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REVIEW

The role of gastric ultrasound in anaesthesia for emergency surgery

A review and clinical guidance

Vincent Godschalx, Marc Vanhoof, Filiep Soetens, Peter Van de Putte, Admir Hadzic, Marc Van de Velde and Imré Van Herreweghe

BACKGROUND The timing and technique of anaesthesia are challenging in patients with a history of recent food intake. The presence of gastric contents increases the risk of aspiration, potentially resulting in acute lung injury, pneumonia, or death. Delayed gastric emptying complicates the estimation of aspiration risk. Surprisingly, there are no fasting guidelines for emergency surgery. Point-of-care gastric ultrasound is a time-efficient, cost-efficient and accurate bedside tool with which to estimate residual gastric content and to guide decision-making in airway management and timing of general anaesthesia. This review summarises the prevailing concepts of ultrasound-guided gastric content assessment for emergency surgery.

METHODS Medline and Embase databases were searched for studies using ultrasound for the evaluation of gastric content in adults scheduled for emergency surgery.

RESULTS Five prospective observational studies representing 793 emergency surgery patients showed that the incidence of 'full stomach' was between 18 and 56% at the time of induction. Risk factors for a full stomach before emergency surgery were abdominal or gynaecological/obstetric surgery, high body mass index and morphine consumption. No correlation between preoperative fasting time and the presence of a full/empty stomach was found. No deaths due to aspiration were reported.

CONCLUSION The preoperative presence of gastric content before emergency surgery is high and the estimates used for clinical management are unreliable. This review demonstrates that gastric ultrasound is a valuable tool for evaluating gastric content. A flow chart for medical decision-making using gastric ultrasound before emergency surgery was developed to assist in clinical decision-making. The validity and practical applicability should be assessed in future studies.

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KEY POINTS

- Fasting guidelines for anaesthesia in emergency surgery are non-existent.
- The clinical estimation of the presence of preoperative gastric content in emergency surgery is unreliable.
- Gastric ultrasound is an accurate bedside tool for estimating residual gastric content.
- Gastric content is present in 18 to 56% of emergency surgery patients undergoing anaesthesia and most studies found no correlation between fasting times and the presence of a full or empty stomach.
- This review includes a flow chart to guide decision-making in airway management and timing of general anaesthesia in emergency surgery based on gastric ultrasound findings.

From the Department of Anaesthesiology, UZ Leuven, Leuven, Belgium (VG), Department of Anaesthesiology, AZ Turnhout, Turnhout, Belgium (MV, FS), Department of Anaesthesiology, Imeldaziekenhuis, Bonheiden, Belgium (PVDP), Department of Anaesthesiology, Ziekenhuis Oost-Limburg, Genk, Belgium (AH, IVH), Department of Anesthesiology & Algology, Faculty of Medicine, KULeuven, Leuven, Belgium (AH), Department Cardiovascular Sciences, KU Leuven, Department of Anaesthesiology, UZ Leuven, Leuven, Belgium (MVDV)

Correspondence to Imré Van Herreweghe, Schiepse Bos 6, 3600 Genk, Belgium.
Tel: +32 89325050; e-mail: imrevanherreweghe@gmail.com

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Introduction

Approximately 10% of all surgical procedures are emergencies.[1] Emergency surgery significantly increases the risk of aspiration compared with elective surgery by factor of 4.5.[2,3] Pulmonary aspiration of gastric contents is a rare but potentially fatal peri-operative complication. The overall incidence varies between 1 in every 2000 to 3000 patients undergoing general anaesthesia.[2–4] Following aspiration, almost half develop lung injury such as pneumonitis or aspiration pneumonia.[5] Over 50% of airway-related deaths in anaesthesia are caused by peri-operative aspiration.[6,7] As a result, anaesthesia societies such as the American Society of Anesthesiologists (ASA) and the European Society of Anaesthesiology and Intensive care (ESAIC) provide guidelines for preoperative fasting in elective surgery: 2 h for clear fluids, 3 h for breast milk, 6 h for non-human milk or light meals and 8 h for fatty foods and meat.[8,9] Importantly, these guidelines only apply to healthy patients undergoing elective procedures. However, the Clinical Practice Committee of the Scandinavian Society of Anaesthesiology and Intensive Care Medicine recommended in 2010 that emergency procedures should be treated similarly to elective surgical procedures with respect to fasting conditions. This recommendation is because randomised studies investigating the optimal period of fasting before emergency surgery are still lacking.[10] To our knowledge, there are no specific fasting guidelines available for patients scheduled for emergency surgery. In the absence of tools that accurately predict the presence of gastric content, the timing and management of non-elective surgery is a clinical decision that must balance both the surgical urgency and the risk of pulmonary aspiration.

Gastric ultrasound has been proven to be an adequate and powerful tool with which to estimate gastric content and, indirectly, the risk for peri-operative aspiration. It is applicable in adults, children, pregnant women and the obese.[11–13] Gastric ultrasound is also a bedside examination with a low intrarater and interrater variability and is easy to learn, taking approximately 33 supervised gastric scans to achieve a success rate of 95%.[14–16] Compared to other techniques that evaluate gastric content such as computed tomography, scintigraphy and suctioning via a gastric tube, gastric ultrasound is a non-invasive technique that is easily repeatable and requires limited resources and time.[17–19] Accordingly, gastric ultrasound can alter medical decision-making in terms of timing and management of anaesthesia.

In this review, we discuss the role of gastric ultrasound in adults requiring emergency surgery, together with an estimate of the incidence of preoperative gastric content, and an evaluation of the accuracy of current practices in risk assessment regarding stomach content in an emergency surgical setting. In addition, we propose a new flow chart, based on the gastric ultrasound findings, to guide clinical decision-making in adults requiring emergency surgery.

Methods

The recommendations and checklist from the PRISMA statement were used to conduct this narrative review.[20] Both Ovid MEDLINE and Ovid EMBASE databases were searched using the terms 'emergency surgery' and 'gastric ultrasound' between 2010 and May 2022. Additional search terms were 'English' and 'adults: +19 years'. Two authors independently assessed the publications for inclusion by title and abstract and when available, the full article was assessed. Prospective as well as retrospective clinical studies using ultrasound to evaluate gastric content in patients scheduled for emergency surgery were included. Suitable studies referenced by the included articles were also searched for additional relevant studies.

Exclusion criteria applied were: publications not reporting on adults, elective surgery cohorts and/or studies including women >15 weeks pregnant. To complete inclusion, the authors collected information on study characteristics, fasting status, positioning during the assessment, type of surgery, qualitative gastric content evaluation (empty, fluid or solid), quantitative assessment (total gastric fluid volume), rates of inconclusive examinations, cut-off values for diagnosis of high-risk stomach content and risk factors associated with increased peri-operative gastric content. If these items were absent or not known (except for the rate of inconclusive examinations and the risk factors associated with increased peri-operative stomach content), the publication was excluded.

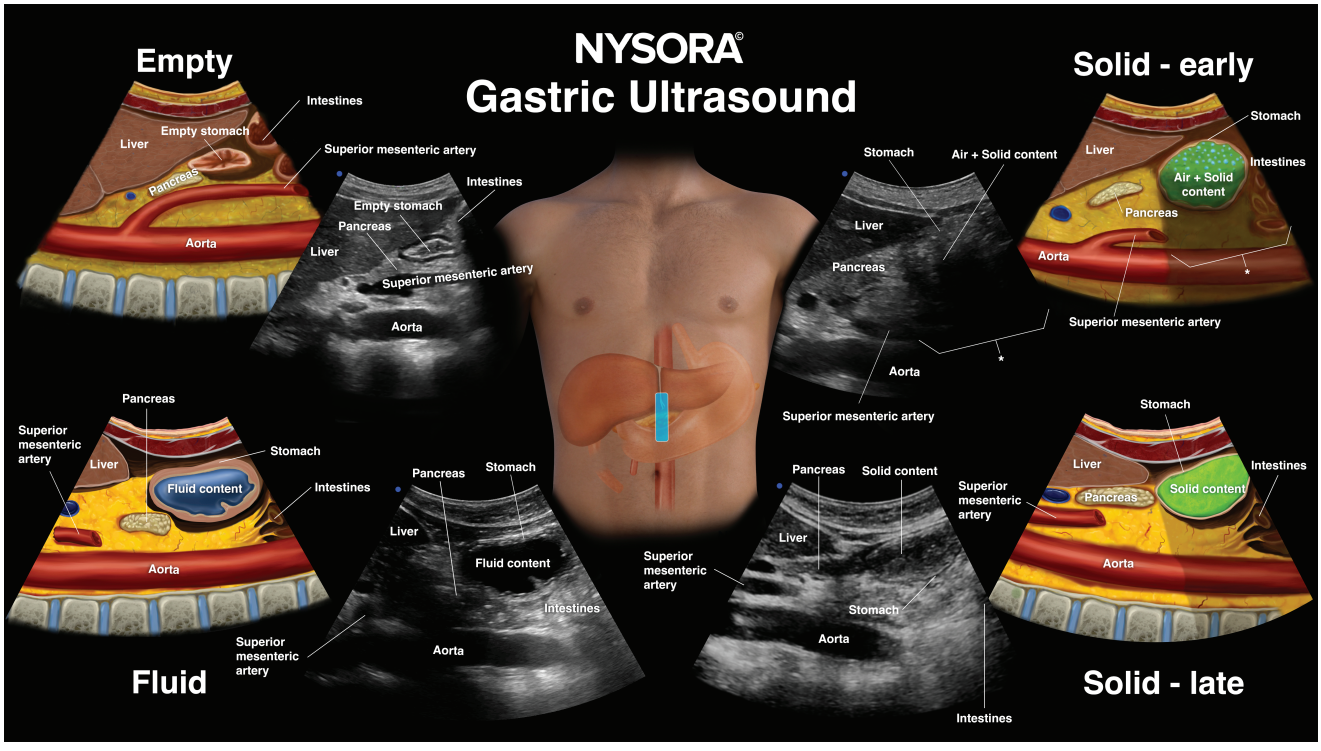
Gastric ultrasound image acquisition

The aim of gastric ultrasound examination is to obtain a sagittal section of the antrum of the stomach at the level where the left lobe of the liver, the aorta and the superior mesenteric artery are also visible (Fig. 1). A gastric ultrasound is first performed in the supine position and when the stomach is thought to be empty or fluid content is present, then the scan will be performed in the right lateral decubitus (RLD) position. In RLD, gravity will displace the gastric content towards the antrum, thereby increasing the sensitivity of the examination. Desgranges *et al.* demonstrated that scanning the antrum in the semi-recumbent position and more especially with a 45° elevation, is a valuable alternative for the assessment of gastric content status before emergency surgical procedures when the right lateral position is not possible.[21,22] The probe is positioned caudal to the xiphoid process in a sagittal or parasagittal plane with the indicator pointing cranially. For adults, a low-frequency curvilinear transducer with standard abdominal settings is used.

If the stomach is empty, the antrum has a typical round or oval-shaped structure with thick hypoechoic walls that is often referred to as the bull's eye pattern.

The presence of intraluminal fluid will result in a rounded and distended appearance of the antrum and thin

Fig. 1 Ultrasound position for gastric ultrasound, ultrasound images of the stomach with no gastric content (empty), fluid, solid gastric content with air (frosted glass) and solid content.



stomach walls. Sonographically, a differentiation can be made between clear fluids and non-clear fluids, suspensions, or milk for example. Clear fluids are anechoic, in contrast to non-clear fluids that appear hyperechoic. For clear fluids, further measurements are necessary in order to estimate the volume of the stomach in the RLD position. The mathematical model of Perlas *et al.* is the one most commonly used for gastric volume estimation. It is based on the cross-sectional area of the antrum (CSA) and has been validated in different patient groups.[23] Alternatively, Desgranges *et al.* presented a threshold cross-sectional area that is measured in the semi-recumbent position and has high sensitivity in the identification of a stomach at risk in non-pregnant adults.[21] The CSA can be measured with ultrasound by measuring the distance from serosa to serosa and using the formula for calculating the area of an ellipse or by using a free tracing tool.

In the early phase after the ingestion of solids, solid content is mixed with air resulting in the reflection of all the ultrasound beams thus making it impossible to visualise the underlying structures. Mixed air and solid content is often described as the 'frosted glass' pattern. The wall of the antrum will be thin. After a couple of hours of digestion, the air will disappear and the gastric content will be better outlined with mixed echogenicity.

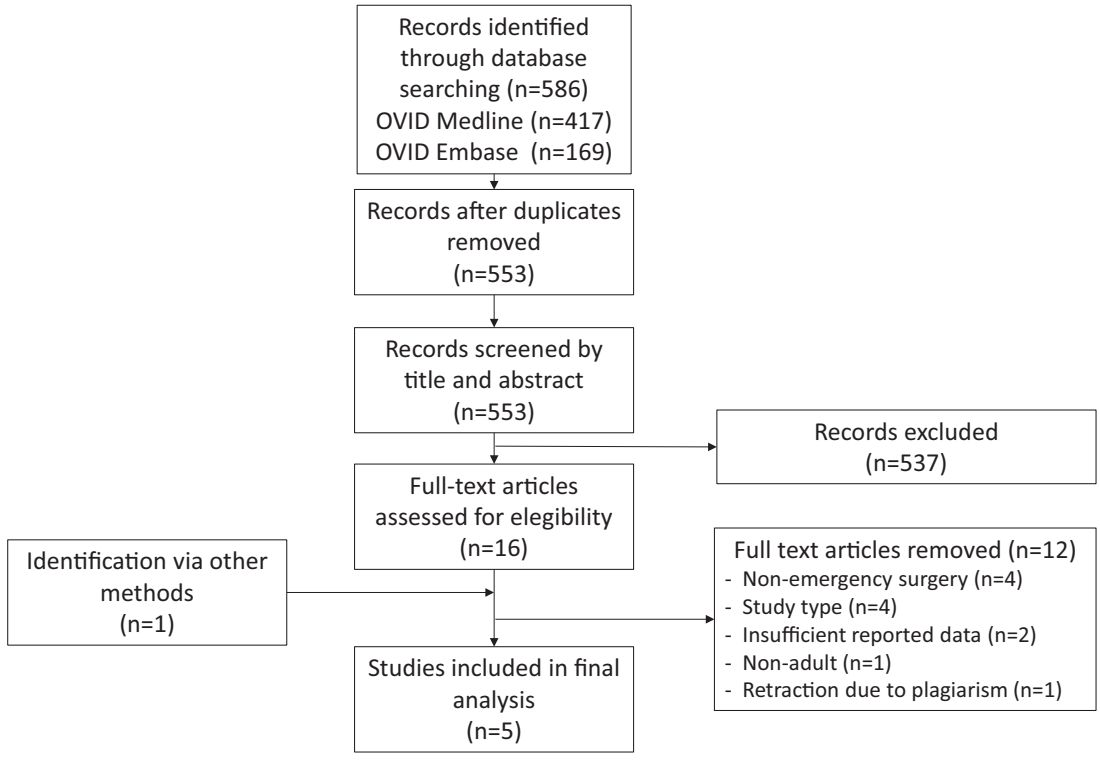
Results

The flow of studies retrieved by the search and the article selection are shown in Fig. 2. The Medline and Embase databases were searched on 1 May 2022, resulting in 586 articles. After the removal of duplicates ($n = 33$), 553 articles were screened by title and abstract, yielding 16 articles for full-text review, of which 12 failed to meet the inclusion criteria and were rejected (Appendix 1, Supplemental Digital Content, http://links.lww.com/EJAIC/A51). One additional article was included after screening of references of relevant studies, making five articles with a total of 793 patients. All five articles were prospective observational studies.[17,24–27]

The selected studies described qualitative and quantitative assessments of gastric content using ultrasound. Three studies used a cut-off of 1.5 ml kg^{-1} [17,24,27] and two a cut-off of 0.8 ml kg^{-1}, [25,26] for clear fluid content, to differentiate between a low-risk and a high-risk stomach. The different positions of the patients during ultrasound examination were RLD,[24,27] 45° semi-recumbent [25–27] and supine position.[17] An overview of the respective characteristics of the included studies is shown in Table 1.

The incidence of a full stomach at the time of induction of anaesthesia for emergency surgery varied between 18 and 56%.[24–27] Okada *et al.* studied patients undergoing

Fig. 2 Flow chart of the articles retrieved on Embase and Medline.



emergency abdominal surgery and reported that 51% had a full stomach prior to anaesthesia.[17] Hasanin *et al.* investigated patients with acute uncomplicated appendicitis scheduled for appendectomy and found that 18% of their patients had a full stomach after 6 h of fasting.[27] The rates of unsuccessful gastric ultrasound examinations in general emergency surgery patients ranged between 4 and 14%.[17,24–26]

For preoperative fasting times, most studies reported median fasting times far exceeding the time intervals outlined in the ASA guideline for preoperative fasting in elective surgery (Table 1).[17,24–26] More importantly, four studies reported that fasting time did not correlate with the presence (or absence) of gastric content on ultrasound in emergency surgery patients.[17,24–26]

The risk factors identified for increased probability of a full stomach prior to emergency surgery were abdominal and gynaecological/obstetric surgery, high body mass index and morphine consumption.[24,26]

Two articles reported the absence of aspiration during the study period.[17,25] Delamarre *et al.* reported regurgitation without aspiration in two patients. Both patients had a full

Table 1 Overview of the five included studies investigating the preoperative gastric content before emergency surgery by gastric ultrasound with their respective study characteristics

Authors	Gastric volume threshold	Patient examination position	Study population (*n*)	Type(s) of surgery	Full stomach on gastric US (%)	Median and [IQR] fasting times (hours)	Correlation between fasting times and gastric content
Delamarre *et al.*[24]	>1.5 ml kg^{-1}	RLD	196	Various	27	Liquids: 11.4 [8 to 16], solids: 15.6 [11 to 20.2]	No
Bouvet *et al.*[25]	>0.8 ml kg^{-1}	45° semi-recumbent, RLD	250	Various	56	18 [11–24]	No
Dupont *et al.*[26]	>0.8 ml kg^{-1}	45° semi-recumbent	263	Various	35	16 [IQR not available, all patients fasted >6 h]	No
Okada *et al.*[17]	>1.5 ml kg^{-1}	Supine	39	Abdominal	51	Liquids: 6 [5 to 7], solids: 16 [10.3 to 23.5]	No
Hasanin *et al.*[27]	>1.5 ml kg^{-1}	45° semi-recumbent, RLD	45	Appendectomy	18*		Unclear**

RLD, right lateral decubitus position. *Full stomach after 6 h fasting. **A correlation was found between fasting time and average gastric volume as well as between fasting time and cross-sectional area of the antrum. No correlation was found between fasting time and incidence of gastric volume >1.5 ml kg^{-1}.

stomach on gastric ultrasound.[24] Dupont *et al.* witnessed one case with pulmonary aspiration during unmodified induction of anaesthesia with no subsequent sequelae.[26]

Discussion

This literature review evaluated the incidence of preoperative gastric content and the accuracy of current practices in the risk assessment of gastric content before anaesthesia for emergency surgery.

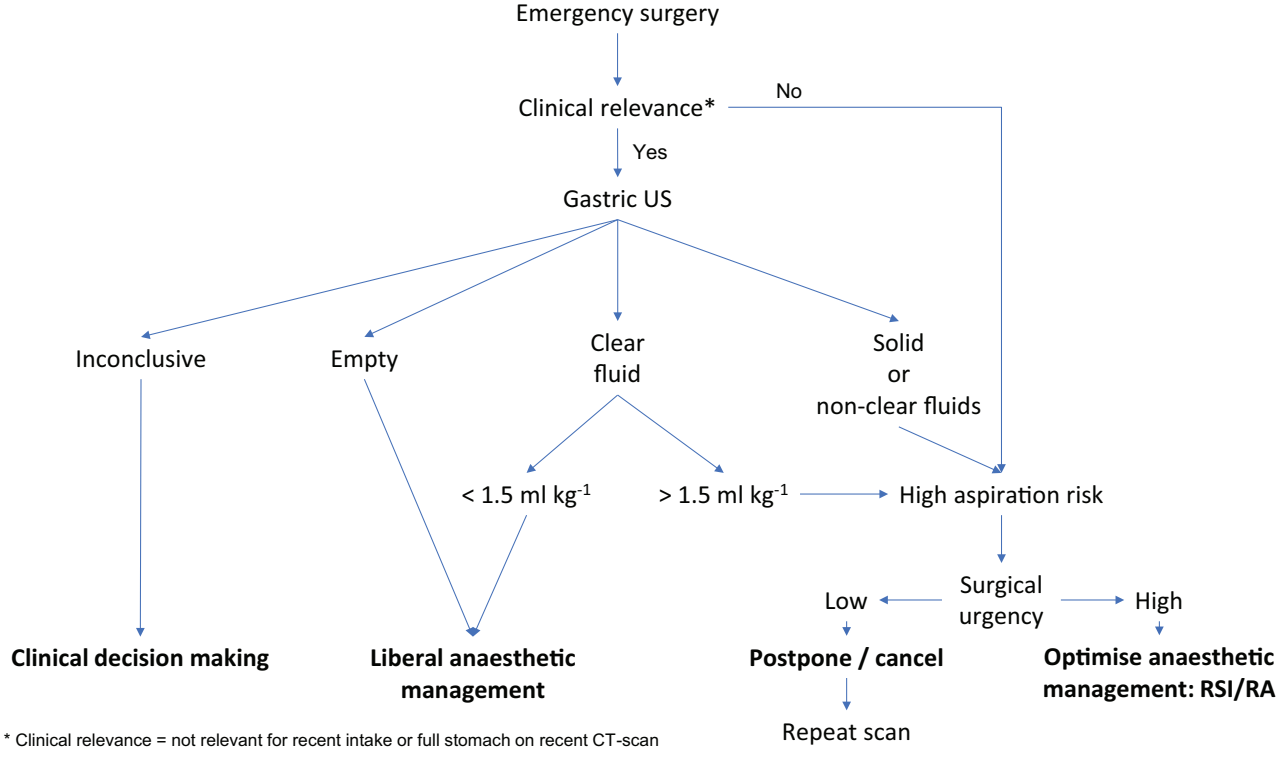
Recent studies with ultrasound showed that the incidence of a 'full stomach' at the time of induction of anaesthesia for elective surgery varies between 3.5 and 5%.[25,28] However, much higher rates for a full stomach are described in emergency surgery, varying between 18 and 56%.[17,24–27] The obvious difference in peri-operative gastric content between patients listed for elective and emergency surgery may be caused by increased levels of pain and stress, preoperative opioid use, comorbidities and in some subgroups the limited duration of fasting. Although most studies did not exclude patients who did not adhere to the ASA guidelines for preoperative fasting before elective surgery, median fasting times of all five studies surpassed those time intervals. Additionally, 4 studies found no correlation between fasting times and the presence of a full or empty stomach, suggesting that postponing the surgery would not reduce the presence of gastric content.[17,24–26]

These findings further imply that clinical decision-making solely based on history is unreliable where preoperative gastric content is concerned. Delamarre *et al.* confirmed that clinical judgment of gastric content status of patients listed for emergency surgery performed poorly compared to judgment based on gastric ultrasound. These authors reported that 58% of the patients who were classified clinically as having a full stomach, actually had low-risk gastric content on ultrasound. On the other hand, 21% of patients who were clinically classified as having an empty stomach had high-risk stomach content on gastric ultrasound.[24] Consequently, clinical misjudgement may result in over and underuse of measures for reducing the risk of peri-operative aspiration. As Bouvet *et al.* suggested, we therefore recommend the use of gastric ultrasound for emergency surgery when feasible.[25]

Clinical management and decision-making

A flow chart for medical decision-making with gastric ultrasound for emergency surgery is shown in Fig. 3. Gastric ultrasound should be considered in every case of emergency surgery, but exceptions can be made where the presence of gastric content is certain (absence of clinical relevance), when gastric ultrasound is not feasible and for high urgency surgery and polytrauma.[29] Of note, most polytrauma patients undergo total body imaging in

Fig. 3 Flowchart for medical decision-making using gastric ultrasound for emergency surgery patients.



US, ultrasound; RSI, rapid sequence induction; RA, regional anaesthesia.

the preoperative period, including computerised tomography of the abdomen. This image might provide an alternative view on the stomach and its content.

Anaesthetic management can be guided by the type of gastric content on ultrasound: empty, clear fluid, non-clear fluid/solid or inconclusive findings. When the stomach is empty a less restrictive approach to anaesthetic management can be considered by the physician, choosing the anaesthetic technique and type of induction with respect to the surgical procedure. When clear fluid is present, determining the gastric volume is essential using the formula of Perlas for gastric volume estimation to guide the risk of aspiration.[23] Alternatively, Desgranges *et al.* described a threshold cross-sectional area of 446 mm^2 that is measured in the semi-recumbent position. This threshold has a 91% sensitivity for identifying a stomach at risk, corresponding to 1.5 ml kg^{-1}, in non-pregnant adults.[21]

We opted to use a cut-off of 1.5 ml kg^{-1} because the mean baseline volume in a healthy fasted adult averages about 0.5 to 0.8 ml kg^{-1} with a 95% CI ranging between 1.2 and 1.5 ml kg^{-1}.[30] Using a threshold of 0.8 ml kg^{-1} might lead to an overestimation of patients with a high-risk stomach content and an overuse of protective measures.[30] A volume smaller than 1.5 ml kg^{-1} carries a very low risk of aspiration and the management can be similar to that for an empty stomach. If the fluid content exceeds 1.5 ml kg^{-1}, the stomach should be considered as full and the same anaesthetic precautions taken as for solid gastric content. If a full stomach is visible on ultrasound, one option is to postpone, or in certain cases even cancel the surgery. Postponing the surgery might allow the stomach to empty. However, since the presence of gastric content is not related to fasting times, additional gastric ultrasound scanning is required before the actual surgery to confirm that the stomach is empty.

If the surgery cannot be postponed due to high urgency, adequate measures are required to prevent aspiration. A rapid sequence induction (RSI) is considered the most appropriate in this situation.[31,32] Although the current fasting guidelines clearly state that they are applicable for regional and general anaesthesia, it may also be reasonable to opt for an anaesthetic technique with a lower requirement for airway management, such as regional anaesthesia.[8]

In 4 to 14% of cases, it is impossible to acquire a sonographic sagittal image of the antrum resulting in an inconclusive examination.[24–26] In these patients, the practitioner has to rely on his/her clinical judgment, keeping in mind that the number of patients scheduled for emergency surgery with a full stomach is high. The flow chart for clinical decision making with gastric ultrasound for emergency surgery is based on current clinical expert opinion and evidence, but this has not yet been validated by clinical studies.[14]

Limitations

This review has some limitations. First, due to the low incidence of aspiration, it is difficult to prove that informed clinical decision-making based on gastric ultrasound actually reduces the risk of aspiration, as outcome data are currently lacking. Moreover, gastric content is not the only variable that influences aspiration, but since it is regarded as one of the most important factors, most studies use gastric volume as a surrogate for the risk of peri-operative aspiration.[30]

Second, gastric ultrasound is most valuable in a scenario of clinical relevance. Although the diagnostic accuracy of gastric ultrasound for detecting a full stomach is excellent, gastric ultrasound remains user dependent and should not be used in situations in which the probability of a full stomach is either very high or very low.[29]

Third, significant heterogeneity is present among the included studies in this review, probably because gastric ultrasound found its way into clinical practice only recently. The included studies vary in patient positioning for the examination (supine, semi-recumbent or RLD) and the volume cut-off for fluid content with a high risk of aspiration (0.8 ml kg^{-1} or 1.5 ml kg^{-1}). The different cut-off values used in international reports may affect the overall percentage of non-empty stomachs.

Fourth, subgroups of patients may also carry different risks for presenting with a full stomach. For example, patients presenting with abdominal pathology, whose gastric ultrasound may be often more difficult to perform, may yield a higher incidence of full stomach. However, the limited number of studies did not allow us to draw definite conclusions.

Fifth, we did not include pregnant women in this study although the risk of pulmonary aspiration is increased in obstetric surgery.[33] The use of gastric ultrasound has proven that gastric emptying after ingestion of solid food is delayed by term pregnancy, labour and during the early postpartum period.[34] Its use in providing reliable bedside information in this subroup has been well established.[12]

Sixth, there is no uniform definition of either emergency surgery or urgent surgery, neither in the studies included in our review nor in the broader literature. For this study, we defined emergency surgery as all non-elective surgery, surgery that is not planned and cannot be postponed for multiple days due to medical reasons.

Finally, gastric ultrasound image acquisition is sometimes less feasible before emergency surgery for several reasons.[25] Pain and altered levels of consciousness may prohibit a reliable measurement of the antral cross-sectional area, the limited amount of time needed for the examination cannot always be spared in critical situations, or the RLD position might not be achievable due to pain or due to contraindications to mobilise.[26] In patients where the examination can only be performed in supine

position, however, a full stomach must be suspected; it cannot be ruled out.

Future areas of research

Most gastric ultrasound studies have been performed in elective surgery and only a few in emergency surgery, which has an increased risk of gastric aspiration. Future studies should therefore examine (1) gastric ultrasound in specific emergency pathology subgroups, and the timing of the insult, (2) strategies that effectively reduce gastric volume and (3) the presence of a full stomach at the end of the surgery. The definition of predictive risk factors for a full stomach can be used to supplement the gastric ultrasound or to replace the ultrasound when it is inconclusive or when the assessment is not feasible, for example when there is no time or in the absence of either the ultrasound machine or a competent examiner. Gastric ultrasound can also be used to evaluate the effect of strategies to enhance gastric emptying since it is accurate, repeatable and easy to perform.[35]

Conclusion

Peri-operative pulmonary aspiration is a severe complication related to general anaesthesia that may challenge clinicians.[6] Emergency surgery poses an increased risk of aspiration, partly due to the high incidence (18 to 56%) of a full stomach.[17,24–27] Currently, there are no fasting guidelines and the clinical judgment of an empty stomach is unreliable in the emergency surgery subgroup.[24] We have shown that gastric ultrasound is a valuable tool for evaluating the presence of gastric content, as most studies found no correlation between fasting times and the presence of a full or empty stomach. Second, we developed a flow chart for medical decision-making using gastric ultrasound for emergency surgery patients. This flow chart is based on current clinical expert opinion and evidence. It is only suitable for the anaesthetic management of non-pregnant adults who are scheduled for emergency surgery, and it should be remembered that the chart has not yet been validated by clinical studies ion any patient group. To conclude, the concept of gastric ultrasound should not be seen as a replacement for fasting guidelines but rather as a readily available tool that can be used to determine gastric content, supplementing patient history and clinical evaluation.

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