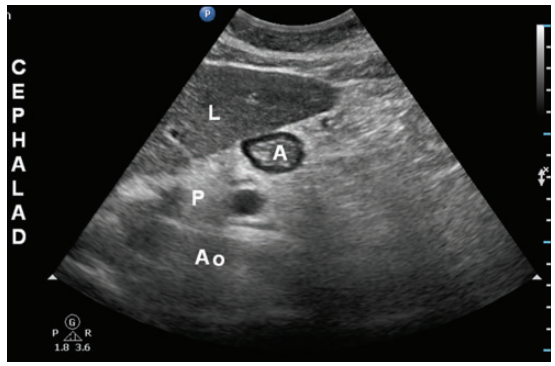

Fig 2 Sonographic image of the gastric antrum of an empty stomach. Note the antrum appears small, with no visible content. The muscularis propia is seen distinctly as a thick hypoechoic layer of the gastric wall. A, antrum; L, liver; P, pancreas; Ao, aorta.

Sonographic evaluation of gastric content

An early study of gastric ultrasound in the anaesthesia literature differentiated between liquid and solid gastric contents.[20] In this patient series, the stomach could only be identified in 60% of patients and could not be located when empty. However, more recent studies using contemporary technology report consistent success in identifying the stomach, especially the gastric antrum, even in the empty state.[23–25 27 30] In the empty stomach, the antrum appears flat with juxtaposed anterior and posterior walls (Fig. 2). In a sagittal plane, it is round to ovoid and has been compared with a 'target' or 'bull's eye' pattern (Table 2).[23 28] In an axial scanning plane, the empty antrum has a 'gloved finger' appearance.[25]

Baseline gastric secretions, water, apple juice, black coffee, and tea appear hypoechoic or anechoic.[23–24 28] With increasing volume, the antrum becomes round and distended, with thin walls (Fig. 3). Air or gas bubbles appear as multiple mobile punctuate echoes, giving the appearance of a 'starry night'.[23] Milk, thick fluids, or suspensions have increased echogenicity.[28] After a solid meal, a 'frosted-glass' pattern has been described caused by substantial amount of air mixed with the food bolus during the chewing and swallowing processes. The air/solid mixture creates multiple ring-down artifacts on the anterior gastric wall, which typically 'blur' the posterior wall of the antrum.[23 28] After some time, the air is displaced and the solid content can be better appreciated with a mixed echogenicity (Fig. 4, Table 2).[23 28] After oral intake of any type, peristaltic gastric contractions occur. They are noted easily on ultrasound and can be lumen occlusive or non-occlusive.[32]

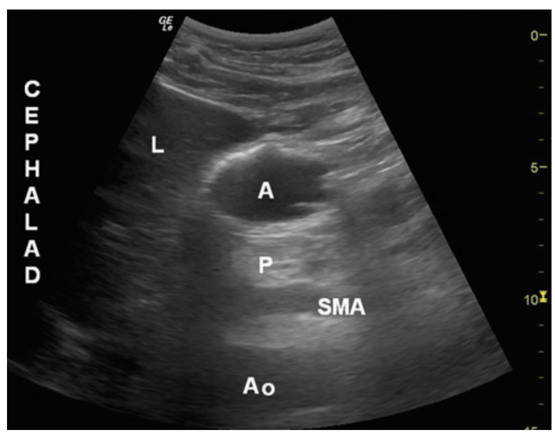

Fig 3 Sonographic image of the gastric antrum containing clear fluid. Note the antrum appears distended with hypoechoic/anechoic content. A, antrum; L, liver; P, Pancreas; Ao, Aorta; SMA, supeior mesenteric artery.

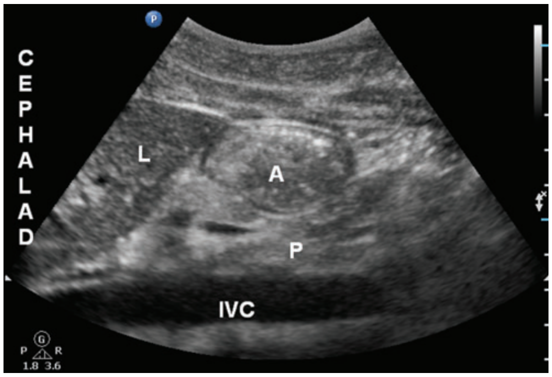

Fig 4 Sonographic image of the gastric antrum with solid content. A, antrum; L, liver; p, pancreas; IVC, inferior vena cava.

Quantitative gastric sonography: can ultrasound estimate the volume of gastric fluid?

Nine articles report a numerical correlation between an ultrasound-determined antral cross-sectional area (CSA) and the total volume of gastric fluid (Table 3). Antral CSA can be measured by using two perpendicular diameters and the formula of the area of an ellipse: CSA=(AP×CC×π)/4 (AP= antero-posterior diameter and CC=craniocaudal diameter) (Fig. 5A).[33] Alternatively, a 'free tracing' tool for area measurement has been used in some reports (Fig. 5B).[29 34] Regardless of the method used, all measurements need to be taken with the antrum at rest (between contractions) to avoid underestimating volume.[23 24 30 31 35] In most recent studies, antral CSA was measured including the full thickness of the gastric wall, from serosa to serosa.[23 24 30 31 34 36] Previously, the inner surface of the mucosa[37] or the muscularis propriae were used.[35]

Most authors report a linear correlation between antral CSA and gastric fluid volume with the Pearson correlation coefficients ranging between 0.6 and 0.91.[29–31 34–36] Three studies directly compare the strength of this correlation in different patient positions.[23 35 36] All three studies conclude that antral CSA measured in the RLD correlates most strongly with GV. This is conceivably explained by a greater proportion of gastric content moving preferentially from the fundus and body towards the more dependent antrum in the RLD. So, for any given GV, the antrum appears larger in the RLD *vs* other patient positions.

Four studies report mathematical models that allow prediction of total GV.[23 27 30 36] In a preliminary study, Perlas and colleagues[23] described a logarithmic predictive model based on 70 adult non-pregnant subjects randomized to ingest six different predetermined volumes of water. This preliminary model was as follows:

$$\text{GV (ml)} = -372.54 + 282.49 \times \log(\text{right-lat CSA}) - 1.68 \times \text{weight}$$

However, in a follow-up validation study using blinded gastroscopic suction as a reference standard in 108 adult subjects, this preliminary model was found to overestimate GV, especially at low-volume states. This may be due to the original study's inability to account for baseline gastric secretions. A new more accurate linear model was reported based on gastroscopic fluid assessment:[31]

$$\text{GV (ml)} = 27.0 + 14.6 \times \text{right-lat CSA} - 1.28 \times \text{age}$$

This newer model is mathematically robust (r=0.86), yet simple to apply clinically with age as the only patient characteristic co-variant (Table 4). It is accurate with a mean difference of 6 ml between the predicted and measured volumes. It is applicable to adult, non-pregnant subjects with BMI up to 40 kg m^{-2} and can predict volumes of up to 500 ml.

In a prospective observational study of 183 surgical patients, Bouvet and colleagues[30] presented an alternative model based on measurements of antral CSA in the semi-sitting position, using blind nasogastric aspiration as a reference standard, as follows:

$$\begin{aligned}\text{GV (ml)} = & -215 + 57 \log \text{CSA (mm}^2) - 0.78 \text{ age (yr)} \\ & - 0.16 \text{ height (cm)} - 0.25 \text{ weight (kg)} \\ & - 0.80 \text{ ASA} + 16 \text{ ml (in the case of emergency)} \\ & + 10 \text{ ml (in the case of preoperative ingestion of} \\ & 100 \text{ ml antacid prophylaxis)}\end{aligned}$$

With a correlation coefficient of 0.72, this model is applicable to the adult non-pregnant population and can predict volumes of up to 250 ml.

One final model has been reported by Schmitz and colleagues[36] who studied 16 children at various intervals after ingestion of 7 ml kg^{-1} of raspberry syrup using magnetic resonance imaging as the reference standard. The reported model is as follows:

$$\text{GV (ml kg}^{-1}) = 0.009 \times \text{antral CSA}_{\text{RLD}}(\text{mm}^2) - 1.36$$

This model has a correlation coefficient of 0.79. However, the limits of agreement between the predicted and measured volumes according to a Bland–Altman analysis were too wide for accurate clinical prediction (2.8 ml kg^{-1}). This is possibly due to the small number of subjects studied (n=16) and total readings used for model development (n=23). Furthermore, most readings were performed in empty (n=6) or near empty (n=14) conditions. The authors of this model indicated it is not accurate enough for clinical application.

In summary, two mathematical models are available to predict GV based on antral CSA in adults (Table 5).[30 31] They are currently thought to be accurate and clinically applicable. Regardless of which of these two models one decides to use, a number of steps need to be followed to ensure accurate results. First, the scanning technique needs to follow a similar scanning plane and patient position as described in the original source publication (i.e. a sagittal plane in the semi-sitting position for Bouvet and colleagues or RLD for Perlas and

Table 3 Quantitative studies. A, antrum; ACSA, antral cross-sectional area; CC, correlation coefficient; INT, interventional; NG, nasogastric; NR, not reported; OBS, observational; RLD, right lateral decubitus; SIT, sitting; SUP, supine; UGE, upper gastric endoscopy. Age and BMI are mean (SD)* or range†

Author	Year	Country	Design	Study population	*n*	Age (yr)	BMI	Patient position	Gastric section	Scanning plane	2D measure	Reference standard	Mathematical model	CC (*r*)
Fujigaki and colleagues[29]	1993	Japan	OBS	Adults	39	46 (3)*	NR	SIT	Distal	Sagittal	ACSA	NG suction	No	NR
Ricci and colleagues[37]	1993	Italy	INT blind	Volunteers	15	24–47†	NR	SUP/SIT	A	Transverse to the organ	ACSA	NG suction	No	NR
Hveem and colleagues[34]	1994	Norway	INT	Adults	35	16–90†	NR	Semi SIT	A	Sagittal	ACSA	Gastroscopy	No	0.91
Tomomasa and colleagues[35]	1996	Japan	INT	Newborns	32	≤1 m†	NR	RLD	A	Sagittal	ACSA	NG suction	No	0.83
Perlas and colleagues[23]	2009	Canada	INT	Volunteers	90	21–42†	21–26†	SUP/RLD	A	Parasagittal	ACSA	Ingested volume	Yes	0.82
Bouvet and colleagues[24]	2009	France	INT Blind	Volunteers	22	27–51†	21–24†	Semi SIT	A	NR	ACSA	Ingested volume	No	NR
Bouvet and colleagues[30]	2011	France	OBS	Adult surg patients	183	49 (18)*	23 (3)*	Semi SIT	A	Sagittal	ACSA	NG suction	Yes	0.72
Schmitz and colleagues[36]	2012	Switzerland	INT	Paediatric volunteers	16	6–13†	NR	SUP/RLD Semi SIT	A	Sagittal	ACSA	MRI	Yes	0.79
Perlas and colleagues[31]	2013	Canada	INT blind	Patients for UGE	110	51 (14)*	25 (5)*	RLD	A	Sagittal	ACSA	Gastroscopy	Yes	0.86

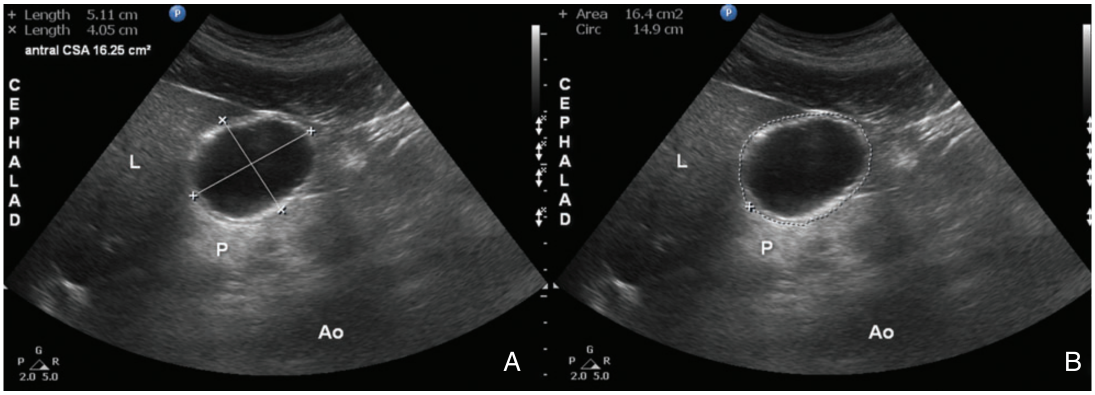

Fig 5 Two alternate methods to measure antral CSA. (A) illustrates a method based on two perpendicular diameters (cranio-caudal and antero-posterior). (B) illustrates a free-tracing method following the outer border of the antrum at the level of the gastric serosa.

Table 4 Predicted GV (ml) based on measured gastric antral CSA (cm^2), stratified by patient age. Adapted and reproduced with permission from Perlas *et al.*[31]

Right lat CSA (cm^2)	Age (yr)						
	20	30	40	50	60	70	80
3	45	32	20	7	0	0	0
5	74	62	49	36	23	10	0
7	103	91	78	65	52	40	27
9	133	120	107	94	82	69	56
11	162	149	136	123	111	98	85
13	191	178	165	153	140	127	114
15	220	207	194	182	169	156	143
17	249	236	224	211	198	185	173
19	278	266	253	240	227	214	202
21	307	295	282	269	256	244	231
23	337	324	311	298	285	273	260
25	366	353	340	327	315	302	289
27	395	382	369	357	344	331	318
29	424	411	398	386	373	360	347

Table 5 Current models for GV assessment based on antral CSA. CSA, cross-sectional area; GV, gastric volume

	Bouvet and colleagues[30]	Perlas and colleagues[31]
Formula	GV (ml) = −215 + 57 log CSA (mm^2) − 0.78 age (yr) − 0.16 height (cm) − 0.25 weight (kg) − 0.80 ASA + 16 ml (emergency) + 10 ml (if antacid prophylaxis 100 ml)	GV (ml) = 27.0 + 14.6 × right-lateral CSA (cm^2) − 1.28 × age (yr)
Scanning plane	Sagittal	Sagittal
Scanning position	Semi-sitting	Right lateral decubitus
Antral CSA measurement	Serosa to serosa	Serosa to serosa
Patient characteristics	Non-pregnant adults	Non-pregnant adults
Age (yr)	18–95	18–85
BMI (kg cm^{-2})	14–31	19–40
Max. predicted volume (ml)	250	500
Correlation coefficient (*r*)	0.72	0.86
Reference standard	Nasogastric suction	Gastroscopy

colleagues). Secondly, measurements need to be taken with the antrum at rest, between peristaltic contractions. Thirdly, CSA is measured from serosa to serosa, including the full thickness of the gastric wall. Finally, each model is only applicable within the patient characteristic range in which it was built (adult, non-pregnant subjects) and within the ranges of volumes studied in the source publication (Table 5).

A semi-quantitative three-point grading system has been reported as a simple screening tool to differentiate low- from high-volume states.[27] This three-point grading system is based solely on qualitative evaluation of the clear-fluid-containing gastric antrum that is scanned in both the supine and RLD positions. A grade 0 antrum appears empty in both positions, and suggests no gastric content is present. A grade 1 antrum appears empty in the supine position, but clear fluid is visible in the RLD, consistent with a small volume of gastric fluid. A subsequent validation study suggests that subjects with a grade 1 antrum have $<$100 ml of gastric fluid in 75% of cases.[31] A grade 2 antrum is that in which clear fluid is evident in both patient positions consistent with a higher volume state. Subjects with a grade 2 antrum have over 100 ml of gastric fluid in 75% of cases.

Discussion

Until recently, there were no readily available tools to assess gastric content in the acute setting. Paracetamol absorption, electrical impedance tomography, radiolabelled diet, polyethylene glycol dilution, and gastric content aspiration are invasive methods to study GV or gastric emptying and are not applicable in the perioperative period.[38–42]

Gastric ultrasonography has been used by gastroenterologists for over two decades to assess gastric motility and emptying[43–46] or to diagnose gastric wall lesions such as cancer.[47–49] Sequential ultrasound measurements of antral CSA at fixed time intervals after a standardized solid–liquid meal have been reported.[33] This approach has been used by gastroenterologists to study gastric emptying time and motility[37 50 51] and has been shown to correlate closely to scintigraphy, a more invasive gold standard using radioactive material.[52]

However, it was only recently that bedside ultrasound has been used to evaluate gastric content and volume to assess perioperative aspiration risk and guide anaesthetic management.

As a new diagnostic tool, gastric sonography needs to be characterized in terms of its *validity* (does it assess what it intends to assess, and how accurately), *reliability* (how reproducible are the results), and *interpretability* (i.e. what are the clinical implications of specific findings). Most studies to date deal with validity considerations and suggest that bedside ultrasound accurately determines GV.[30 31 34] Even though several descriptions of the type of content (i.e. empty, clear fluid, solid) have been published,[19 23 26 28] the sensitivity and specificity of a qualitative exam (how well can we differentiate between different types of content) remain to be studied in a systematic manner.

One single study on 15 subjects scanned by two independent sonographers suggests that antral assessment is highly reproducible.[37] The range of differences between the two observers was 1–13 ml when empty and 2–85 ml after a standardized meal. More rigorous studies after current recommended guidelines for assessing reliability need to be done.[53]

As data on the validity (i.e. accuracy) and reliability (i.e. reproducibility) of gastric sonography become increasingly available, the next important question is how to best incorporate this new diagnostic tool into daily clinical practice to assess aspiration risk and tailor anaesthetic management in appropriate cases.[54 55] We envision this tool to be useful in many clinical situations in which aspiration risk is unclear or undetermined. Three common clinical scenarios are as follows: first, patients who have not followed fasting guidelines, either because of a communication gap or due to the urgent nature of the clinical situation. Secondly, patients with delayed gastric emptying due to significant comorbidities in whom recommended fasting intervals may not reliably ensure an empty stomach (e.g. diabetic gastroparesis, advanced liver or renal dysfunction, critically ill patients). Finally, patients with unreliable or unclear history (e.g. language barrier, cognitive dysfunction, altered sensorium). In the absence of data, it is safer to assume a ‘full stomach’, leading to either surgical cancellations or re-scheduling in elective cases or in interventions to prevent aspiration, such as a rapid sequence induction and tracheal intubation. However, gastric ultrasound can help clinicians individualize aspiration risk at the bedside and more appropriately guide anaesthetic management (Fig. 6).

An empty stomach implies a low aspiration risk and can be determined solely on qualitative assessment. Solid, particulate, or thick fluid content, carrying a high aspiration risk, can also be detected based on sonographic appearance as previously discussed.[56–58]

In the presence of clear fluid, a sonographic volume assessment can determine if the volume present is consistent with baseline gastric secretions and negligible risk (up to 1.5 ml kg^{-1}) or if it is a higher volume posing a significant aspiration risk requiring intervention.[9–13 59–61]

Several areas require further investigation including defining the minimum training requirements to ensure accurate assessments. In addition, most of the current published data pertains to adult individuals. Volume assessment models in particular have only been validated for adult non-pregnant patients and further work is required in the paediatric and obstetric patient populations. In addition, 3D and 4D ultrasonography are newer imaging modalities that may have a future role in ultrasound gastric assessment.[62]

Authors’ contributions

P.V.P. performed literature searches, selected citations and articles for eligibility, performed data extraction, summarized the results on tables, prepared Figures 1, 5, and 6, prepared the first draft of the manuscript, and read and approved the final manuscript; A.P. conceived the study, performed literature searches, selected citations and articles for eligibility, performed

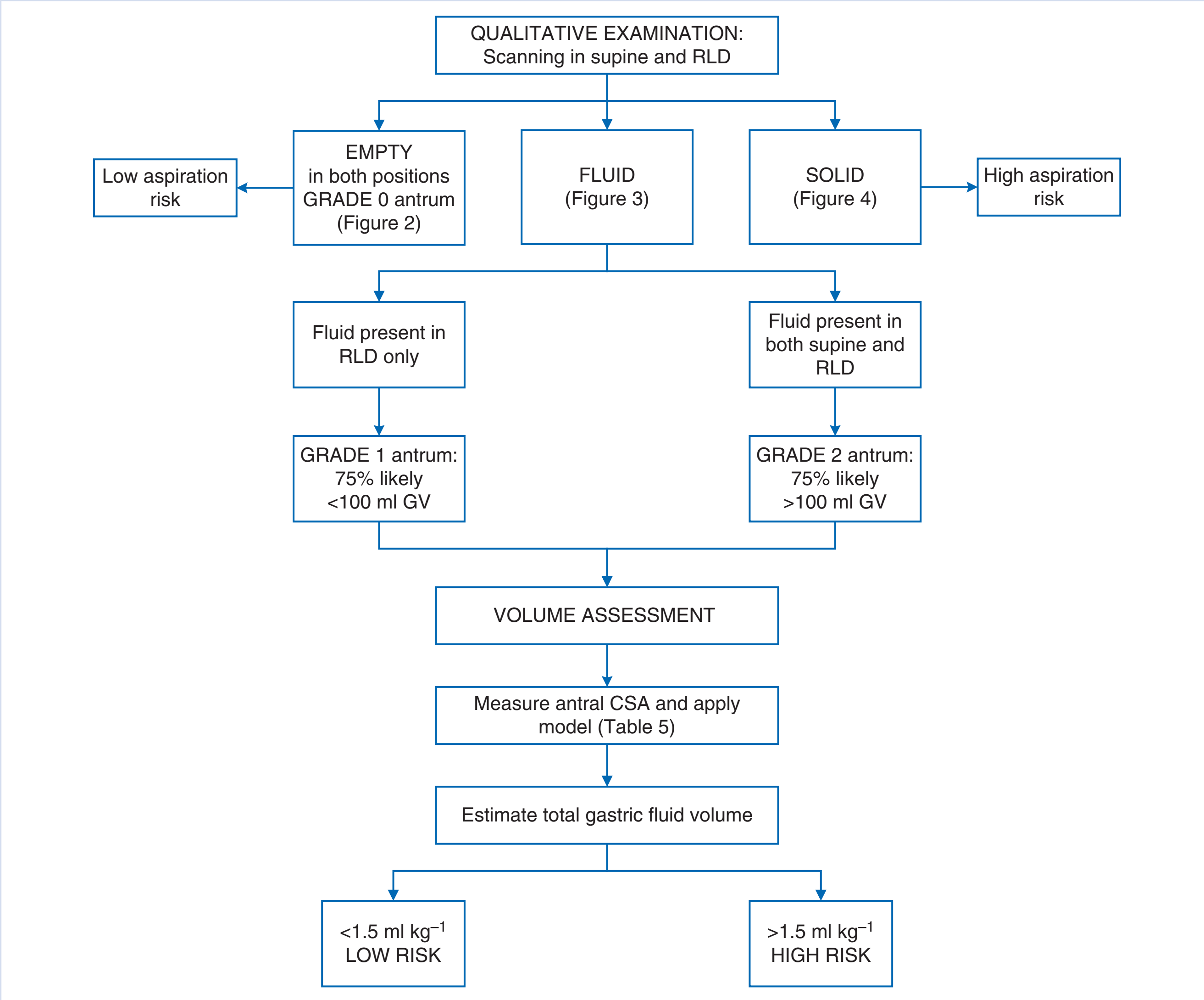

Fig 6 Suggested clinical algorithm for gastric ultrasound and aspiration risk assessment. CSA, cross-sectional area; GV: gastric volume; RLD, right lateral decubitus.

data extraction, edited the manuscript and tables, prepared Figures 2–4, and read and approved the final manuscript.

Declaration of interest

None declared.

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