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REVIEW

Ultrasound to assess gastric content and fluid volume: new kid on the block for aspiration risk assessment in critically ill patients?

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Abstract

Introduction: Aspiration is associated with significant morbidity and mortality. Fasting guidelines do not apply to critically ill and emergency patients. Gastric point-of-care ultrasound (PoCUS) is a promising approach to assess aspiration risk. This review discusses its feasibility, clinical implications, limitations and future perspectives.

Methods: This is a narrative review. A search in PubMed and EMBASE to find relevant articles was performed.

Results: Gastric PoCUS provides both qualitative and quantitative information about gastric content and fluid volume. Based on qualitative findings, the antrum is empty or contains fluids or solids. Based on quantitative findings, a fluid volume of up to 500 ml is accurately measured. Gastric PoCUS is feasible in over 90% of subjects. An algorithm for clinical application is presented.

Conclusion: Gastric PoCUS is a promising tool to assess gastric content and fluid volume in critical care and emergency patients. Further research on whether the information obtained improves patient outcome is needed.

Introduction

Pulmonary aspiration of gastric content is a rare but potentially serious complication of airway management in critically ill patients. It is associated with significant morbidity, including prolonged mechanical ventilation, increased length of intensive care unit (ICU) stay and increased mortality.[1,2] Patients undergoing general anaesthesia are also at increased risk of aspiration.[3,4] In a national audit of all anaesthesia-related deaths in the setting of airway management in the United Kingdom, pulmonary aspiration was the single commonest cause of death and accounted for 50% of all cases.[5] Pulmonary aspiration was associated with inadequate assessment of aspiration risk and failure to alter anaesthetic technique when aspiration risk was present. The main risk factor for aspiration is the presence of gastric content. ICU patients are at risk because of delayed gastric emptying due to multi-organ dysfunction, surgical interventions, use of opioids, disease processes of the bowel and systemic diseases such as diabetes or chronic renal impairment.[5-7] Furthermore, sedation and general anaesthesia reduce the physiological tone of the lower oesophageal sphincter and upper airway protective reflexes increasing the risk of aspiration.[5] This has led to the development of fasting guidelines, which only apply to healthy individuals and are unreliable in patients undergoing emergency surgery or critically ill patients with delayed gastric emptying.[8] Hence, in any clinical situation where the risk of aspiration is uncertain, assessing the nature of gastric content and estimating total gastric fluid volume before intubation by using a simple, reliable, noninvasive bedside test is of great importance.

Currently, several techniques, such as scintigraphy, gastric impedance monitoring and paracetamol absorption tests are available for assessing gastric emptying. However, these methods are time consuming, invasive and lack standardisation.[9] Over the past decade there has been growing interest in bedside ultrasound to assess stomach content and fluid volume to inform aspiration risk. Most of the research has focused on gastric PoCUS in a perioperative anaesthetic setting, but it is also very relevant in critical care patients.[6,8]

This narrative review is part of a Netherlands Journal of Critical Care series on ultrasound beyond the heart and lungs.[10-12] Ultrasound assessment of gastric content and total fluid volume and its clinical implications are addressed. In addition, evidence on feasibility and reproducibility will be discussed and limitations will be listed.

Methods

This is a narrative review. A thorough literature search in PubMed and EMBASE was conducted to find relevant articles from inception to 16 March 2018. Two independent researchers (SSLM and NT) evaluated all abstracts and selected a sub-set of articles for full text-review. The MeSH terms "diagnostic imaging" or "ultrasonography" or "ultrasound" and "gastric emptying" or "stomach" or "gastroesophageal reflux" and "pneumonia", aspiration" or "respiratory aspiration of gastric content" were used. Animal studies or those conducted on paediatric patients (younger than 18 years) were excluded.

Results

Image acquisition

The exam is best performed with a curvilinear, low frequency (2-5 MHz) probe and the ultrasound machine in standard abdominal setting. The sagittal plane is used between the xiphoid and the umbilicus with the patient lying in the supine *(figure 1)* and the right lateral decubitus position. In general, the gastric antrum is the most accessible part of the stomach due to its superficial location in the epigastrium and the left side of the liver providing an amenable acoustic window. This is in contrast to the gastric body and the deeply located gastric fundus.[3,13]

Figure 1. Gastric PoCUS in the supine position using a curved array low-frequency abdominal probe (2-5MHz)

Swiping the transducer from the left to right subcostal margins and gently tilting and rotating the probe makes the antrum appear as a hollow viscus identified by important landmarks, including the left lobe of the liver, body of the pancreas, abdominal aorta, inferior vena cava and both the superior mesenteric artery and vein *(figure 2)*. It is important to see the liver, aorta or inferior vena cava and antrum in the same ultrasound image in a sagittal epigastric section. In this way you are sure to image the antrum. The antrum is first scanned in the supine and then the right lateral decubitus position because the stomach's contents flow towards the more dependent areas of the distal antrum. This increases the accuracy to assess gastric content in

Figure 2. Gastric PoCUS of the antrum and important landmarks optained in the sagittal plane. A=antrum; Ao=aorta; L=liver; P=pancreas;

low-volume states.[3,13] The antrum reflects the contents of the entire stomach. However, an examination that is limited to the supine position only can grossly underestimate the amount of gastric content and therefore the risk of aspiration. In critically ill or traumatic brain injury patients in whom the examination in the right lateral decubitus position is not feasible, a semi-recumbent position (with the head elevated in 45 degrees) may be an acceptable alternative.[3,6] Of note, in the sagittal plane the gastric wall appears 4-6 mm thick and consists of five distinctive echogenic layers. From the inner to the outer surface, the five layers are as follows: a) hyperechoic mucosal-air interface, b) hypoechoic muscularis mucosae, c) hyperechoic submucosa, d) hypoechoic muscularis propria, and e) hyperechoic serosa-surrounding tissue interface.[3,13] These layers help differentiate the stomach from other hollow viscus.

Image interpretation and results

Qualitative assessment of gastric content: empty, clear fluid or thick fluid/solid contents?

Determining the nature of gastric content is a key aspect in predicting aspiration risk. If the stomach is empty, the antrum appears small and may be either round or ovoid resembling a bull`s eye target pattern due to the absence of content, or flat with the anterior and posterior walls of the antrum juxtaposed. When clear fluid is present, the antrum increases in volume and becomes round and distended with hypoechoic or anechoic content *(figure 3)*. Gastric secretions, water, apple juice, tea and coffee appear hypoechoic or anechoic. Milk, thick fluids or suspensions have increased echogenicity.[3] The mixture of air bubbles or gas suspended in a background of clear fluid gives the antrum the aspect of a 'starry night'. These gas bubbles disappear rapidly within minutes of ingestion. Following a solid meal, the air mixes with the solid food during the chewing and swallowing processes. The relative amount of air, solids and liquid ingested in a larger meal will give the appearance of heterogeneous content with large particles or a 'frosted-glass' pattern on ultrasound imaging.[14,15]

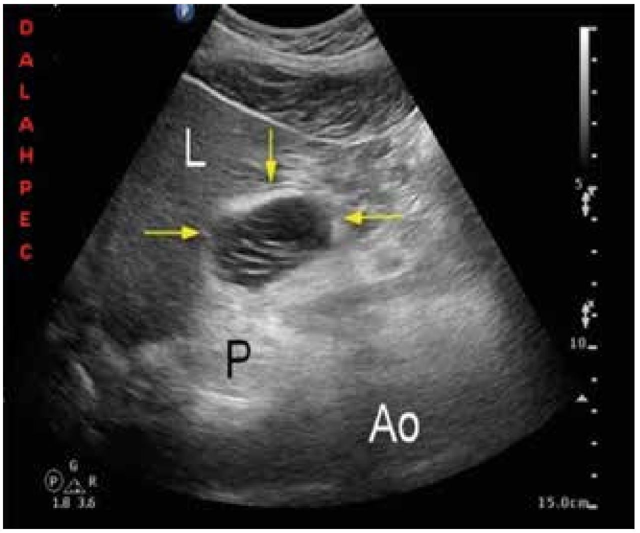

Figure 3. Gastric PoCUS of the antrum with clear fluid, shown between the yellow arrows. Ao=aorta; L=liver; P=pancreas;

Quantitative assessment of gastric fluid volume

To assess gastric fluid volume, first the cross-sectional area (CSA) of the antrum is measured by one of the following methods:

1) The two-diameter method, which calculates the CSA by measuring two perpendicular diameters of the antrum from serosa to serosa, assuming that the antrum has an elliptical shape and using a standard formula of the surface area of an ellipse.[16]
   Formula:

   $$CSA = (AP \times CC \times \pi)/4$$

   where AP represents the anteroposterior antral diameter, CC represents the craniocaudal antral diameter.
2) The free-tracing method, which is applied by using the free-tracing calliper of the ultrasound machine to measure the antral CSA. It is a simpler method that relies on a single dimensional measurement and does not require a formula. It has been shown to be accurate and to provide similar results to the two-diameter method.[16]

Essentially, both methods are equal, e.g. for a volume of 300 ml in the stomach, the difference between the two methods is not greater than 25 ml. Furthermore, all measurements need to be taken between peristaltic contractions to avoid underestimating gastric fluid volume and the full thickness of the gastric wall, thus serosa to serosa, must be included.[16] Lastly, when used for research purposes it is advised to measure the antral CSA three times and calculate the mean of these measurements for gastric fluid volume calculation.

A semi-quantitative three-point grading system is an easier method to differentiate low from high volume states *(table 1)*. Perlas et al. developed this three point grading system based on qualitative evaluation of the gastric antrum that is scanned in the supine and the right lateral decubitus position.[4] This grading system can be thought of as a 'screening' step as increasing grades correlate with higher gastric volume.[3,4] A grade 0 antrum is defined as one that appears empty in both the supine and right lateral decubitus position and suggests no gastric content. A grade 1 antrum appears empty in the supine position but clear fluid (anechoic content) is present in the right lateral decubitus position. The vast majority (95-98%) of healthy fasted adults presenting for elective surgery with a low aspiration risk have a grade 0 or 1 antrum.[4] These two grades correlate with low, negligible volumes of gastric secretions and suggest a low aspiration risk. On the other hand, a grade 2 antrum is defined as that in which clear fluid is present in both the supine and right lateral decubitus position. Neither a grade 2 antrum, nor solid content are common in fasting healthy subjects (<5%) and suggest a higher-than-baseline risk.

Table 1. Sonographic imaging of the antrum and content[3]

	Grade 0	Grade 1	Grade 2
Antral shape	Small, collapsed or round (bull's eye or target pattern)	Round, distended	Round, distended
Antral wall	Thick	Thin	Thin
Content	Empty	Clear fluid in the right lateral decubitus position only	Clear fluid in both supine and right lateral decubitus position

After the antral CSA is measured as described above, the gastric fluid volume can be calculated by using one of the two available mathematical models. Both models were validated in non-pregnant adults and are contrasted in *table 2*. Both models are conceptually similar in that they show a linear correlation between a cross-sectional area of the gastric antrum and the total gastric fluid volume. They are also similar in that the antral area was measured scanning in a sagittal plane in the epigastric area, between peristaltic contractions and including the full thickness of the antral wall (from serosa to serosa). However, there were significant differences in the original patient sample used, the details of the scanning technique and the gold standard method that should be considered when deciding on the external validity and clinical application of each model.[17,18] In addition, Bouvet's model was derived with antral areas obtained in the semi-sitting position and is accurate for volumes up to 250 ml, while Perlas's model was derived from measurements in the right lateral decubitus position and is accurate for volumes up to 500 ml. The volume model derived in the right lateral decubitus position had a higher correlation coefficient of 0.86, p<0.001, compared with that derived in the semi-sitting position *(tables*

2 and 3). Multiple studies have suggested that measuring antral CSA in the right lateral decubitus position had the strongest correlation with gastric fluid volume.[19-21]

Table 2. Current models for gastric volume assessment

Author	Perlas et al.(18)	Bouvet et al.(22)
Model	GV(ml)= 27.0+14.6 x right lateral CSA (cm^2) – 1.28 x age (years)	GV(ml)= -215+57 log CSA (mm2) – 0.78 age (years) – 0.16 height (cm) – 0.25 weight (kg) – 0.80 ASA + 16 ml (emergency) + 10 mL (if antacid prophylaxis 100 ml)
Scanning plane	Sagittal	Sagittal
Patient position	Right lateral decubitus	Semi-sitting
Patient population	Non-pregnant adults (both obese and non-obese)	Non-pregnant adults with a BMI <31 kg/ m^2
Correlation coefficient	0.86	0.72
Minimum threshold of gastric volume increasing aspiration risk	>1.5 ml/ kg^{-1}	>0.8 ml/ kg^{-1}
Maximum predicted volume (ml)	0-500	0-250
Reference standard	Gastroscopy	Nasogastric suctioning

GV=gastric volume, ASA=America Society of Anesthesiologists Physical Status Classification

Accuracy of gastric PoCUS to assess gastric fluid volume

In 180 preoperative elective and emergency surgery patients, Bouvet`s mathematical model measured gastric fluid volume in the semi-sitting position and was compared with blind nasogastric aspiration as reference standard.[22] They were able to determine an at-risk stomach with an area under the curve of 0.90 (95% CI, p = 0.0001). Perlas`s mathematical model was developed in 108 patients undergoing upper gastrointestinal endoscopy. A mean difference or 'bias' of only 6 ml of gastric volume between the predicted and measured volumes was found.[18] This model was further validated in a sample of severely obese subjects (BMI >40 kg/ m^2).[17] Although there are valid methods to measure fluid volume, there is uncertainty when it comes to differentiating a low risk versus a high risk stomach depending on the cut-off values. The two authors use different conceptual frameworks in the interpretation of the findings. Previous animal experiments conducted in rhesus monkeys concluded that >0.8 ml/ kg of acid (equivalent to 50 ml in an average human adult) directly instilled into the tracheas of rhesus monkeys were more likely to result in lung injury than smaller volumes.[22-25] Based on these animal studies Bouvet suggests that any volume >0.8 ml/ kg (or an antral CSA >340 mm^2 in non-pregnant and 380 mm^2 in pregnant subjects) should be considered a marker of 'at-risk stomach.'[22,23] On the other hand, for similar volumes of fluid in the stomach to pose a risk of aspiration, the stomach would have to empty completely and all its contents enter the trachea. Not only is this an unlikely scenario but extrapolating these values to volumes of gastric content does not seem to be supported by contemporary human data which suggests that volumes of up to about 1.5 ml/ kg (approximately 100-110 ml in the average adult) are normal and common in healthy fasted individuals with a low risk of aspiration.[22,23,25] Based on these contemporary human data, Perlas suggests using a threshold of 1.5 ml/ kg (or antral CSA of 9-10 cm^2) to differentiate a low-volume state compatible with baseline gastric secretions from a higher-than-baseline volume and risk.[18,23] In summary, it can be concluded that gastric PoCUS can accurately predict gastric volume, but a threshold of volume that increases aspiration risk is still controversial and a matter of debate *(table 2)*[23-25].

An algorithm for clinical application of gastric PoCUS and aspiration risk assessment is presented in *figure 4*.

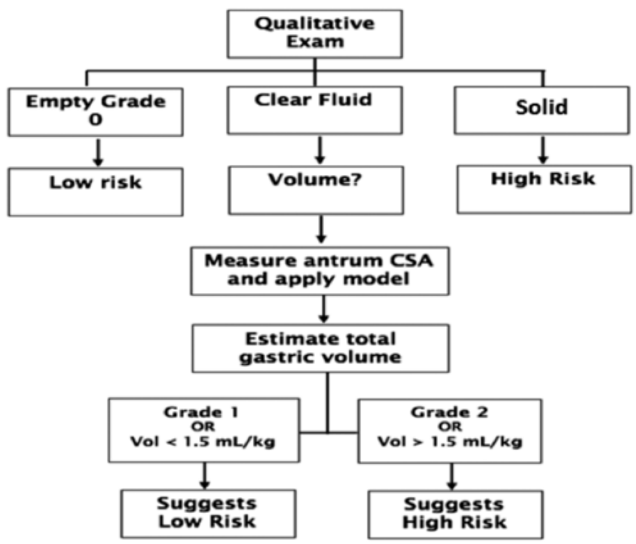

Figure 4. Suggested clinical algorithm for gastric PoCUS and aspiration risk assessment. Modified from www.gastricultrasound.org with permission

Morbidly obese patients

Two studies, including a total of 98 patients, were conducted in severely obese patients.[17,26] In a prospective cohort study, the antrum was graded in 53 out of 60 fasted severely obese surgical patients (88.3%, 95 CI, 0.77-0.95). Twenty-one patients (39.6%) presented a grade 0 antrum, 29 patients (54.7%) presented a grade 1 antrum and 3 patients (5.7%) presented a grade 2 antrum. Furthermore, increasing antral grade was significantly associated with larger CSA in the right lateral decubitus position and higher predicted gastric fluid volume (p<0.0001). Comparing these results with data from non-obese patients, the authors concluded that severely obese patients presented with larger CSA and larger baseline volumes but there was no difference between groups in ml/kg (p<0.0001).[26] In 38 severely obese patients, the gastric fluid volume calculated based on measurements of the antral CSA after fluid ingestion strongly correlated with the measured gastric fluid volumes by endoscopic suctioning. These gastric fluid volumes were calculated by using Perlas`s mathematical model and showed to be quite accurate, with a concordance correlation coefficient of 0.82 and Pearson`s correlation coefficient of 0.86, respectively. A mean difference of 35 ml was found between the calculated and suctioned gastric fluid volumes.[17] In summary, both studies demonstrated that obese patients presented with significantly larger antral CSAs at baseline corresponding to higher gastric fluid volumes in fasted states. Nevertheless, the fasting gastric fluid volume per unit body weight remained within the range of physiological gastric secretions (≤1.5ml/ kg $^{-1}$).[17,26]

Obstetric patients

Three studies, including a total of 193 patients, were conducted in pregnant women.[27-29] A prospective cohort study analysing 73 labouring pregnant women showed that a grade 0 antrum with the parturient in the supine position significantly correlated with an antral CSA cut-off value <381 mm^2 with a sensitivity of 81%, specificity of 76%, negative predictive value of 80%, positive predictive value of 76% and area under the curve 0.85. Thirty-four patients (46.6%) had antral CSA <381 mm^2 and 23 (67%) of these 34 patients had a fasting duration for solids of more than 8 hours, whereas 25 patients out of 35 (71%) with an antral CSA >381 mm2 had a fasting duration for solids less than 8 hours (p=0.002). However, no statistically significant relationship was found between clear liquid fasting and antral status.[27] Another prospective cohort study conducted in 60 labouring pregnant women, was able to measure an antral CSA >320 mm^2 in 29 out of 58 parturients (50%) at epidural insertion and in 7 out of 52 patients (13%) at full cervical dilatation in the supine position after a median duration of fasting of 6 hours for liquids and 14 hours for solids. The median CSA at epidural insertion was 319 mm2 and decreased to 203 mm^2 at full cervical dilatation meaning that gastric motility persisted during labour and only 13% of the parturients presented significant gastric content at the end of the first stage of labour, before delivery.[28] Furthermore, in non-labouring third trimester pregnant women the measured antral CSA in the right lateral decubitus position significantly correlated with the ingested volume with a Spearman rank correlation of 0.7; p<0.0001. A predictive mathematical model (volume(ml) = -327.1 + 215.2 x log (CSA in cm^2) to estimate gastric volume in pregnant women was developed and showed that a cut-off value of 9.6 cm^2 in the right lateral decubitus position correlated with ingested volumes ≥1.5ml/ kg^{-1} with a sensitivity of 80%, specificity of 66.7% and an area under the curve of 0.82.[29]

Preoperative gastric PoCUS to guide anaesthetic management

Fasting guidelines apply to healthy individuals for elective surgery but can fall short in emergency situations or patients with comorbidities that affect gastric emptying. This was shown in a retrospective cohort study on baseline gastric content in 538 fasted elective surgical patients, where gastric PoCUS detected a full stomach in 32 patients (6.2%). Nine of these patients (1.7%) had solid gastric content and 23 (4.5%) had a volume of clear fluid >1.5 ml/ kg^{-1}. Three of these 9 patients had risk factors for delayed gastric emptying.[8] In two studies in elective surgical patients who had been non-compliant to fasting guidelines, gastric PoCUS changed aspiration risk assessment and anaesthetic management in 27 out of 38 (70%) and 24 out of 37 (65%), respectively.[30,31]

Critically ill patients

Two studies were performed in critically ill patients.[6,32] In 55 critically ill patients ultrasonographic measurement of the antral CSA was compared with computed tomography as reference standard. Gastric PoCUS was able to diagnose an at-risk stomach, defined as a gastric fluid volume >0.8 ml/ kg, with an area under the curve of 0.799. This correlated with a cut-off value of 360 mm^2 with a sensitivity of 76% and a specificity of 78%.[6] Another small study in 19 enterally fed critically ill patients found that the antral CSA using the inferior vena cava or aorta as a landmark correlated with aspirated gastric residual volume, R^2 =0.92 and R^2 =0.86 (p<0.0001 for both), respectively.[32]

Gastric PoCUS as a versatile tool

Next to the fact that gastric PoCUS can accurately predict aspiration risk in different patient populations, it is also a versatile tool. Recent reports suggest that ultrasonography provides good diagnostic accuracy estimates in confirming appropriate nasogastric tube placement (NGT) in critically ill patients.[33,34] In 92.8% of 56 mechanically ventilated ICU patients they were able to visualise passage of the NGT through the oesophagus with real time ultrasonography.[33] Gastric PoCUS verified NGT insertion in patients with low consciousness in an emergency medical centre with a positive predictive value of 97.4% and negative predictive value of 25%.[34] However, a recent Cochrane analysis of 10 studies with 545 participants concluded that due to limited evidence gastric PoCUS does not have sufficient accuracy as a single test to confirm NGT insertion.[35] Further research needs to be conducted in larger groups of patients. Furthermore, one study showed that bedside ultrasound can measure gastric residual volume and guide enteral nutrition in neurosurgical patients.[36]

Is gastric ultrasound feasible, reproducible and easy to learn?

In healthy volunteers, feasibility of ultrasound imaging of the antrum was 100%.[14,15,37,38] In different patient populations, such as critically ill patients, severely obese subjects, parturients or patients undergoing emergency surgery, the gastric antrum was identified in 90-100%, although the number of studies and patients is limited *(table 3)*[3].

Table 3. Studies conducted on feasibility and/or accuracy in different patient populations
SP = supine position; RLD = right lateral decubitus position; NA = not applicable; CSA = cross-sectional area; BMI = body mass index; ICU = intensive care unit; CC = correlation coefficient; IVC = inferior vena cava

Author	Year	Study design	Study population	Patient position	Reference standard	Mathematical model	Antral CSA: at-risk stomach	Accuracy	Feasibility (%)
Perlas et al.(19)	2009	Phase 1: qualitative assessment Phase II: development of quantitative model	Phase 1: healthy volunteers (n=18) Phase II: healthy volunteers (n=36)	SP and RLD	Ingested volume	Perlas	24 cm^2	0.82 CC	100
Cubillos et al.(14)	2012	Observational study	Healthy volunteers (n=6)	RLD	NA	---	---	---	100
Kruisselbrink et al. (38)	2018	Prospective randomised study	Healthy volunteers (n=40)	RLD	NA	Perlas	---	100% sensitivity/ 97.5 specificity	100
Perlas et al. (18)	2013	Blind interventional study	Patients undergoing upper gastrointestinal endoscopy (n=108)	RLD	Gastroscopy	Perlas	---	0.86 CC	---
Van de Putte et al. (26)	2014	Prospective cohort study	Severely obese patients (n=60) (BMI range 35-69 kg/m^2)	SP and RLD	Historical data	Perlas	12.1 cm^2 (RLD)	---	90% in SP/ 95% in RLD position
Kruisselbrink et al. (17)	2017	Blind experimental study	Severely obese patients (n=38) (BMI >35kg/ m^2)	SP and RLD	Endoscopic suctioning	Perlas	14 cm^2	0.82 CC	95
Bataille et al. (28)	2014	Prospective cohort study	Labouring pregnant women	SP	NA	---	---	---	96%
Arzola et al.(29)	2018	Randomised controlled trial	Non-labouring third trimester pregnant women (n=60)	SP and RLD	Ingested volume	Volume(ml) = -327.1 + 215.2 x log (CSA in cm^2)	9.6 cm^2	0.7 CC	95
Bouvet et al. (22)	2011	Observational study	Elective or emergency surgery patients (n=180)	SP	Nasogastric suctioning	Bouvet	3.4 cm^2	0.72 CC	98
Hamada et al. (6)	2014	Prospective cross-sectional study	ICU patients (n=55)	SP	CT-abdomen	Perlas	3.6 cm^2	76% sensitivity/ 78% specificity	95
Sharma et al.(32)	2017	Prospective cohort study	ICU patients (n=19)	SP	Aspirated volume	---	---	R^2 0.92 (IVC landmark) R^2 0.86 (aorta landmark)	---

Two studies investigated the reproducibility of the use of gastric PoCUS.[6,16] Repeatability (within observer) and reproducibility (between observers) on ultrasound measurements in healthy volunteers showed an overall interrater reliability with an intraclass correlation coefficient (ICC) of 0.96 and intrarater reliability with an ICC range of 0.96-0.99 among three sonographers. The median absolute difference from measured mean values was 9.5 ml. This value is acceptable within the margins of error, given that fasted individuals have a baseline gastric fluid volume of up to approximately 1.5 ml/ kg, e.g. approximately 100 ml for the average adult.[16] Another study also showed a good reproducibility between observers of ultrasound antral CSA measurements in critically ill patients with an ICC of 0.97, CI 95% 0.96-0.99.[6]

One study evaluated the learning curves of gastric PoCUS.[39] They concluded that an average of 24 and 33 consecutive measurements are required to achieve competence with an accuracy rate of 90% and 95%, respectively. However, the physicians who performed the ultrasound examination were all anaesthesiologists with previous experience in ultrasound for other non-gastric diagnostic and interventional applications. This could have influenced the learning curve.[39]

In summary, the available data suggest that the feasibility, reproducibility and the learning curve of gastric PoCUS are excellent, but evidence is still limited.

Limitations

Although gastric PoCUS offers many advantages and can potentially prevent devastating complications, it has some limitations. For instance, as for every PoCUS exam, there is the chance of variability between observers. Modest tilting of the probe is sometimes necessary for optimal imaging but can result in oblique images of the antrum causing an overestimation of the antral CSA and thereby gastric fluid volume. This can create a false image of an at-risk stomach. However, closely following a standardised scanning technique as previously described and a rigorous method of measurement can minimise inter-observer variability and increase accuracy and reliability.[18]

While most studies used a gastric fluid volume of >1.5 ml/ kg or 100 ml in the average adult as indicative of an 'at-risk' stomach, this threshold remains controversial and is a matter of debate and further research.[23]

Also, all studies to date have excluded patients with pre-existing abnormal anatomy of the upper gastrointestinal tract, e.g. hiatus hernia, previous oesophageal or gastric surgery, meaning that there are no data on predicting aspiration risk for these groups of patients when using gastric PoCUS.

In addition, there is no perfect gold standard to compare the ultrasound measurements with. Some studies compared ultrasound measurements with either CT abdomen, gastric suctioning or upper gastrointestinal endoscopy.[6, 18, 22] However, under direct visualisation with endoscopy most of the gastric contents can be suctioned and compared with the measured gastric fluid volume. Therefore, endoscopy can be considered a gold standard.

Furthermore, it is important to remember that most studies focused their findings on surrogate markers instead of clinical outcome.[13] Lastly, and most importantly, it is a very difficult task to accurately measure gastric fluid volume in the right lateral decubitus position in an ICU patient.

Future perspectives

PoCUS of the gastric antrum has a lot of potential to become a standard bedside tool to evaluate aspiration risk for anaesthesiologists and ICU physicians. Nevertheless, it needs further validation in larger and specific patient populations, such as critically ill patients, parturients and the elderly. Also, further research is needed in ICU patients to determine a cut-off value in the supine or semi-recumbent position that correlates with an at-risk stomach and if it is able to measure gastric residual volume in enterally fed patients. In addition, analysing the existing data through a meta-analysis can determine which threshold of gastric volume increases the risk of aspiration in humans. After that it may be implemented in guidelines as a mandatory bedside tool before intubation. Lastly, novel techniques such as artificial intelligence to automatise measurements, and 3D and 4D ultrasound may play a future role in further refining this technique.

Conclusion

Gastric PoCUS is a promising diagnostic tool for standard assessment of gastric content and total gastric fluid volume in patients before intubation, especially in patients at risk of aspiration, such as critically ill and emergency surgery patients. Gastric PoCUS is highly feasible in a variety of patient populations, such as critically ill, elective or emergency surgery, severely obese and pregnant patients. Limitations are that the current evidence is limited due to the small sample size of studies and effects on outcome have not been studied.

Disclosures

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