REVIEW ARTICLE

The Significance of Ultrasound for Gastric Content Assessment in Anesthetized Patients

Warunee Buayam, BNS[1], Ladda Permpolprasert, BNS[1], Aree Sangsai, BNS[2], Phongthara Vichitvejpaisal, MD, PhD[1]

[1] Department of Anesthesiology, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand; [2] Anesthesia Nursing Unit, Nakhon Pathom Hospital, Nakhon Pathom, Thailand

Although various methods can be used for gastric content assessment, X-rays have a limited ability to distinguish between mixed contents and expose patients to ionizing radiation while endoscopy is invasive, time-consuming, and uncomfortable for patients. Ultrasound, a non-invasive, bedside, and portable method, provides real-time information and is easy to use, making it a cost-effective tool for assessing the size and shape of the stomach and the volume and nature of the gastric contents. Ultrasound can improve patient safety and outcomes by providing more accurate and timely information, allowing for better decision making regarding the timing and safety of surgery.

However, ultrasound has limitations, including operator dependence, patient factors, a limited field of view, and a limited ability to detect solid and fatty contents. To obtain accurate and reliable results, ultrasound requires a trained and experienced operator who must have knowledge of proper image acquisition techniques, accurately interpret the results, and consider safety.

The integration of artificial intelligence and virtual reality technologies into the ultrasound process, as well as the use of contrast agents and more portable devices, could further improve the accuracy and feasibility of ultrasound for gastric content assessment. These developments have the potential to improve patient outcomes during surgery and to expand the accessibility of remote training and assessment.

Keywords: Anesthesia; Aspiration; Gastric content assessment; Surgery; Ultrasound

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During general anesthesia, ensuring an empty stomach is of paramount importance to minimize the risk of regurgitation and aspiration, both of which can give rise to severe and life-threatening complications, including pneumonitis, bronchitis, and acute respiratory distress syndrome (ARDS)[1,2]. The concept of gastric material encompasses the volume and composition of stomach contents, encompassing solid and liquid foods, gastric juice, and other substances[3]. Presently, ultrasound serves as a valuable tool for visualizing the stomach, estimating the volume, and characterizing its contents. This technique is non-invasive, painless, free from the need for contrast agents, and avoids ionizing radiation, rendering it both safe and practical for aiding decisions related to airway management during surgery[4-6].

Studies have corroborated the high sensitivity and specificity of ultrasound in detecting the presence of gastric contents in anesthetized patients. What further enhances its appeal is its ease of acquisition and swift performance, making it an indispensable asset in clinical practice[7,8]. In light of this, it is imperative to recognize that this article delves into the systematic review and meta-analysis research concerning ultrasound and gastric volume assessment. The authors had meticulously reviewed and curated the most pertinent information for discussion, emphasizing that the present work stood on the foundation of existing knowledge in the field.

Aspiration during anesthesia

Regurgitation occurs when stomach contents move up into the patient's throat, whereas aspiration occurs when they move into the lungs, causing a serious pulmonary infection[9]. This complication can occur in patients with a full stomach during surgery, critically ill patients, and those with neurological or swallowing disorders. Aspiration during anesthesia

Correspondence to:

Vichitvejpaisal P.

Department of Anesthesiology, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.

Phone: +66-81-8384393

Email: phongthara@gmail.com

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is particularly dangerous because the airway is unprotected, and sedatives or opioids can inhibit protective reflexes[10].

Preventive measures include preoperative fasting guidelines, avoidance of certain medications, and use of specific anesthetic techniques. The guidelines typically involve a period of fasting before surgery to ensure that the stomach is empty[11]. Traditionally, patients are asked to fast for several hours before surgery. The duration of the fasting period depends on the type of food consumed and the duration of the procedure. For example, patients may be instructed to fast for at least six hours before surgery if they had consumed a light meal or eight hours for a heavy meal[12]. Adherence to fasting guidelines can significantly reduce the risk of aspiration and improve patient outcomes. Other measures to reduce the risk of aspiration during surgery may include using medications to reduce gastric acid production, such as proton pump inhibitors, and certain anesthetic techniques, such as rapid-sequence induction in high-risk patients[13,14].

Gastric content assessment

To minimize the risk of aspiration, anesthesia personnel use information obtained from accurate gastric content assessment to make informed decisions about the appropriate timing for anesthetizing patients, the use of airway management techniques, and the administration of medications. This assessment is crucial to ensure that patients comply with fasting guidelines, considering that factors can affect gastric emptying, such as obesity, pregnancy, diabetes, hiatal hernia, gastroesophageal reflux disease (GERD), gastric outlet obstruction, and some surgeries[6,8,15,16].

High-risk patients can be identified through a thorough history, physical examination, and diagnostic testing. Traditional methods, such as visual inspection, X-ray, and endoscopy, are still used but have limitations, including unreliable results and adverse effects[17-19]. In some cases, a nasogastric tube (NGT) can be used to remove gastric residual volume (GRV), and the characteristics of the content can be assessed to determine the pH and nature of the composition. However, it is an uncomfortable method and not commonly used[17].

Currently, imaging techniques such as ultrasound, computer tomography (CT) scans, and magnetic resonance imaging (MRI) can be used to assess gastric content[20,21]. CT scans and MRI provide more detailed information but require more time and resources. Ultrasound, on the other hand, is a cost-effective, portable option that can be performed quickly and non-invasively. However, the accuracy and reliability of the assessment can be affected by the operator's skill level and technique[22].

Indications for gastric ultrasound

Gastric ultrasound has specific indications in cases where prandial status is uncertain or gastric emptying is delayed. Uncertainty regarding prandial status occurs in patients with acute or chronic cognitive dysfunction, language barriers, or those presenting with unclear medical history, such as pediatric patients. Delayed gastric emptying can occur in systemic pathologies such as chronic kidney disease or diabetes. Additionally, patients experiencing acute pain, obesity, or those treated with systemic medications that may delay gastric emptying, such as opioids, may benefit from gastric ultrasound to guide anesthesia management[23].

Anesthetic management following ultrasound assessment

The anesthetic management in patients at risk of aspiration after ultrasound assessment depends on the clinical situation. In elective cases, the presence of solid food in the stomach will likely result in the deferral of the surgical timing. However, in urgent or emergency situations, the surgery may need to proceed despite the risk of aspiration. In such cases, the anesthetic technique should be tailored to minimize aspiration risk, which could include regional anesthesia, keeping the patient awake, or employing a rapid sequence induction of anesthesia with tracheal intubation[6].

The ultrasound

Ultrasound, also known as ultrasonography, utilizes high-frequency sound waves that bounce off tissues and organs and are then detected by the transducer. The returning sound waves are converted into electrical signals and processed by a computer to create an image. The ultrasound image is based on different densities of the tissues. Dense tissues such as bone reflect more sound waves than soft tissues such as muscle or fat[24].

To perform an examination to determine gastric content, the patient is positioned in a supine position, followed by scanning in the right lateral decubitus (RLD) position (Figure 1). A low-frequency (2 to 5 MHz) ultrasound transducer is then placed on the upper abdomen immediately below the xiphoid process. The transducer is moved in the

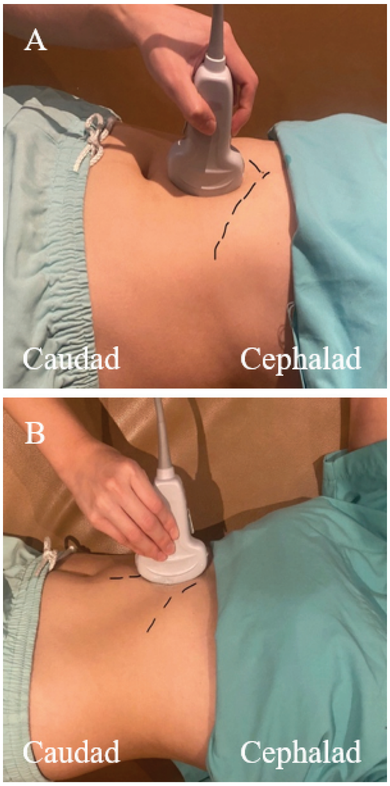

Figure 1. Scanning positions: (A) Supine, (B) Right lateral decubitus.

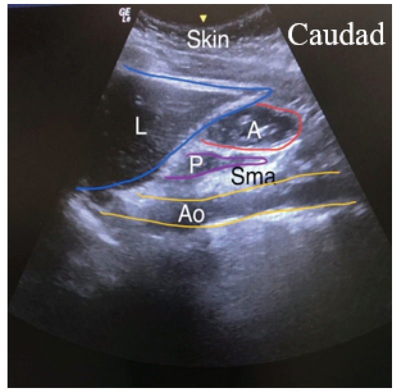

Figure 2. The gastric antrum is situated posterior and inferior to the medial margin of the left lobe of the liver (L), and anterior to the tail of the pancreas (P). Important anatomical landmarks for reference include the aorta (Ao) and the superior mesenteric artery (SMA).

cephalocaudal direction to visualize the stomach. Gastric content can be estimated by measuring the cross-sectional area (CSA) and multiplying it by the length of the antrum[5,25].

The content is identified as empty, clear liquid, or solid. The CSA is measured using a freehand tracing tool built into the ultrasound machine. Gastric volume is calculated using the formula described by Perlas et al., which is Volume (mL) = 27.0 + 14.6 × right-lateral CSA – 1.28 × age[26] (Figure 2-4).

A gastric antrum that is empty or contains less than 1.5 mL/kg of clear fluid is consistent with a state of fasting, whereas a volume of 1.5 mL/kg or more of clear fluid or solids is consistent with a full stomach[5,27].

Medical applications and impact of ultrasound in various specialties

Ultrasound has many medical applications, including obstetrics, gynecology, cardiology, urology, gastroenterology, and many others. In obstetrics, ultrasound monitors fetal development and detects abnormalities, whereas in cardiology, it evaluates the structure and function of the heart. In urology,

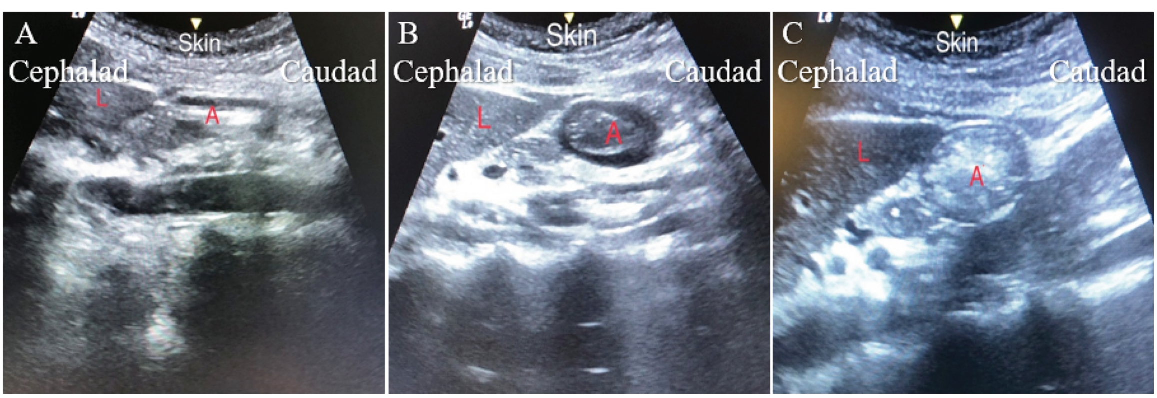

Figure 3. In the sagittal plane: (A) the antrum appears flat and collapsed or takes on a round-ovoid shape (resembling a bull's eye) when the stomach is empty. (B) The antrum appears distended with hypoechoic or anechoic content (indicated by a black arrow showing gastric residue floating), with small gas bubbles creating a starry night-like appearance, typically seen after the ingestion of clear liquids. (C) The antrum exhibits a 'ground glass' or 'frosted glass' appearance following the consumption of solid food.

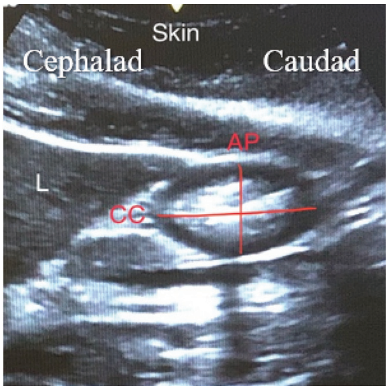

Figure 4. The craniocaudal (CC) and anteroposterior (AP) diameters in the antrum are utilized to calculate the cross-sectional area (CSA) in the right lateral position (RLP). The formula for calculating CSA is CSA = $(\pi \times CC \times AP)/4$, where π is approximately 3.14.

ultrasonography is useful for diagnosing kidney and bladder tumors[24].

In addition to producing images, Doppler ultrasound can also measure blood flow and tissue stiffness. This technique detects changes in the frequency of sound waves as they bounce off moving blood cells or tissues, making it useful for diagnosing conditions such as blood clots, deep vein thrombosis, and peripheral arterial disease[28].

Ultrasound has emerged as a successful method for assessing gastric contents in anesthetized patients. Johnson et al. conducted a study revealing that ultrasound demonstrated a sensitivity ranging from 95% to 100% and a specificity of 87.5% to 90% in identifying liquids within the gastric region[7]. Additionally, Holtan-Hartwig et al. discovered that during rapid sequence induction of anesthesia, gastric ultrasound assessment indicated no elevated risk of aspiration in half of the patients[29]. Shorbagy et al. further reported a reduction in the incidence of aspiration, with a subsequent 31.1% change in the risk assessment and anesthesia technique following routine gastric ultrasound examination[30]. Similarly, van de Putte et al. observed that the implementation of ultrasound resulted in a 64.9% alteration in aspiration risk assessment and anesthetic management[31]. These findings collectively demonstrate the potential of ultrasound to enhance the evaluation of gastric contents and subsequently influence risk assessment and anesthesia techniques.

Advantages

Ultrasound has several advantages in peri-operative gastric content assessment. First, it can be performed at the bedside and used for continuous monitoring, especially in emergency situations with patients at a high risk of aspiration, such as those with delayed gastric emptying or gastroparesis, or when rapid assessment is necessary. It does not require the patient to be transported to a specialized imaging suite or operating room, and does not use ionizing radiation, sedation, or contrast agents, which can reduce the risk of adverse events and make the procedure more comfortable for patients[4-6,8].

Second, although ultrasonography requires training and expertise[22], it is considered a user-friendly method for gastric content assessment. The real-time visualization produced by ultrasound is easy to interpret, and the results can be obtained quickly, allowing for timely decision-making[6].

Third, bedside ultrasound allows for better communication between physicians and patients, which can help alleviate anxiety and improve patient comfort. Thus, it can be used to guide procedures such as the placement of a biopsy needle, feeding tube, or NGT for gastric decompression or aspiration, which can improve the safety and efficacy of these procedures[32,33].

Fourth, healthcare providers can use ultrasound to measure the thickness of the gastric wall at different locations, which can be a sign of abnormalities or pathological changes such as gastric tumors, polyps, or inflammation[34].

Finally, ultrasound is a cost-effective method for gastric content assessment, particularly when compared to more invasive methods such as endoscopy. Ultrasound does not require specialized equipment or personnel, and it can be performed quickly and easily, reducing the overall cost of the procedure[18,26,35].

Limitation

The quality of ultrasound images requires a trained and experienced operator knowledgeable about image acquisition techniques, normal gastric anatomy, appearance of different types of gastric contents, and how to adjust for patient factors that can affect accuracy[22,36]. The operator should also be aware of the limitations of ultrasound and know when additional methods may be necessary, such as a limited ability to detect solid or fatty contents and inability to assess the lower gastrointestinal tract. Moreover, proper use and maintenance of the equipment as well as minimizing the risk of injury to the patient are also important[6,37].

Ultrasound has a limited field of view, which means that only a portion of the stomach can be visualized at a time, particularly if the content is not evenly distributed throughout the stomach. Additionally, patient intolerance due to discomfort or anxiety can make it more difficult to visualize the stomach and its contents, and the type of ultrasound machine used can affect the accuracy of gastric content assessment[6,7].

Although ultrasound can accurately detect liquid gastric contents, it may not be as reliable in detecting solid or fatty contents, particularly in individuals who have consumed a high-fat meal or those with delayed gastric emptying[20].

Ultrasound may also not be feasible or may be more challenging in certain situations, such as in obese patients, because the thickness of the abdominal wall, bowel gas, or abdominal distension can cause shadows or artifacts that may make it difficult to visualize the contents or in patients with implantable devices such as pacemakers that can interfere with ultrasound waves. Other factors include body habitus or the presence of structures such as bowel gas or bone, which can obstruct ultrasound waves[23,38].

Additionally, there are situations in which endoscopy or radiography may be necessary to confirm the ultrasound results. For example, patients with delayed gastric emptying may have an uneven distribution of gastric content, which makes it difficult to obtain a comprehensive assessment. Patients with a history of GERD or esophageal stricture are at high risk of aspiration during airway management. In addition, altered gastric anatomy due to bariatric surgery or gastric bypass can make it challenging to obtain clear and accurate images of the gastric content. Finally, patients with suspected or known gastrointestinal obstruction may have an altered distribution of gastric content[19,39].

Potential future

One area of development is the integration of artificial intelligence (AI) into the ultrasound process. AI algorithms can analyze ultrasound images in real time and provide automated assessments of the gastric content. This could help reduce the need for highly trained operators and improve accuracy. In addition, AI has the benefit of standardizing the assessment process and ensuring consistency across different operators and clinical settings[40,41].

Another potential development is the use of virtual reality (VR) technology for ultrasound training and assessment. VR can provide a realistic simulation of ultrasound procedures, allowing trainees to practice and develop their skills in a safe and controlled environment. Additionally, VR can help overcome the limitations of ultrasound, such as difficulty in visualizing certain structures or anatomical variations[42].

The integration of AI and VR technologies into the ultrasound process can further improve the accuracy and feasibility of ultrasound. These developments have the potential to improve patient outcomes while also expanding the accessibility of remote training and assessment, improving access to ultrasound training, and reducing the need for in-person training[42,43].

Other potential developments in the use of ultrasound include the use of contrast agents to enhance the visualization of gastric content and the development of more portable and user-friendly ultrasound devices[44].

Conclusion

Ultrasound is a promising method for gastric content assessment in anesthetized patients. It is non-invasive, readily available, and can provide real-time visualization of the stomach, allowing for accurate and efficient assessment. It can help reduce the risk of aspiration and other complications while also minimizing the duration of preoperative fasting and the need for more invasive methods.

However, there are limitations to ultrasound, such as the need for a trained and experienced operator and the potential for inaccuracies in certain situations. It is important to use ultrasound in conjunction with other methods to confirm assessment in certain situations.

Future directions for the use of ultrasound include the integration of AI, VR technology, and machine learning algorithms into the process of gastric content assessment. The use of contrast agents and more portable devices could further improve the accuracy and feasibility of ultrasound. These developments have the potential to improve patient outcomes and safety during surgery while also expanding the accessibility of ultrasound training and assessment.

What is already known on this topic?

It is crucial to have an empty stomach in anesthetized patients to minimize the risk of regurgitation and aspiration, which can lead to serious complications.

Gastric content assessment is important to determine the volume and nature of stomach content and guide decisions regarding airway management during surgery.

Traditional methods of gastric content assessment, such as visual inspection, X-ray, and endoscopy, have limitations.

Ultrasound has emerged as a non-invasive, safe, and practical tool for visualizing the stomach and estimating gastric content in anesthetized patients.

Studies have shown that ultrasound is highly sensitive and specific for identifying the presence of gastric content.

Ultrasound is easy to learn, can be performed quickly, and has become a valuable tool in clinical practice for assessing gastric content.

What does this study add?

This study highlights the advantages of ultrasound in perioperative gastric content assessment, including its bedside availability, non-invasiveness, lack of ionizing radiation, and absence of sedation or contrast agents. Ultrasound is considered user-friendly, provides real-time visualization, and allows for timely decision-making.

It can be used for continuous monitoring, especially in high-risk situations or emergencies, and can guide procedures such as the placement of tubes for gastric decompression or aspiration. Ultrasound is cost-effective compared to more invasive methods like endoscopy.

This article also acknowledges the limitations of ultrasound, including the need for a trained operator, difficulty in visualizing certain structures or content, and the potential need for additional methods in specific situations.

It suggests potential future developments, such as integrating AI algorithms into the ultrasound process for automated assessments and using VR technology for training and assessment. The use of contrast agents and the development of more portable and user-friendly ultrasound devices are also mentioned as potential advancements in the field.

Conflicts of interest

The authors declare no conflict of interest.

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