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Running Title (within 10 words)	***THE ROLE OF GASTRIC ULTRASOUND IN ANAESTHESIA FOR EMERGENCY SURGERY***
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Abstract

Pulmonary aspiration is a life-threatening complication in emergency surgery, with a mortality rate of 6.6%. The incidence is 1 in 2,000-3,000 cases, and it occurs 4.5 times more frequently than in elective procedures. Although Rapid Sequence Induction (RSI) helps reduce the risk of aspiration, it can also increase the risk of adverse events, such as an undetected difficult airway, hypotension, and hypoxemia during induction. Identifying risk factors related to the patient's condition, surgical impact, and effects of the anesthesia technique is crucial in planning optimal perioperative management for each patient. Gastric ultrasound is an effective tool for anesthesia planning in emergency surgery. It helps assess stomach contents, which in turn minimizes the risk of aspiration and the need for unnecessary rapid sequence induction (RSI). With 95% sensitivity and 88-95% specificity, it allows for precise risk stratification. A practical flowchart guides decisions on surgical timing and anesthesia techniques, ultimately reducing complications like aspiration and improving patient safety by tailoring care to the patient's gastric status.

Keywords: *Gastric ultrasound, Gastric Emptying, emergency surgery, pulmonary aspiration.*

1. INTRODUCTION

Patients undergoing emergency surgery face a multitude of risks from their underlying medical conditions, the technique of anesthesia, the effects of surgery, and potential postoperative complications. The 30-day postoperative complication and mortality rate in emergency surgery patients, encompassing infections, cardiovascular events, respiratory complications, aspiration, and other related issues, is approximately 16.1%, compared to only 7.1% in elective surgeries [1]. Perioperative pulmonary aspiration pneumonia occurs in 1 in 2000 to 1 in 3000 cases during anesthesia. Although its incidence is low, the complication is extremely severe when it occurs, with over 50% of affected patients experiencing severe conditions related to lung damage and multiple organ failure after pulmonary aspiration, resulting in a 6.6% mortality rate [2,3].

Determining the suitable timing of surgery and selecting the appropriate anesthesia technique can minimize the risk of pulmonary aspiration and adverse effects related to anesthesia. However, this remains a challenge for anesthesiologists in clinical practice. This review aims to summarize the evidence on the utility of gastric ultrasound in assessing gastric content to guide anesthesia planning and reduce aspiration risk in emergency surgery, based on PubMed searches for studies on gastric ultrasound in anesthesia from 2000 to 2023, with a focus on emergency surgery.

2. EMERGENCY SURGERY: CHALLENGES AND RISKS

According to the American Society of Anesthesiologists (ASA) fasting guidelines, clear liquids should be restricted for at least 2 hours before elective surgical procedures. Breast milk may be safely consumed up to 4 hours before anesthesia induction, while non-human milk and light meals require a minimum fasting period of 6 hours. For fatty foods or meat, a fasting duration of at least 8 hours is recommended. These guidelines are intended for healthy individuals undergoing elective surgery [4]. However, in emergency surgery, patients often have short fasting periods, accompanied by pain and the effects of trauma or gastrointestinal diseases, leading to impaired gastric emptying and residual contents in the stomach at the time of surgery. The pulmonary aspiration risk in emergency surgery patients is 4.5 times higher than in elective

surgeries [5]. However, no fasting recommendations indicate safety for patients undergoing emergency surgery. To prevent pulmonary aspiration during anesthesia, most anesthesiologists prioritize the rapid sequence induction (RSI) technique in cases where patients have full stomachs. However, RSI poses challenges, requiring large doses of anesthetics in a short time to induce unconsciousness rapidly, followed by immediate airway control to prevent severe hypoxemia [6]. Additional concerns in emergency patients include hypovolemia from fluid loss or bleeding, respiratory disorders, and infections in elderly patients. Vasodilation and myocardial depression from anesthetic drugs can lead to rapid circulatory collapse, compounded by hypercapnia and severe arterial oxygen desaturation due to apnea during induction, which will exacerbate existing disorders and quickly put the patient in a life-threatening situation.

Unanticipated difficult airways are more common in emergency surgery patients, increasing the risk of organ damage due to hypoxia and death if airway management fails. The incidence of unanticipated difficult airways in emergency surgeries is 1 in every 300 anesthesia cases, compared to 1 in every 2000 elective surgeries [7,8].

3. ROLE OF GASTRIC ULTRASOUND

In anesthesia practice, evaluating gastric content is essential in cases with unknown fasting times, delayed gastric emptying, or emergency surgeries. Several tools that can help evaluate gastric volume, such as nasogastric aspiration, CT, or MRI, are available; however, the effectiveness and applicability of these methods have not fully met the requirements in current clinical practice. Meanwhile, ultrasound is a portable, non-invasive, and safe method widely used to assess gastric volume across patient populations, including children, adults, pregnant women, and obese patients. The success rate of gastric surveys exceeds 90%, with high accuracy, and the sensitivity of this technique ranges from 95% to 100%, while specificity ranges from 87.5% to 95%, according to various studies [9,10].

3.1. Positioning the patient

Both the supine and right lateral decubitus positions are applicable for the identification of the gastric antrum. However, the right lateral decubitus position is considered the optimal patient positioning for reliable confirmation of antral contents. In this position, full exposure of the upper abdomen is required. A longitudinally oriented ultrasound probe placed in the epigastric region facilitates visualization of the gastric antrum, enabling qualitative or semi-quantitative assessment of gastric contents.

3.2. Image interpretation

Empty Stomach: In the fasting state, the gastric antrum typically appears contracted, measuring approximately 2–3 cm in diameter. Sonographically, it presents a flattened, hypoechoic structure with concentric ring-like layers, often described as a 'bull’s-eye' or 'target sign. ' The alternating hyperechoic and hypoechoic layers of the gastric wall may be distinctly visualized in this state [11].

[Place Figure 1 near this point]

Clear Fluid: In the presence of clear fluid, the gastric antrum becomes distended, adopting a more rounded morphology with a progressively thinner wall. The hypoechoic muscularis propria layer correspondingly decreases in thickness. Intragastric clear fluids may contain small air

bubbles, which appear sonographically as hyperechoic foci dispersed throughout the antrum, producing an imaging pattern reminiscent of a 'starry night' appearance [11].

[Place Figure 2 near this point]

[Place Figure 3 near this point]

Gastric volume can be estimated using Perlas' formula: Gastric volume (mL)= 27 + 14.6 x Right lateral CSA - 1.28 x age [12].

[Place Figure 4 near this point]

Solid Food: Postprandially, the stomach expands to accommodate food, so the gastric antrum is usually enlarged. Ultrasound at this time records a structure with thin walls, heterogeneous echogenicity, or a "frosted-glass" appearance, which will hinder observation of the posterior wall and structures located behind the stomach [11].

Currently, the threshold for residual gastric volume to assess patients with a full stomach has not been standardized. Bouvet and Gagey used a gastric volume threshold of 0.8 $mL \cdot kg^{-1}$ to evaluate the condition of a full stomach [13,14]. For scheduled surgeries, even if patients adhere to the recommended fasting of 2 hours for clear liquids or 8 hours for solid meals, some cases still report gastric volumes reaching the threshold of 1.5 $mL.kg^{-1}$ at the time of induction. However, reports indicate that these cases did not record any aspiration events during anesthesia [15]. Consequently, the presence of clear gastric fluid exceeding 1.5 $mL \cdot kg^{-1}$ or any detectable amount of solid or particulate matter within the stomach is indicative of a non-fasted state (i.e., a 'full stomach'). This condition is associated with an increased risk of pulmonary aspiration.

Depending on the specific pathological characteristics, the condition of gastric emptying can vary, and certainly, not all emergency surgery patients have a full stomach. Holtan-Hartwig conducted ultrasound examinations of gastric volume in emergency surgery patients undergoing anesthesia with a rapid sequence induction protocol. The results were surprising, as over half of the patients were induced with rapid sequence despite not having a full stomach. This event did not provide benefits and increased adverse events for these patients [16].

The rate of a full stomach in emergency surgery surveyed before induction varied from 18% to 56% [13,17]. One common point in these studies is that all patients with a full stomach, as determined by ultrasound, had a fasting time of at least 6 hours, and the analysis results did not show any significant relationship between fasting time and the state of a full stomach in this group of patients. Gastric ultrasound has provided valuable data for anesthesiologists, and the survey results can completely change the strategy in the perioperative anesthesia management plan for patients undergoing emergency surgery.

4. ANESTHESIA STRATEGY FOR EMERGENCY SURGERY

All emergency surgery patients should undergo a gastric ultrasound to assess gastric residual volume before deciding on the optimal timing of surgery and the appropriate technique of anesthesia, except in cases where a gastric ultrasound cannot be performed, such as in extreme emergencies or severe trauma. In addition, in cases where there is clear evidence of a full stomach, such as patients who have just eaten before admission or have abdominal CT scan results, performing a gastric ultrasound may not be necessary. A flow chart for anesthetic

management approach in emergency surgical patients based on gastric ultrasound is shown in Fig. 5.

The risk of pulmonary aspiration can be stratified into high or low categories based on the findings of the gastric ultrasound:

- Empty stomach: V = 0 or very little, the patient has a minimal risk of pulmonary aspiration.

- Stomach-containing liquid: High risk of pulmonary aspiration for gastric volume greater than 1.5 $mL.kg^{-1}$. In contrast, the patient usually has a low risk of pulmonary aspiration.

- Stomach with solid food: the patient has an elevated risk of pulmonary aspiration.

If the patient is identified as having a full stomach and a high risk of pulmonary aspiration, one potential approach is to delay or, in certain cases, cancel the surgical procedure. The next step is to assess surgical urgency**.** In situations where the procedure cannot be deferred due to its emergent nature, the administration of anesthesia via rapid sequence induction is considered the most appropriate technique, and placing a nasogastric tube to decompress the stomach or using acid-neutralizing agents may be beneficial. Alternatively, for patients who are hemodynamically stable and scheduled for procedures involving the extremities or lower abdomen, regional anesthesia may be a viable option to reduce both hemodynamic disturbances and the risk of aspiration. Conversely, if the surgery is deemed non-urgent, it should be delayed until complete gastric emptying, confirmed through repeated gastric ultrasound evaluations to assess residual gastric volume.

Fig. 1. [Place Figure 4 near this point [18]**.**

In cases where ultrasound shows an empty stomach or a stomach containing fluid with a volume of <1.5 $mL.kg^{-1}$, surgery can be done with a low risk of aspiration, and standard anesthesia can be administered if the patient is to be anesthetized.

In some situations, ultrasound may not be able to assess the gastric structure or provide a conclusion on whether the stomach is full or empty. At this time, the anesthesiologist will make assessments regarding the risk of aspiration and choose an appropriate anesthesia strategy based on information obtained from clinical examinations and gathered from the patient. However, during the administration of anesthesia, it is imperative to maintain a high level of vigilance regarding the potential presence of a full stomach and the associated elevated risk of pulmonary aspiration in patients undergoing emergency surgical procedures.

5. CONCLUSION

Emergency surgery patients often present full stomachs and high perioperative pulmonary aspiration risk. Gastric ultrasound plays a vital role in accurately assessing gastric volume and providing rapid, reliable evaluations. Gastric ultrasound is recommended for all emergency surgery patients unless contraindicated. Anesthesia strategies guided by ultrasound results enable anesthesiologists to choose appropriate techniques of anesthesia, reducing adverse events related to anesthesia and surgery for the patient. Further research is needed to standardize gastric fullness thresholds and to widely implement gastric ultrasound training programs in clinical practice.

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Fig. 2. Patient positioning for performing gastric ultrasound in the RLD position, with the ultrasound transducer placed in the epigastrium beneath the xiphoid process

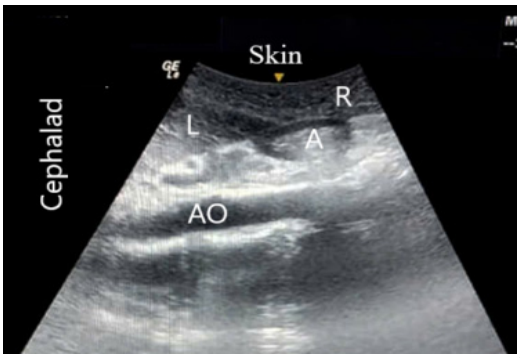

Fig. 3. Sonographic image showing an empty stomach antrum. A = antrum; Ao = aorta; L = liver; R = rectus abdominis muscle.

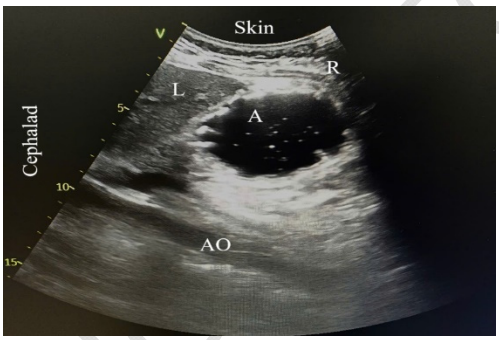

Fig. 4. Sonographic image of the stomach showing clear fluid. A = antrum; Ao = aorta; L = liver; R = rectus abdominis muscle.

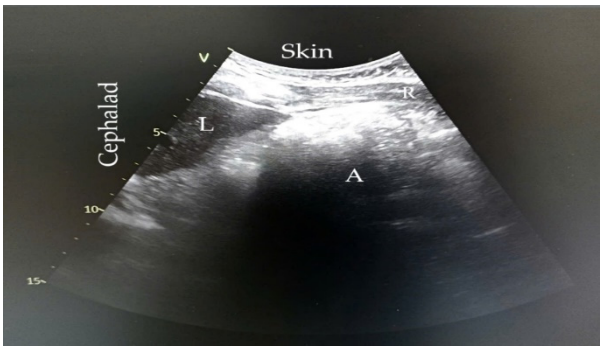

Fig. 5. Sonographic image of the stomach showing solid gastric contents with a 'frosted glass' appearance. A = antrum; Ao = aorta; L = liver; R = rectus; abdominal muscle

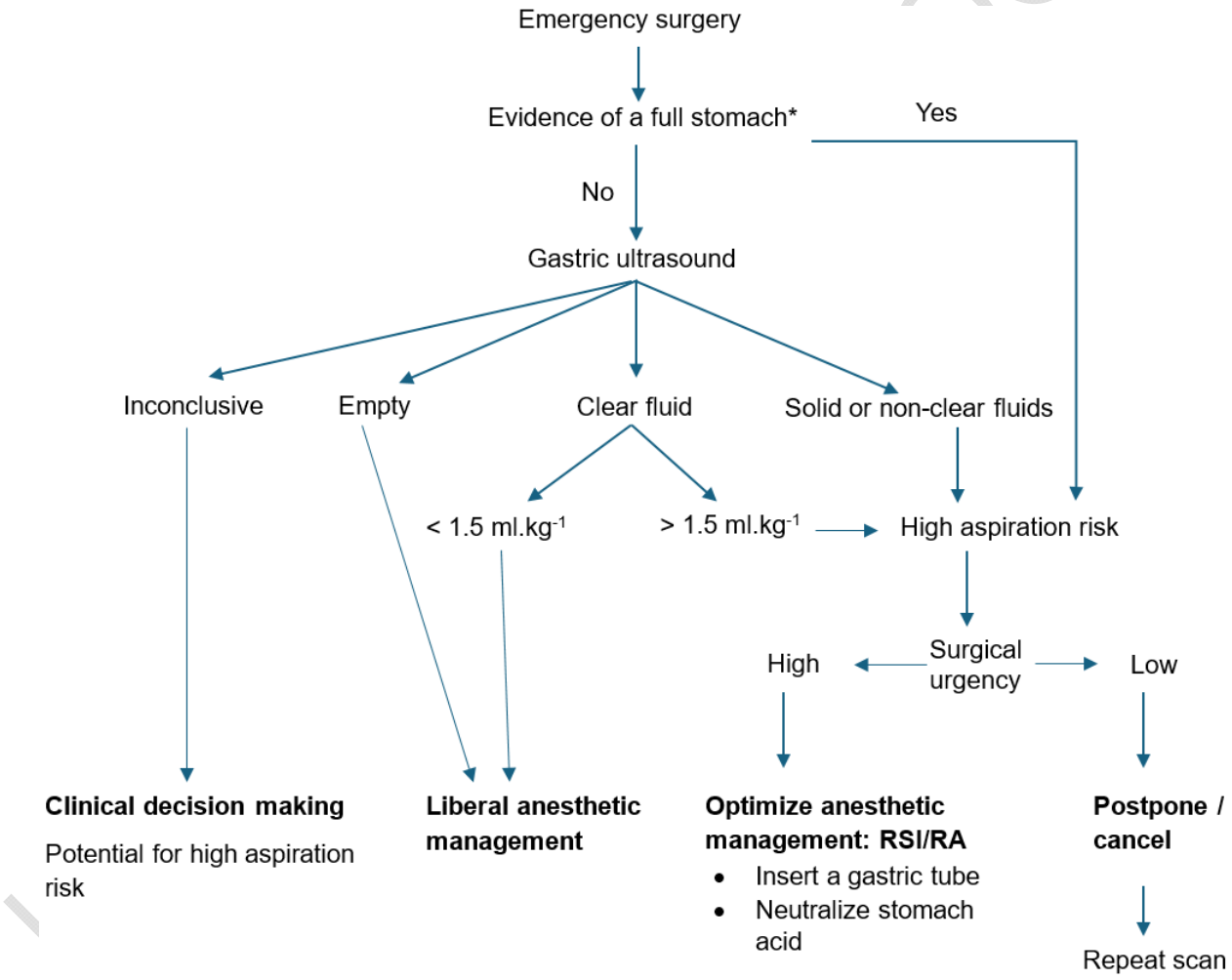

Fig. 6. Flowchart for medical decision-making using gastric ultrasound for emergency surgery patients [16].