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REVIEW ARTICLE

# Ultrasound to guide the individual medical decision by evaluating the gastric contents and risk of aspiration: A literature review

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A B S T R A C T

Pulmonary aspiration of gastric contents is one of the most terrible complications following general anesthesia. It is important for patients to prevent this complication by obeying the preoperative fasting protocol strictly. At present, it has been reported by many studies that bedside ultrasound, as a non-invasive and convenient method, could be used to evaluate gastric contents qualitatively and quantitatively. With the advantages of reliability, accuracy and repeatability, it can greatly reduce the risk of aspiration and ensure patients' life security. But most of the data were acquired from the healthy volunteers. For the gastrointestinal disorder, the pregnant women, obesity, children, the elderly and diabetes patients, the accuracy and reliability of ultrasound to predict the risk of aspiration remains to be identified by more further studies. For these patients with increasing risk of aspiration, I-AIM (Indication, Acquisition, Interpretation, Medical decision-making) framework plays an important role in ensuring the safety of patients. It is crucial to make appropriate clinical decisions by evaluating the gastric contents with ultrasound.



## 1. Introduction

Pulmonary aspiration is one of the most serious causes of death among general anesthesia. It was reported that the incidence of this complication was 0.1%–19%, and the mortality was up to 9%.[1] Since the birth of modern anesthesiology, there have been some reports of aspiration. In 1848, James Simpson reported a case of death caused by aspiration.[2] In 1946, Mendelson reported the incidence of aspiration was 0.15% in obstetric anesthesia.[3] Aspiration of large amounts of solid or liquids with low pH often leads severe respiratory symptoms. It will lead a higher mortality when the total amount of aspiration is greater than 25 ml or 0.4 ml/kg and pH is less than 2.5.[4] With the rapid development of modern anesthesiology, perioperative safety of patients has been greatly guaranteed. However, pulmonary aspiration is still the primary cause of death and disability lead by anesthesia.[5] In recent years, the application of ultrasound has improved the safety and quality of anesthesia by helping anesthesiologists to make effective preoperative evaluation, intraoperative monitoring and postoperative follow-up.[6]

Ultrasound can also be used to guide anesthesiologists to adopt more appropriate strategies to reduce aspiration by evaluating the nature and volume of gastric contents.[7] A study showed that with proper training (examination may be repeated 33 times), the success rate could reach to 95% in evaluation of the nature of gastric contents. This also showed gastric ultrasound could be easily mastered by anesthesiologist.[8]

## 2. Methods

This literature was conducted by searching the databases including PubMed, EBSCO, Springer, Science Direct and China National Knowledge Infrastructure (CNKI). Key searching words included ultrasound, anaesthesia, pulmonary aspiration, gastric volume, gastric content, gastric antrum, fasting, water-deprivation, risk stomach, pregnancy, obesity, advanced age and diabetes.There were no limits on the type of article and date of publication. A full-text assessment of 89 were included in the final review. We summarized methods for assessing gastric volume and risk of

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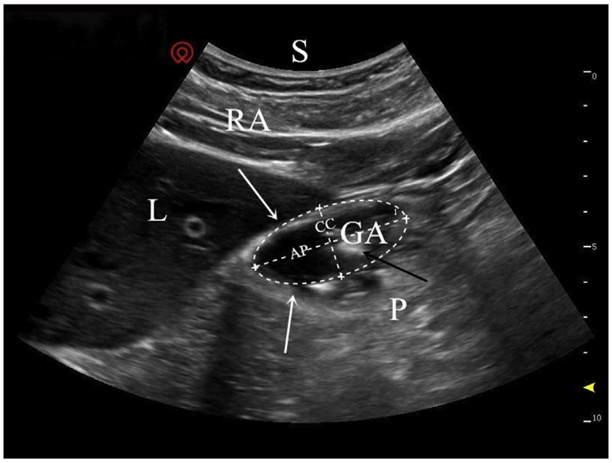


**Fig. 1.** The antrum after 5min of taking 400ml clear water. Note the hypoechoic (The white arrows).The black arrow shows gastric residue floating in water. AP: antero posterior diameter; CC: craniocaudal diameter; S: skin; RA: rectus abdominis; L: liver; GA: gastric antrum; P: pancreas.

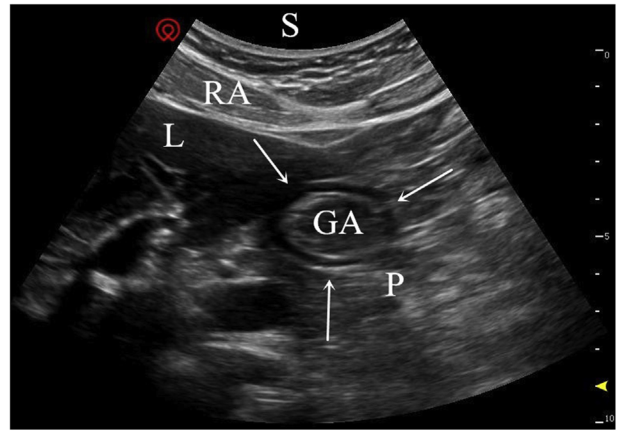


**Fig. 2.** In the sagittal plane, the antrum resembles an bull's eye when stomach is empty (white arrows). S: skin; RA: rectus abdominis; L: liver; GA: gastric antrum; P: pancreas.

aspiration, and concluded how the medical decisions made by the results from ultrasound.

## 3. The evaluation of antrum area by ultrasound

Theoretically, it includes the body, fundus and antrum of the stomach that can be evaluated by ultrasound. However, it is difficult to image the entire section of the gastric body for the air of the stomach. For the great depth and the lack of a large acoustic window in the chest, the fundus becomes the most difficult part of the stomach to image. Several studies showed that the antrum was the best area to be evaluated by ultrasound. The probability that gastric antrum can be detected was 98%–100%. The cross-sectional area (CSA) of antrum can reflect the whole gastric volume (GV), and a remarkably positive correlation existes between CSA and GV.[9] CSA is the most important parameter to measure GV.[10] To make the data more accurate, some details should be paid attention to when measuring CSA. The time of antrum measurement should be restricted to the systolic intervals of stomach and the measurement of CSA should include the serous layer.[10] In 1980s, Bolondi L et al proposed that the ultrasonic section of gastric antrum was an ellipsoid, and the section area could be obtained by the antero posterior (AP) diameter and craniocaudal (CC) diamete. The calculation formula was $CSA = AP \times CC \times \pi$.[7] (Fig. 1).

## 4. Body positions

At present, there are three body positions to measure CSA, namely supine position (SP), right lateral position (RLP) and semi-decumbent position. However, it was generally accepted that the best position for scanning was RLP, since antrum was at the lowest point of the stomach in this position. And compared with SP, there was a better correlation between CSA and GV in RLP.[11] A study was conducted in both SP an RLP, which showed that the RLP could maximize the sensitivity and specificity of ultrasonic scanning results. It also proposed that the RLP was the best position for ultrasonic scanning of antrum.[12,13]

## 5. Measurement of GV

There are many methods to evaluate GV and gastric emptying, such as acetaminophen absorption, electrical impedance tomography, radiolabeled diet, polyethylene glycol dilution, and gastric contents aspiration. Suction by stomach tube could provide more accurate information about the process of gastric emptying and it was often used to verify the accuracy of other methods.[14] While this method was quite complex and highly invasive, required repeated intubation. Moreover, it was more suitable for detecting the liquid rather than solid.[15] Nuclide scanning is regarded as the gold standard to study the gastric emptying, but its disadvantages such as radiation, high cost have limited the availability in clinical applications.[16] Ultrasound could achieved the same clinical effect as the gold standard nuclide scanning to evaluate gastric emptying.[16]

## 6. Feasibility of evaluation by ultrasound

A study showed that with proper training (examination may be repeated 33 times), the success rate could reach to 95% in evaluation of the nature of gastric contents by ultrasound. This also showed that gastric ultrasound could be easily mastered by anesthesiologist.[8] There also existed high reliability to evaluate gastric contents in the third trimester of pregnancy and the consistency reliability was 0.74.[17] An ultrasonic operation in 15 subjects by two independent sonographers suggested that antral assessments were highly reproducible. The difference in gastric volume measurement by the two observers just ranged from 1 to 13ml on an empty stomach, and that ranged from 2 to 85ml after a standard meal.[18] Ultrasonic evaluation should be focused on the nature and the amount of gastric contents. Therefore, the following questions should be identified: (1) whether the patient had an empty stomach before surgery? (2) if not, what was the kind of food (the nature of food such as soft drinks, digestible food or solid food)? (3) how much was the food in stomach and whether it would increase the risk of pulmonary aspiration after general anesthesia? To solve the problems above, there were three methods to evaluate gastric antrum, namely qualitative assessment, semi-quantitative assessment and quantitative assessment.

## 7. Qualitative assessment

In an empty stomach, the antrum is flat. In the sagittal plane, the antrum is round or oval, resembling an bull's eye (Fig. 2). In the coronal plane, the empty antrum looks like a gloved finger.[13,19] The liquid including clear water, clear beverage, apple juice, black coffee and gastric fluid displayed the character of low or no echo (Fig. 1).

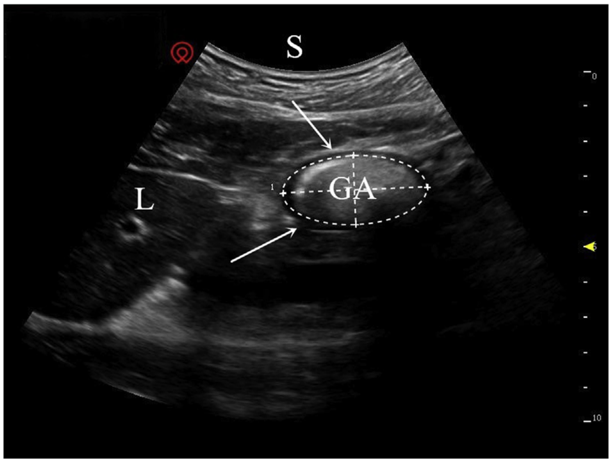


**Fig. 3.** Antrum resembles "ground glass" in the sagittal plane after 5 minute after taking about 100 g solid food (white arrows). S: skin; L: liver; GA: gastric antrum.

When drinking a large amount of liquid, the antrum can expand obviously.[13,20] With gastric peristalsis, the clear liquid will mixe with the air in the stomach, leading a large number of bubbles. That will produce a scene of "all over the sky star".[20] The shape of the gastric antrum containing viscous drinks including milk, thick liquid, and slaggy beverage is similar to that with clear liquid, showing a round or oval appearance. However, the former demonstrates homogeneous hyperecho without bubbles, which is the main distinction between viscous drinks and clear water.[13] After ingesting solid food, food debris will mix with a large amount of air as chewing and swallowing, making the antrum resemble "ground glass" in the sagittal plane (Fig. 3). With the continuous progress of gastric digestion, the gas mixed with food will gradually disappeare.[13]

## 8. Semi-quantitative assessment

Gastric antrum is evaluated in both SP and RLP, and GV can be estimated according to the scan results.[21] According to the results, patients can be divided into three grades (Table 1). Grade 0: Nothing can be seen under either position, indicating that stomach is empty. Grade 1: Nothing can be seen in SP, but gastric contents are visible in RLP. Grade 2: Gastric contents are visible in both positions.[22] A prospective study showed the Mean±SD of gastric volume was 0±2ml in patients with Grade 0, which could be regarded as an empty stomach. There were less than 100 ml of gastric juice in 75% patients of Grade 1. This study also showed that GV of Grade 2 were about 2.8 to 180 ml, 75% patients of Grade 2 had a GV greater than 100ml, and 50% patients of Grade 2 had a GV greater than 250ml.[21] Another study reported Grade 1 combined with CSA<340mm$^2$ can be regarded as an empty stomach. It could be regarded as the intermediate gastric contents between full stomach and empty stomach,[23] indicating that GV was larger than 0.8 ml/kg and it was more likely to cause aspiration when complicated with difficult airway, coughing/straining and gastroesophageal reflux.[24]

## 9. Quantitative assessment

Quantitative evaluation of GV is based on CSA. Several studies have shown that CSA increased proportionally with the amount of GV.[9,22] A linear correlation exists between GV and CSA, which was more significant in the RLP.[25] Bouvet reported a predictive model based on a prospective observational study of 183 patients in the semi-sitting position. This model was suitable for non-pregnant adults, and the correlation coefficient was 0.72.[9] Perlas proposed a more accurate model in RLP based on the results from a study of 108 adult subjects. The correlation ($r = 0.86$) between CSA and GV was stronger in this model. It was suitable for the non-pregnant adult with body mass index (BMI) less than 40 kg/m$^2$ and the age was the only variable left in the formula.[20,22] In another study, the total GV including fluid and air was examined by magnetic resonance imaging (MRI) in healthy children ($r = 0.79$).[25] An equation, showing a negative correlation between GV and fasting time, was calculated.[26]

Spencer and colleagues evaluated GV by endoscopic suction in children undergoing gastrointestinal endoscopy. In their formula, GV to be measured was restricted to positive values. It indicated the stomach was empty when GV was calculated as negative values.[27]

All the formulas above were listed in Table 2.

**Table 1**
A 3-point grading system.

| Grades | Body positions | |
|---|---|---|
| | Right lateral decubitus | Supine position |
| Grade 0 | N | N |
| Grade 1 | Y | N |
| Grade 2 | Y | Y |

Abbreviations: N, gastric contents can't be seen by ultrasound; Y, gastric contents can be seen by ultrasound.

## 10. Limitation of measurement

The original mathematical model to measure CSA was based on data from healthy volunteers who were randomly assigned to take a given volume of water after fasting, but it ignored gastric juices had a base level of secretion before intake, leading a higher CSA.[21] Similarly, Bouvet's mathematical model was established in a double-blind study relying on the data obtained through aspiration of gastric tube, but the data were not completely accurate and reliable depending on the position of gastric tube in the patient's stomach.[9]

## 11. Assessment and treatment of risk stomach

There was still no consensus on the critical valume of risk stomach. It was reported that at least 200ml of GV was required to induce pulmonary aspiration. Bouvet considered GV of 50 ml (or 0.8 ml/kg) as the critical valume for serious aspiration in adults.[28] While in another study, Reide reported that just 10 to 30 ml of GV could lead aspiration in adult patients.[29] Gastric ultrasound was performed on 440 emergency patients prior to induction of anesthesia and a three-piont scoring system could also be used as an important indicator to evaluate the risk of aspiration.[23] In supine position, patients with CSA less than 340mm$^2$ was considered as fasting. On the contrary, a moderate GV greater than 0.8 ml/kg could be identified when CSA was greater than 340mm$^2$.[9] When the GV was less than 0.4 ml/kg, the incidence of vomiting was only 6.7%. Once the volume exceeded 0.8 ml/kg, the incidence of vomiting was as high as 44.1%.[9] Fukunaga et al also measured CSA in 44 patients after endotracheal intubation and analyzed the relationship between CSA and GV. When CSA reached 340mm$^2$, GV would exceed 0.8 ml/kg, which could be a criteria to predict a high risk of aspiration.[30] But a recent clinical trial does not support this conclusion. This study found that GV with a total of 100–130 ml (1.5 ml/kg) was common in healthy fasting subjects and didn't increase the risk of aspiration. In most previous researches, 1.5 ml/kg

**Table 2**
Formulas to calculate GV.

| References | Formula | BP | MR (ml) | Age (y) | BMI (kg/$m^2$) | TC | R | GV Measuring |
|---|---|---|---|---|---|---|---|---|
| Perlas[22] and colleagues | GV(ml) = 27.0 + 14.6 × CSA($cm^2$) -1.28 × Age(years) | RLD | <500 | 18–85 | <40 | Healthy adults | 0.86 | Aspired by UGE |
| Bouvet[9] and colleagues | GV(ml) = -215 + 57 × log[CSA($mm^2$)]-0.78 × Age(years)-0.16 × Height(cm)-0.25 × Weigh-t(kg)-0.80 × ASA(1–4)+16ml/10ml[&] | SRP | <250 | 49 ± 18 | 23 ± 3 | Healthy adults | 0.72 | Aspired by gastric tube |
| Perlas[22] and colleagues | GV(ml) = -372.54 + 282.49 × log[CSA($cm^2$)] -1.68 × Weight(kg) | RLD | <300 | 18–55 | 19–28 | Healthy adults | 0.86 | Drinking a known volume of beverage |
| Schmitz[25] and colleagues | GV(ml/kg) = 0.009 × CSA ($mm^2$)-1.36 | RLD | NR | 6.4–12.8 | NR | Healthy children | 0.79 | MRI volumetry |
| Michiko[26] and colleagues | GV(ml) = -0.78 × fasting time(min)+263.7 | RLD | NR | 31.5 ± 4.9 | NR | Healthy adult | 0.81 | Perlas formula |
| Spencer[27] and colleagues | GV(ml) = -7.8 + 3.5 × CSA($cm^2$)+0.127 × Age(months) | RLD | >0 | 11.8 ± 4.8 | 11.8 ± 4.4 | Children Undergo-ing UGE | 0.77 | Aspired by UGE |

Abbreviations: GV, gastric volume; BP, body position; RLD, right lateral decubitus; SRP, semireclining position; MR, measuring range; BMI: body mass index; NR, not recorded; TC, target crowd; UGE, upper gastrointestinal endoscopy; R, pearson correlation coefficient; MRI: magnetic resonance imaging.
&: 16 ml in case of emergency; 10 ml in case of preoperative intake of 100 ml antacid prophylaxis.

of GV was a more reliable threshold to assess the risk of aspiration.[31–35] Conversely, GV larger than 1.5 ml/kg indicated a non-fasting state (or "full stomach").[22] In emergency patients, there was no correlation between duration of fasting and risk stomach.[23,36] In another study, emergency patients was considered fasting when "2h has elapsed since the last intake of clear fluids and more than 6h have elapsed since the last meal".[37] European and American diet structure and habits are different from that of Asians. Whether these data above apply to Asians remains to be confirmed by a large number of further clinical studies.

For the patients with high risk of aspiration, elective surgery should be delayed or canceled until the stomach meets fasting states evaluated by ultrasound (GV<1.5 ml/kg was considered as low risk of aspiration in most researches). For the emergency operation, the optimal drug pre-treatment with antacids including proton pump inhibitors or $H_2$ blockers was recommended. It has been proved to be effective in reducing the incidence of vomiting when serotonin receptor antagonists and dexamethasone were administrated.[38,39] For these patients, it can also avoid aspiration when general anesthesia is turned to regional block.[40] Rapid sequence induction (RSI) was also recommend in patients with no 2h liquid and no 6h food fasting or acute vomiting, sub-ileus or ileus, or no protective reflexes or a gastrointestinal disorder.[41]

## 12. Application of I-AIM framework

The I-AIM framework is a proper paradigm to guide the clinical practice.[40,42,43] When the gastric contents are unknown or uncertain (Indication), ultrasound images of the stomach could be obtained in a standardized manner (Acquisition). Qualitative and quantitative evaluation (Interpretation) according to the images will be used to guide the medical decisions (Medical decision-making).

### *12.1. Indication to evaluate the risk of aspiration before anaesthesia*

Patients undergoing elective surgery did not follow the fasting guidelines; patients undergiong emergency operation; patients with unknown preoperative fasting status.

### *12.2. Acquisition of ultrasound images*

In both RLP and SP, ultrasound images were acquired in a standardized manner.[40,42,43]

### *12.3. Interpretation according to ultrasound images*

The nature of gastric contents can be evaluated by qualitative assessment.

Gastric volume can be evaluated by semi-quantitative assessment and quantitative assessment.

### *12.4. Medical decision-making*

A low risk of aspiration: the operation should be performed as planned.

A high risk of aspiration (GV>1.5 ml/kg or gastric contents are viscous liquids or solids): for the elective surgery, operation should be delayed or until the stomach meets fasting states; for the emergency surgery, antacids, antemetics, gastrointestinal decompression, RSI should be administrated and regional block was recommended if necessary.

## 13. Status quo of fasting

It is not ideal for the implementation of American Society of Anesthesiologists (ASA) fasting guidelines and the duration of fasting was too long for most patients. In clinical practice, it is generally required that patients undergoing the first elective surgery should start to fast at midnight before operation, while a longer fasting time will exist in patients undergoing the following selective surgery. In 2014, a survey of 292 patients at Edinburgh Royal Hospital found that the median duration of solid fasting for elective patients was 13.5 h and that was 17.8 h for the emergency, far longer than 6–8 h recommended. For the clear beverage, the median duration was 9.63 h for the elective surgery and that was 12.97 h for the emergency, also significantly longer than 2 h recommended.[44] In 2011, a study by the European Society of Anesthesiology also found that most patients fasted longer than the guidelines recommended.[45] In a large multicenter trial in Japan, it was found the duration of water-deprivation and fasting were 6–9 h, 12–13 h respectivly, which was significantly longer than that recommended by ASA. Among the 795 hospitals included, the fasting time was too long in more than 94% of hospitals, which was consistent with the result reported by Morris and Crenshaw.[46,47] In 2018, a Chinese clinical trial reported the average duration of fasting was 14 to 16 h, with a maximum of 21 h and the average duration of water-deprivation was 12 to 14 h, with a maximum of 19 h in 200 patients undergoing elective surgery. A number of clinical trial found that most of the children undergoing general anesthesia also experienced prolonged fasting time longer than that proposed in guidelines.[48] Most doctors and patients hold the tradition that the longer the duration of fasting, the safer the operation.[49] For the difficulty in estimating the specific time when each elective operation starts, the fasting protocol can't be strictly implemented in accordance with the guidelines.[50] Therefore, the duration of fasting for elective surgery is much longer. However, a longer fasting time can lead a series of adverse reactions. First, patients are in a state of insufficient circulation, resulting difficulty in venipuncture and anesthetic management, especially the elderly and infants. Secondly, the continuous thirst and hunger will also cause the patient to stay in stress state, which will reduce the body's insulin sensitivity and lead insulin resistance.[51] However, the enhanced recovery after surgery (ERAS) changed the traditional preoperative fasting protocol. A growing number of studies showed that it was beneficial for the patients to drink a small amount of clear liquid at 2 h before surgery with the exception of patients with delayed gastric emptying.[52,53] Carbohydrate drinks of 800ml could be ingested at 10h before the operation, and the intake of that less than 400ml was also recommended at 2h before the operation.[54] In healthy volunteers, time of gastric emptying was only 30–60 min after drinking clear water of 200–400 ml.[55]

## 14. Evaluation in the special patients

Numerous previous studies have shown that gastrointestinal disorder, pregnancy, obesity, advanced age, diabetes, and emergency surgery are independent risk factors for full stomach by delaying gastric emptying and increasing gastric capacity.[56] For these patients with increasing risk of aspiration, I-AIM framework plays an important role in ensuring the safety of patients. It is crucial to make appropriate clinical decisions by evaluating the gastric contents with ultrasound.

### *14.1. The gastrointestinal disorder*

Ileus is frequently complicated following colon and rectal surgery, leading impaired contractility and motility to extend gastric emptying.[57,58] When ileus is suspected, strict fasting is recommended. Once confirmed, gastrointestinal decompression should be performed. It was also reported by a randomized controlled trial that dexmedetomidine could reduce the risk of aspiration during anesthesia induction in the elderly with intestinal obstruction. Peritonitis can also lead delayed gastric emptying by causing intestinal obstruction. For patients with previous gastrointestinal surgery, function delayed gastric emptying (FDGE) is a common complication of abdominal surgery, especially gastrointestinal resection.[59]

For these patients with increasing risk of aspiration, I-AIM framework plays an important role in ensuring the safety of patients. It is crucial to make appropriate clinical decisions by evaluating the gastric contents with ultrasound.

### *14.2. The pregnant women*

Emergency caesarean sections are common, and adequate duration of fasting often can't be guaranteed. Direct pressure from the pregnant uterus will delay gastric emptying.[60] Sakurai et al monitored parturients by ultrasound and found gastric contents could still be seen in 3 women after fasting for more than 10 h.[61] Other studies have found that compared with non-pregnant women, stomachs of parturient dilated more slowly and gastric emptying delayed more obviously after meals.[62] For the effects of hormone levels and the growing uterus, the axis of the stomach will rotate nearly 45° to the right from its normal horizontal position.[22,63] As a result, the location and shape of the antrum may change. If so, CSA of 340mm$^2$ is not suitable for evaluating the risk stomach of parturient women.[64] At the same time, the increasing pressure of the stomach will delay gastric emptying and lead aspiration easier to occur in pregnant women.[65] There was no significant difference to evaluate CSA between before and after cesarean section under RLD, suggesting that the accuracy of CSA was higher under this position.[66] One study showed that the three-point scoring system could still be used to assess the risk of aspiration for the pregency.[67] For the unipara, there was a positive correlation between GV and three-point scoring system: 0.4 ml/kg(Grade 0), 1.0 ml/kg(Grade 1), and 2.7 ml/kg(Grade 2). However, these data are only calculated from a mathematical model rather than clinical practice, needing to be verified by further clinical studies.[64] For full-term women strictly following the fasting protocol, the normal upper limit of CSA to evaluate risk stomach was 10.3 cm$^2$ in RLD.[64] It may prolong the time of ultrasound scanning in the emergency parturient under this position. In 2016, a study to rapidly evaluate the GV suggested that CSA of 381mm$^2$ was the critical value to evaluate risk stomach of pregnant women in the supine position.[68]

### *14.3. The children*

Subjective sense of thirst or hunger can not be used as a method to judge empty stomach and bedside ultrasound is the only noninvasive technique to estimate gastric volume in infants.[69] Recent research indicated that the past recommended fasting time might be too conservative, while ultrasonography before anesthesia played an important role in assessing the risk of aspiration in pediatric patients.[27] A recent study of 100 children (11 to 216 months) showed that CSA had a good correlation with the total GV in both supine and right decubitus positions, and the three-point scoring system could also reflected GV. There were no events of aspiration during anesthesia when the time of water-deprivation was shortened to 2.0, 2.5 and 3.0 h. While there was no hunger or thirst when the time was shortened to 2 h.[70] Studies have shown that it didn't increase the incidence of aspiration and could reduce the incidence of adverse reactions when children were allowed to drink an appropriate amount of non-residue apple juice at 2 to 3 h before general anesthesia.[71,72] For the children, it does not increase the risk of aspiration, but can relieve thirst and improve patients' satisfaction when drinking a proper amount of water at 2 h before surgery.

### *14.4. The obesity*

Since the obesity is an independent risk factor for full stomachs and airway management may be difficult in these patients, preoperative gastric ultrasound is recommended to assess the risk of aspiration.[23] For the obesity, it is more difficult to conduct ultrasonic examination, requiring more excellent ultrasonic skills.[73] However, in the majority of the obese patients, the gastric antrum is identifiable. While the increase of depth and fat reduced the accuracy of bedside ultrasound in locating the boundary of gastric antrum, making the examination more challenging.[74] In overweight patients, GV will be overestimated by bedside ultrasound when total volume is less than 150 ml, which is related to the thickening of gastric wall.[75] The risk of aspiration can still be assessed by ultrasonography in extremely obese patients. Although the BMI may be more than 40kg/m2, the three-piont scoring system by Perlas is still valid to assess the risk of aspiration.[74]

### 14.5. The advanced age

Old age was considered to be an independent risk factor for delayed gastric emptying.[76] Elderly people are prone to symptoms of stomach dysfunction such as anorexia and dyspepsia, which may be related to decreased gastric peristalsis and delayed gastric emptying.[77] It was reported by another study that these symptoms might be related to long-term hyperglycemia, hypertension, microvascular disease.[78] Kupfer and Evans et al found that gastric emptying time of liquid was significantly shorter in the elderly.[79,80] Klingensmith et al measured gastric emptying time in 12 healthy volunteers by using oatmeal and found that there was a clear correlation between gastric emptying and age. In other words, advanced age would increase the time of gastric emptying.[81] As a result, older people who fasted strictly according to the guidelines are still at risk of aspiration and preoperative reassessment of gastric contents by ultrasound is recommended.

### 14.6. The diabetes

Diabetes is a common endocrine and metabolic disease, complicated with diabetic gastroparesis, known as gastric paralysis.[82] Lyrena et al found that the occurrence of diabetic gastroparesis may be related to long-term sustained hyperglycemia.[83] Therefore, the disorders of gastric emptying often appear in diabetic patients.[84,85] In the fasting state, induced hyperglycemia can reduce the activity of gastric antrum, and cause delayed gastric emptying.[86] RayneI et al showed that hyperglycemia could prolong gastric emptying in diabetic patients with more than 5 years.[87] Recent studies have also shown that there was a complex relationship between gastric emptying and blood glucose and gastric emptying was regulated by blood glucose.[88] The delay of gastric empting may be related to the high blood glucose in the body. Conversely, low blood glucose can accelerate gastric empting. The frequency of gastric contraction decreased significantly in patients with hemoglobin A1c more than 7%, leading a high incidence of delayed gastric emptying, while the risk score of aspiration increased significantly ($P<0.01$).[89]

## 15. Conclusion

Regurgitation and aspiration is a serious threat to the safety of patients and the risk could be decreased by a long fasting time. While with the development of ERAS, anesthesia doctors have gradually realized the disadvantages (such as hunger, thirst and insulin resistance) lead by the inappropriate fasting time. As a result, fasting protocol recommended by ASA will provide a balance between decreasing the risk of aspiration and keeping a normal physiological function. However, it is carried out not ideally for the concerns that the reduced fasting time could increase risk of aspiration. Current studies have shown that bedside ultrasound can provide reliable information about the volume and nature of gastric contents. With this technology, anesthesiologists can make individual decision to minimize the risk of perioperative aspiration. I-AIM framework directed by ultrasound also provided a standard procedure to diagnose and treat the patients with high risk of aspiration. It will benefit the implementation of proper fasting protocol. However, a best fasting protocol still remains to be answered by more clinical studies in the future.

## Declaration of competing interest

Gang Zhang, Xiaoyan Huang, Yunhua Shui, Chunqiong Luo and Lan Zhang declare that they have no conflict of interest.

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