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I-AIM framework for point-of-care gastric ultrasound

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Gastric ultrasound (GUS) is an emerging point-of-care diagnostic tool to examine stomach contents and determine pulmonary aspiration risk at the bedside.[1–7] This type of assessment is useful to guide airway and/or anaesthetic management in the acute care setting, when NPO (nil per oral) status is questionable or unknown. A point-of-care ultrasound application has a well-defined purpose, aimed at improving patient outcome and is therefore focused and goal oriented; the findings need to be easily recognizable and the examination easily learnt and quickly performed at the patient's bedside.[8]

GUS complies with these characteristics. It is a limited examination to assess gastric content type (empty, clear fluid, thick fluid/solid)[1 3 4] and volume,[2 5] with the ultimate goal of preventing pulmonary aspiration, therefore being focused and goal-oriented. t can be performed by clinical anaesthesiologists with a minimum of 33 scans, required by trainees to obtain an accuracy of 90%, which suggests that it is easy to learn.[9] In addition, the findings are accurate and reliable.[2 5 10]

The ultrasound diagnosis of empty and solid content states is usually self-evident and represents extremes of aspiration risk (low and high respectively).[1 3 4] In addition, when the stomach contains clear fluid, its volume can be determined based on a cross-sectional area of the gastric antrum (CSA) which further defines aspiration risk.[2 5 7]

However, ultrasound is often cited as the most operator-dependent of all imaging modalities.[11] Protocol-guided ultrasonography ensures examination consistency, fast and correct image acquisition, decreased examination times and accurate diagnosis and annotation.[11] Several protocols and guidelines for point-of-care ultrasonography have been described in the intensive and emergency care settings. Examples of such protocols are the focused assessment of transthoracic echocardiography (FATE),[12] the focused echocardiography in emergency life support (FEEL),[13] and focused lung ultrasound (BLUE).[14] Focused assessment with sonography for trauma (FAST) is a well-established backbone of emergency trauma management.[15] The recently proposed I-AIM framework (Indication; Acquisition; Interpretation; Medical management) describes a logical stepwise approach to point-of-care ultrasound exams and offers a procedure-specific standardized approach to implementation for improving use and performance.[16 17]

We suggest a framework, based on the I-AIM model, for the clinical implementation of point-of-care GUS which can also serve as an educational tool during theoretical and hands-on sessions. In addition we present a sample report template for standardized written communication of findings.

Indication

Being a new tool, most current indications for GUS are mechanism-based rather than evidence-based (Table 1). The main indication is pre-anaesthetic aspiration risk assessment, in patients in whom prandial status is questionable. This includes urgent or emergency surgical procedures, major comorbidities that may delay gastric emptying (e.g. diabetic gastroparesis, advanced liver or renal dysfunction, critically illness), or questionable adherence to fasting instructions (e.g. cognitive dysfunction, altered sensorium).[7] Preliminary but growing evidence suggest that GUS changes aspiration risk stratification and helps guide anaesthetic and airway management.[6 18]

GUS findings have been validated in patients with normal gastric anatomy. Qualitative information on stomach contents in patients with structural abnormalities (e.g. previous lower oesophageal or gastric surgery, hiatal hernia, gastric cancer) can still be useful. However, volume assessment may not be accurate.

Acquisition

Image acquisition relates to patient, probe, picture and protocol considerations.[16]

The most useful patient position is the right lateral decubitus (RLD), as a greater proportion of stomach contents will move towards the more dependent antrum following gravity, thus increasing the sensitivity of the test to detect small volumes.[1] In critically ill patients however, it might not be possible to scan in a position other than supine.[19] The upper abdomen is exposed and gel is used as an acoustic medium.

In adult patients, a curved array low-frequency probe (2–5 MHz) is required and abdominal settings are selected. In lean or paediatric patients, a linear high-frequency probe (10–12 MHz)

Table 1 I-AIM framework for gastric ultrasound

(I) INDICATION

Pre-anaesthetic aspiration risk assessment in the setting of questionable per os intake:

- elective procedures but NPO guidelines not followed
- urgent/emergency procedures
- NPO status unknown

(A) ACQUISITION

Patient	• Position: supine and RLD • Adjust ambient light • Expose the upper abdomen	**Probe**	• Adults: low frequency curved probe • Pediatrics: consider high frequency linear probe • Acoustic medium: gel • Sagittal scanning plane in the epigastrium
Picture	Scan		• sweep widely from left to right subcostal margin to systematically identify the stomach as a hollow viscus located superficially between the left lobe of the liver and the pancreas with a prominent muscularis layer within its wall • rock and slide to positively identify the antrum at the level of the aorta • rotate to obtain a true cross section of the antrum avoiding oblique views • heel to toe movement to optimize acoustic reflections
	Knobology		• primary: adjust depth and gain • secondary: adjust tissue harmonics and focal zone • tertiary: color or power Doppler to confirm vessel identity if required
	Capture		• still frame or video as required • if clear fluid content, measure antral CSA in RLD as a mean of 3 readings, between peristaltic contractions and estimate gastric volume as follows: (Volume(ml)=27.0+14.6×Right-lat CSA–1.28×age)
Protocol	Complete written report (appendix 2)		

(I) INTERPRETATION

Pattern recognition: gastric content nature

- Empty stomach, grade 0 antrum: minimal clear fluid/air content, flat antrum or 'bull's eye' pattern in both supine and RLD
- Clear fluid (distended antrum with hypoechoic content)
  - Grade 1 antrum (fluid visible in RLD only, suggesting low gastric volume)
  - Grade 2 antrum (fluid visible in both supine and RLD, suggesting high gastric volume)
- Thick fluid or solid (distended antrum with hyperechoic/heterogeneous content)

Volume estimation

Differentiates clinically insignificant volume consistent with baseline gastric secretions (<1.5 ml kg^{-1} of clear fluid) from greater than baseline volumes (>1.5 ml kg^{-1})

(M) MEDICAL DECISION MAKING

Clinical context

- History and physical exam
- Elective *vs* urgent *vs* emergency procedure
- Time interval since last meal
- Type and amount of meal
- Other aspiration risk factors (diabetes, GERD, stroke, active labor, Neuromuscular disease)

Image analysis

- Adequate
- Technically difficult
- Inadequate

Physician interpretation and decision making

Classify findings into one of 3 categories:

Continued

Table 1 *Continued*

	• Empty stomach or baseline gastric secretions suggesting LOW aspiration risk • Clear fluid content (>1.5 ml kg^{-1}) suggesting higher than baseline gastric volume and HIGH aspiration risk • Thick fluid or solid content suggesting HIGH aspiration risk
Medical decision making	• Decide on anaesthetic/surgical timing: proceed, delay, cancel • Decide on anaesthetic technique: general *vs* regional anaesthesia • Decide on the need for aspiration precautions (e.g., need for intubation, rapid sequence induction, NG tube placement)

can be used. The epigastrium is scanned in a sagittal or parasagittal plane and the transducer is swept widely from the left to the right subcostal margin to image the stomach.

The stomach can be found superficially as a hollow viscus between the left lobe of the liver anteriorly and the pancreas posteriorly.[1 3–5] Important regional vascular landmarks are the aorta, the inferior vena cava and the superior mesenteric artery and vein (Supplementary Figures S1 and S2).[1 3 4] The gastric wall is about 4 mm thick in the healthy adult and has 5 characteristic sonographic layers that are well described elsewhere.[4] These can be appreciated with a linear high frequency probe, especially in the empty state.[3 4] With a curved low frequency probe, the 5 layers are rarely distinguishable, except for the prominent muscularis propriae (a thick hypoechoic layer) that is consistently observed (Supplementary Figures S1 and S2). The transducer is moved gently (rocking, sliding, rotation and heel-to-toe movement) to identify the antrum at the level of the aorta and to optimize acoustic reflections while avoiding oblique views. The antrum is usually located superficially at a depth of 2–3 cm. In severely obese patients, it can be found approximately at a depth of 7 cm.[20] Depth, gain, tissue harmonics and focal zone are adjusted to center the antrum and to reduce image artifacts. Colour Doppler or Colour Power Doppler can be used to confirm vessel identity if necessary. The images can be captured as still frames or videos. Storing images may be useful for comparison with previous exams, and for quality assurance, educational and medicolegal purposes.

If a volume estimate is desired (in case of clear fluid content), then the following steps are followed:

(a) The antrum is identified in cross-section at the level of the abdominal aorta in the RLD
(b) A still image is obtained with the antrum at rest (between peristaltic contractions)
(c) Antral CSA is measured using the free-tracing tool of the ultrasound equipment and including the full thickness of the gastric wall (from serosa to serosa).[1 2 5]
(d) The total gastric volume is estimated using the following model:

Volume (ml)=27.0+14.6×Right-lat CSA–1.28×age.[6]

This model has been validated for non-pregnant adult patients with BMI up to 40 kg m^{-2}, and accurately predicts gastric volumes from 0 to 500 ml (Supplementary Appendix S1).[5]

It is recommended that the findings of the bedside examination be recorded in a written report. There is no current consensus on what constitutes a good ultrasound report/protocol.[21] However, it should contain a logical clear structure, document accurately all relevant information (e.g. patient identification data and relevant medical history) and all salient qualitative and quantitative findings, that will help answer the clinical question.[22] It should offer, if appropriate, management suggestions supported by precise findings. We hereby present a sample report form with limited open text-field that can be used as a template (Supplementary Appendix S1).

Interpretation

After identifying the relevant structures, the qualitative appearance of the antrum is used to establish the nature of the gastric content (empty, clear fluid, thick fluid/ solid). When the stomach is empty, after a long period of fasting, the antrum appears collapsed with juxtaposed anterior and posterior walls and a round to ovoid shape that has been compared with a 'bull's eye' or 'target' pattern (Supplementary Figure S1).[1 4] An empty stomach carries a low aspiration risk.

At the other end of the aspiration risk spectrum, thick fluid content such as milk or particulate fruit juice appears relatively homogenous and of high echogenicity (Supplementary Figure S3). Immediately after a solid meal a distended antrum with a 'frosted-glass' pattern is common (Supplementary Figure S4).[1 4] At this point, the air mixed with the solid food during the chewing process forms a mucosal-air interface along the anterior wall of the antrum that casts an artifact of multiple 'ring-down' artifacts, blurring the gastric content and the posterior wall of the antrum. After a variable period of time, the air is displaced, and the antrum appears distended with heterogeneous content of mixed echogenicity (Supplementary Figure S5).[1 4] Particulate fluid of solid gastric content is considered to pose a serious risk of aspiration often correlated with poor patient outcome .

On the other hand, baseline gastric secretions and clear fluids (e.g. water, tea, black coffee) appear anechoic or hypoechoic (Supplementary Figure S2).[1 4] Increasing fluid volume renders the antrum round and distended with a thin wall. Air bubbles can appear as fluctuating small echoes ('starry night' appearance).[1] When the stomach contains clear fluid a volume assessment is indicated. A volume of <1.5 ml kg^{-1} is normal in fasted patients, in keeping with baseline gastric secretions and low aspiration risk. Conversely, volumes >1.5 ml kg^{-1} are not common in fasted individuals, therefore suggesting incomplete gastric emptying and possibly higher aspiration risk. Although a strict threshold of gastric volume over which aspiration risk increases is still controversial, clinical data strongly suggest that gastric fluid volumes of up to 1.5 ml kg^{-1} (approximately 100 ml for the average adult) are normal in fasted individuals and safe.[23–25]

It is also possible to use a semi-quantitative three-point grading system to differentiate low- from high-volume states.[3 5] It is based solely on qualitative evaluation of a clear fluid containing antrum, that is scanned in both supine and RLD positions. The antrum is classified as grade 0 if it appears empty in both positions. This suggests minimal or no fluid content is present. Close to 50% of fasted adults present a Grade 0 antrum. The antrum is defined as grade 1 when fluid is apparent in the RLD only, correlating with low gastric volume. Approximately 50% of fasted individuals present a grade 1 antrum.[3] Finally, in a grade 2 antrum, clear fluid is apparent in both supine and RLD positions. A grade 2 antrum correlates with higher than baseline gastric volume and is uncommon in fasted subjects 0.[4 20]

Medical decision making

GUS is a clear example of point-of-care ultrasonography. The overriding aim of this exam is to guide safe airway and anaesthetic management and prevent pulmonary aspiration in cases of clinical equipoise, when aspiration risk is unclear and the management options carry potential risks for the patient.

Both qualitative and quantitative findings contribute to risk stratification. The clinician will distinguish a low risk situation (empty stomach, or low volume consistent with baseline secretions) *vs* a high risk situation (clear fluid in excess of baseline secretions, thick fluid or solid content) (Fig. 1). Once aspiration risk is classified as low or baseline *vs* high, the medical intervention to follow will depend on the clinical scenario. For example, if an elective surgical procedure is planned (e.g. diagnostic knee arthroscopy), the presence of solid food in the stomach will likely result in deferral of the surgical timing. If however, the patient being evaluated is presenting for urgent or emergency treatment (e.g. emergency open reduction and internal fixation of an open ankle fracture), postponing the surgical procedure would carry a high risk of infection and surgery should proceed despite the aspiration risk. In this case, the anaesthetic technique should be tailored to minimize aspiration risk (e.g. a spinal anaesthetic with an awake patient or a rapid sequence induction of anaesthesia with tracheal intubation).

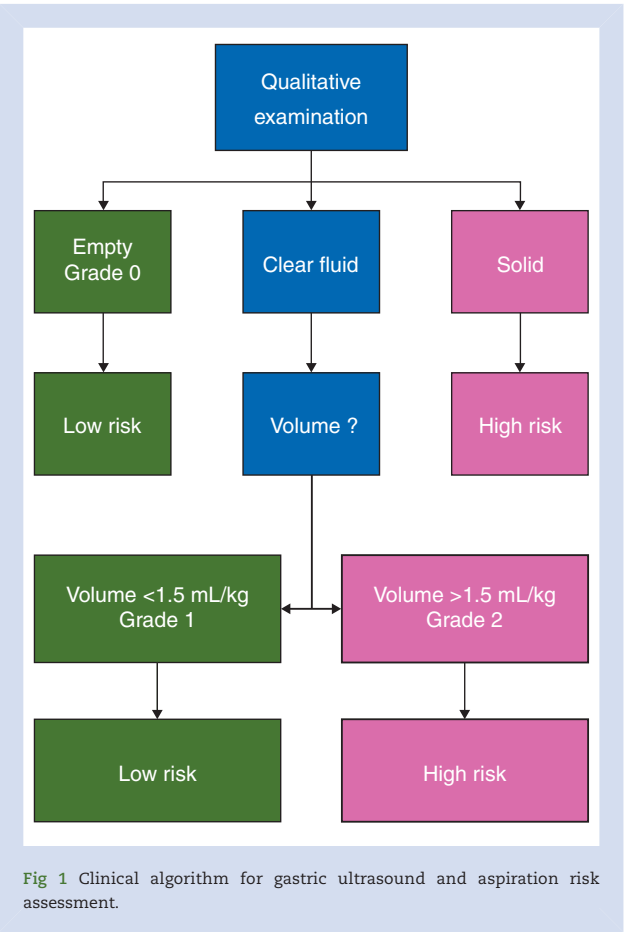

Fig 1 Clinical algorithm for gastric ultrasound and aspiration risk assessment.

In conclusion, gastric ultrasound is an emerging tool to examine stomach contents and to determine pulmonary aspiration risk at the bedside. This article proposes a framework based on the I-AIM model for the clinical implementation of point-of-care gastric ultrasound. It also presents a standardized sample report template.

Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.

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Propofol and food allergy

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'How do you like your eggs in the morning?' begins the song made famous by Dean Martin and Helen O'Connell in 1975. If you are one of the 1 in 1000 of the population who is allergic to eggs,[1] the answer to the question posed in the song might be 'No eggs for me, thank you'.

Shortly after the song became a hit, Brian Kay, a UK anaesthetist, conducted the first clinical trial of propofol in Professor Rolly's department in the Belgian city of Ghent, surely one of the most important trials in the history of anaesthesia.[2] A significant clinical question hanging in the air since the subsequent clinical launch of propofol is whether anaesthetists should avoid propofol in patients with specific food allergies. It is remarkable that almost 40 years have elapsed between the first clinical trial of propofol and the fog finally clearing around the putative association between food allergy and hypersensitivity to propofol.

The formulation of di-isopropylphenol used in the initial clinical trials contained Cremophore EL and ethyl alcohol as solubilizing agents. Pain on injection was very common; consequently ethyl alcohol was removed and the concentration of di-isopropylphenol was reduced from 2 to 1%. Cremophore was implicated in triggering severe anaphylactic reactions to the i.v. anaesthetic Althesin (alphaxolone and alphadolone), which was withdrawn from human use in the mid 1980s. A number of hypersensitivity reactions occurred during the early clinical trials of propofol. Consequently, Chremophore and ethyl alcohol were replaced by a lipid emulsion before the preparation was eventually introduced to the market. Several different formulations of propofol are currently available, with different constituents. A commonly-used formulation contains a soybean oil emulsion with long-chain triglycerides, glycerol, egg lecithin (phospholipids), and disodium edetate (EDTA) as an antimicrobial agent. The proportion of long-chain and medium-chain triglycerides may differ between formulations available from different manufacturers. Some preparations may contain sodium metabisulfite or sodium benzoate as a preservative, rather than EDTA. Fospropofol is a recently-introduced water-soluble pro-drug of propofol and is preservative-free.

Propofol was developed in a regulatory environment where there was heightened concern about potential allergic reactions to anaesthetic drugs, and attention became focused on any constituent that might conceivably trigger an allergic reaction, such as lecithin, derived from egg yolk. The pharmaceutical processing of egg lecithin removes or significantly modifies the proteins that could theoretically cause allergy, but concerns persisted. In addition, allergy to egg is almost invariably the result of sensitization to ovalbumin or ovomucoid proteins found in egg-white but not in yolk.

So, how did the putative association between food-allergy and propofol-allergy arise? It is interesting to examine the evidence. In 1994, Bassett and colleagues[3] reported the development of widespread pruritus after the administration of propofol in a single patient who happened to be allergic to egg and suggested that a history of egg-allergy may have to be considered before the administration of propofol. In 2001 Nishiyama[4] reported bronchospasm in two patients after receiving propofol, associated with cutaneous flushing in one of the individuals. No testing for propofol or other allergy was performed. The authors surmised