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Ultrasonic assessment of gastric solid contents in patients undergoing upper endoscope with sedation

Jing Wang¹, Xuan Yu¹, Ying Wang², JieLei Xu¹, Zhao Wang¹ and Yi Zhang^{1*}

Abstract

Background Perioperative reflux aspiration presents a grave concern during sedation or general anesthesia, particularly when solid gastric contents prompt acute upper respiratory obstruction, potentially resulting in fatal consequences for patients. Currently, there are limited means for promptly assessing solid gastric contents in clinical settings. Therefore, this study examined the efficacy of ultrasound assessment for solid gastric contents, offering a rapid and non-invasive approach for early detection and decision-making regarding interventions.

Methods The study included 400 patients scheduled for upper endoscopy procedures, which encompassed both gastroscopy and gastroscopy combined colonoscopy examinations with sedation. Ultrasound scanning of the antrum was performed while patients were positioned semi-sitting or in the right lateral decubitus (RLD) posture. The evaluation of solid gastric contents relied on direct visual observation during endoscopy. Gastric volume measurement occurred subsequent to endoscopic suction of gastric contents. Receiver operating characteristic curves were utilized to assess the effectiveness of ultrasonography in discerning solid contents.

Result Seven patients undergoing gastroscopy with sedation were found to have solid gastric contents. The sensitivity, specificity, positive predictive value, and negative predictive value of the ultrasound qualitative evaluation of solid contents were 85.7%, 99%, 60%, and 99.7%, respectively.

Conclusion Solid stomach contents can be evaluated qualitatively with reasonable accuracy using ultrasonography. Additionally, in patients undergoing upper endoscopy and assessed to have solid gastric contents with ultrasound, administration of mild sedation is recommended.

Trial registration www.chictr.org.cn (ChiCTR2100048994); registered 19/07/2021.

Keywords Gastric solid contents, Gastric ultrasound, Upper endoscope

*Correspondence:

Yi Zhang
zyzy@zmu.edu.cn

¹Department of Anesthesiology, the Second Affiliated Hospital of Zunyi Medical University, Intersection of Xinglong Avenue and Xinpu Avenue, Zunyi 563000, Zunyi, China

²Department of the Second Clinical College, the Second Affiliated Hospital of Zunyi Medical University, Zunyi, China



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Introduction

Pulmonary aspiration with gastric residues is a serious complication during sedation or general anesthesia that may lead to irreversible consequences, such as death or a fatal injury. In an investigation of closed claims following aspiration, it was revealed that two out of every three patients died or suffered permanent serious injury following aspiration [1]. The quantity and nature of the gastric residues are associated with the severity of pulmonary damage following aspiration. Acute airway blockage owing to aspiration of particles can result in hypoxia and mortality [2], and according to animal research, an adult's threshold for serious aspiration incidents is approximately 50 mL [3]. A full stomach is defined as having gastric fluid $>1.5 \text{ mL}\cdot\text{kg}^{-1}$ or solid gastric contents, and it is correlated with an increased risk of pulmonary aspiration [4, 5]. Due to the suppression of throat reflexes during sedation and the absence of a device to safeguard against airway obstruction, patients undergoing upper endoscopy, which includes both gastroscopy and gastroscopy combined colonoscopy procedures, are at an elevated risk of pulmonary aspiration if they experience delayed gastric emptying due to gastrointestinal conditions (such as gastric surgery or deformities), pain, medication (such as opioids), or comorbidities (such as diabetes or Parkinson's disease) [6]. A retrospective analysis on the occurrence of pulmonary aspiration during procedural sedation showed that 229 incidences occurred during gastrointestinal endoscopy and 34 occurred during other events [7].

The limitations of previous methods in determining gastric emptying, such as fasting duration, measurement of serum paracetamol concentration [8], and standardized gastric emptying scintigraphy using a $^{99\text{m}}\text{Tc}$ -sulfur colloid [9], have been overcome by the bedside ultrasound, which can also assess the characteristics and volume of gastric contents. The contents of the gastric antrum can be qualitatively assessed using ultrasound, allowing for differentiation between an empty stomach, liquids, and solids. The 3-point scale suggested by Perlas et al. [10], relying on qualitative evaluation of the gastric antrum, demonstrates a strong correlation with gastric volume. Ultrasound measurements of the RLD antrum cross-sectional area have previously been validated to be effective in predicting gastric volume $>1.5 \text{ mL}\cdot\text{kg}^{-1}$ [11], however, it is unknown whether the gastric ultrasound can effectively diagnose or rule out the presence of solid gastric contents in patients undergoing upper endoscopy with sedation.

The objective of this study is to determine the ability of ultrasound to qualitatively detect solid gastric contents in patients undergoing upper endoscopy with sedation.

Methods

Ethical approval for this study (KYL-2022-010) was provided by the Ethical Committee of the Second Affiliated Hospital of Zunyi Medical University. This trial was registered at the Chinese Clinical Trials Register prior to patient enrollment (ChiCTR2100048994), and written informed consent was obtained from the participants. Patients scheduled for a gastroscopy or gastroscopy combined colonoscopy were enrolled in this prospective study from February to December 2022. The inclusion criteria were as follows: age ≥ 18 years, physical status I–III according to the American Society of Anesthesiologists, a minimum 2-h drinking limit, and an 8-h time without solid food. The exclusion criteria were as follows: pregnancy, sedative allergies, and existing upper gastrointestinal hemorrhage or lesions, such as achalasia of the cardia and hiatus hernia.

Patients who are scheduled for a gastroscopy combined colonoscopy should consume polyethylene glycol electrolyte powder (a medication for clearing intestinal residue) mixed with 2000 mL of water or soft drinks and consumed within 2 h at 8 pm a day prior to the examination. Another 1000 mL of the electrolyte solution was consumed within an hour at 4 am on the day of the examination, whereas patients who are scheduled for a gastroscopy do not need to consume the electrolyte. Additionally, 10 mL of a local anesthetic was administered to each patient to clear the gastric froth before ultrasound and endoscopy and to anesthetize the larynx.

Ultrasound examination

After securing informed consent from the patients, they underwent assessment using ultrasonography. This examination began with the patients in a semi-sitting posture, with particular attention to the detection of gastric contents, which have been shown to be more reliably detected in this position [12]. The assessment was then completed with the patients placed in the RLD position. To perform the ultrasonography, a low-frequency transducer with a range of 2–5 MHz and a color Doppler ultrasound device equipped with image-compounding technology (Model M-9, Mindray, Shenzhen) were employed. The location of the gastric antrum, situated in the sagittal plane of the upper abdomen, was identified with reference to anatomical landmarks such as the superior mesenteric artery, the liver, or the abdominal aorta [13]. All ultrasound screening and evaluation procedures were conducted by an experienced anesthesiologist with two years of expertise in stomach ultrasound.

Based on qualitative sonographic observations, the contents within the gastric antrum were categorized into three groups: “nothing” (indicating a flat anterior wall adhered to the posterior wall of the antrum), “clear fluid” (characterized by an expanded antrum with hypoechoic

contents), or “solid” (noted as an enlarged antrum with hyperechoic contents or mixed echogenicity) [12]. The grading system was used to quantify the amount of stomach fluid. In this scale, “Grade 0” signified the absence of liquid in both positions, “Grade 1” denoted a small quantity of liquid observed in the RLD position, and “Grade 2” indicated the presence of liquid in both positions, suggesting a higher volume.

Finally, patients were repositioned in the left lateral decubitus position for endoscope, and the gastroenterologists performing the procedure were kept unaware of the previous ultrasonographic findings. The evaluation of solid gastric contents relied on direct visual observation during endoscopy. The exact quantity of stomach contents was aspirated during endoscope.

Outcomes

The primary results were as follows: (a) the ability of ultrasound to perform a qualitative assessment of the solid gastric contents.

The secondary results comprised the following: (a) the frequency of satiety, (b) the distribution of antrum grades 0–2, and the comparison of suctioned volume in

patients undergoing gastroscope and gastroscope combined colonoscopy; and (c) the recording of adverse events.

Statistical analysis

Measurement data with non-normal distribution were presented as median and interquartile ranges using the Shapiro–Wilk test. Group comparisons were analyzed using the Mann–Whitney U test. Frequency data were given as counts (with percentages and 95% confidence interval [CI]) and compared across groups using the chi-square test or corrected chi-square test. The receiver operating characteristic curves (ROC) were constructed to measure the ability of ultrasound to qualitatively assess a solid stomach contents. IBM SPSS for Windows version 26.0 (IBM Corp, Armonk, NY, USA) was used for statistical analysis, and a p -value < 0.05 was considered statistically significant.

Results

Demographic characteristics

In both the semi-sitting and RLD positions, the antrum could not be detected in 12 out of 400 participants. The remaining 388 patients were also examined, and the demographics and main endoscopic findings are displayed in Table 1.

Table 1 Demographics characteristics of 388 patients include in this study. Data are expressed as the median (interquartile range)

Age	52 (25)
Sex, n/total N (%)	
Male	174 /388(45%)
Female	214 /388(55%)
BMI ($\text{kg}\cdot\text{m}^{-2}$)	23 (5)
Fasting interval for solids (h)	16 (4)
Fasting interval for fluid (h)	12 (10)
Suctioned volume (mL)	15 (30)
Suctioned volume ($\text{mL}\cdot\text{kg}^{-1}$)	0.3 (0.5)
Co-morbidities, n/total N (%)	
Diabetes	17/388(4.4%)
Hyperlipidemia	25/388(6.4%)
Obesity	33/388(8.5%)
Chronic renal disease	10/388(2.6%)
Endoscopy findings, n/total N (%)	
Reflux esophagitis	169/388 (44%)
Chronic atrophic gastritis	37/388 (9.5%)
Chronic atrophic gastritis with bile regurgitation or/and erosion	33/388 (8.5%)
Chronic non-atrophic gastritis	149 /388(38.4%)
Chronic non-atrophic gastritis with bile regurgitation or/and erosion	150/388 (38.7%)
Duodenal bulbar inflammation or/and ulcer	61/388 (15.7%)
Antral mucosa inflammation or/and ulcer	30 /388(7.7%)
Gastric retention	7/388 (1.8%)
Others	32/388 (8.2%)

BMI=body mass index; IQR=interquartile range; RLD=right lateral decubitus; CSA=cross-sectional area;

Incidence of a full stomach

Seven and sixteen patients were revealed to have solid gastric contents and gastric fluid $> 1.5 \text{ mL}\cdot\text{kg}^{-1}$, respectively. Hence, the incidence of a full stomach in patients undergoing upper endoscopy was 23/388 (5.9%; 95% CI, 3.8–8.9%). In patients who were assessed as having solid contents with ultrasound, only mild sedation (intravenous administration of 2 mg midazolam combined with 0.5 mg alfentanil) was performed. No episode of reflux or aspiration occurred. Table 2 shows the individual patient data with gastric solid contents or gastric fluid $> 1.5 \text{ mL}\cdot\text{kg}^{-1}$, including demographic characteristics, ultrasound assessments, and endoscopic examination outcomes.

Distribution of antrum grades 0–2, and comparison of the suctioned volume in patients having gastroscope and gastroscope combined colonoscopy

Because the antrum scanning was infeasible in the semi-sitting position but expanded with hypoechoic contents in the RLD posture, two patients undergoing gastroscope combined colonoscopy could not be distinguished between grades 1 and 2. There were no statistically significant differences observed in the distribution of antrum grades 0–2, the median suctioned volume, volume per unit of weight, and the rates of stomach solid contents and gastric fluid $> 1.5 \text{ mL}\cdot\text{kg}^{-1}$ between patients

Table 2 Patients with full stomach

Table 2 Patients with full stomach									
Patient No.	Age	Sex	Fasting interval (h)		Volume (mL)	Volume (mL·kg ⁻¹)	Perlas grade	Co-morbidities	Diagnosis
			Solids	Fluid					
Patients undergoing gastroscopy combined colonoscopy.									
1	50	female	15	5	80	1.70	2	/	CAG
2	25	female	22	4	80	1.60	1	/	CNAG
3	62	male	22	5	140	2.26	2	/	CNAG
4	23	female	19	4.5	117	2.72	2	/	CNAG; RE
5	66	female	15	5	70	1.63	1	/	CNAG with erosion
6	67	male	21	4	110	1.53	2	/	CAG with erosion; RE
7	57	male	15	3	100	1.85	1	/	CNAG with erosion; RE
Patients undergoing gastroscopy									
1	22	male	20	12	100	1.67	2	/	CNAG
2	29	female	15	10	130	1.83	2	/	CNAG
3	23	female	20	18	70	1.67	0	/	CNAG
4	64	male	19	12	85	1.63	2	/	CAG ; RE
5	38	female	19	10	170	2.70	2	Obesity	CNAG; RE
6	59	male	14	10	105	1.72	2	/	CAG with erosion
7	34	female	14	10	90	1.88	2	/	CNAG with bile regurgitation
8	29	male	18	11	185	2.68	2	/	CNAG with bile regurgitation; RE
9	66	male	17	17	62	1.55	1	/	CNAG with bile regurgitation; RE
10	63	male	16	16	solid	solid	/	/	RE
11	71	male	9	9	solid	solid	/	/	CAG with erosion; RE
12	63	female	15	11	solid	solid	/	/	CNAG with erosion; RE
13	71	female	24	7.5	solid	solid	/	/	Duodenal bulb stenosis; RE
14	60	male	48	24	solid	solid	/	/	Duodenal bulb stenosis; RE
15	52	male	14	14	solid	solid	/	/	CNAG with bile regurgitation; RE
16	52	male	17	16	solid	solid	/	type 2 diabetes mellitus	After the repair of gastric perforation, RE

CNAG=chronic non-atrophic gastritis, CAG=chronic atrophic gastritis, RE=reflux esophagitis

undergoing gastroscopy and gastroscopy combined colonoscopy procedures (Table 3). The patients receiving gastroscopy had shorter fasting intervals for solids and larger fasting intervals for fluids when compared with those receiving gastroscopy combined colonoscopy (Table 3).

Receiver operating characteristic curves for the ultrasound qualitative assessment of solid gastric contents

The ROC curves and diagnostic performance for ultrasound qualitative assessment of solid gastric contents are presented in Fig. 1; Table 4.

Discussion

The study's objective was to assess the efficacy of ultrasound in detecting solid gastric contents associated with increased aspiration risk. Upon ultrasound diagnosis of solid gastric contents in patients, sedation depth during perioperative care was adjusted to minimize reflux aspiration. Our approach involved observing stomach emptying within the endoscopic field of view, a highly precise method to validate ultrasound assessment of solid gastric

contents. Findings demonstrate ultrasound's effectiveness in diagnosing or excluding solid gastric contents.

In this large sample study, a total of 5.9% [95% CI, 3.8–8.9%] of patients reported feeling full, including 7 patients with solid gastric contents and 16 patients with gastric volume exceeding 1.5 mL·kg⁻¹, despite having met their fasting time. Of these 16 patients, 7 underwent gastroscopy combined colonoscopy, while the remaining 9 patients and the 7 patients with solid contents underwent gastroscopy. Despite the fact that patients undergoing gastroscopy combined colonoscopy had a significantly shorter fasting period for fluids compared to those undergoing gastroscopy, there was no significant difference in gastric volume between the two groups. The distribution of antrum grades 0–2, and the number of patients with gastric volume exceeding 1.5 mL·kg⁻¹ was also similar in both groups, suggesting that extended fasting interval for fluid before gastroscopy is unnecessary. Prolonged deprivation of water can lead to anxiety and insufficient circulation. Although the recommended practice guidelines for preoperative fasting advise healthy adults to consume clear beverages containing either simple or

Table 3 Result of antrum grades and suctioned volume by endoscope. Data are expressed as the median (interquartile range)

Parameter	Endoscope		Absolute difference (95% CI)	P-Value
	Gastroscope N=255	Gastroscope combined colonoscopy N=133		
Suctioned volume (mL)	15(28)	15(30)	0(0 to 5)	0.37 ^a
Suctioned volume (mL·kg ⁻¹)	0.3(0.5)	0.3(0.5)	0.03(-0.01 to 0.1)	0.20 ^a
Perlas grade [n/total N (%)]				
0	173/248(70%)	77/131(59%)	11%(-6–28%)	0.10 ^b
1	61/248(25%)	45/131(34%)	-10%(-22–2%)	
2	14/248(5%)	9/131(7%)	-1.2%(-6–4%)	
Patients with suctioned volume > 1.5 mL·kg ⁻¹ [n/total N (%)]	9/255(3.5%)	7/133(5.2%)	-1.7%(-6.3 to 2.8)	0.42 ^b
Solid [n/total N (%)]	7/255(2.7%)	0/133(0)	2.7%(0.7 to 4.8)	0.13 ^c
Fasting interval for solids (h)	16(3)	17(5)	-1(-2 to 0)	0.01 ^a
Fasting interval for fluid (h)	14(4)	4.5(1)	9(9 to 10)	<0.001 ^a

^aP-values based on a Mann-Whitney U test between gastroscope and gastroscopy combined colonoscopy

^bP-values based on a chi-square test between gastroscope and gastroscopy combined colonoscopy

^cP-values based on a corrected chi-square test between gastroscope and gastroscopy combined colonoscopy

complex carbohydrates up to 2 h before elective procedures that require general anesthesia or procedural sedation [14], its practical implementation is less than ideal. According to a clinical study conducted in China in 2018, patients typically endure dehydration for an average of 12–14 h prior to elective surgery, in contrast to 6–9 h in Japan and 9.36 h in the UK [15]. This is because the fasting procedure cannot be properly followed as it is challenging to predict the precise moment an elective surgery will begin. However, this circumstance is anticipated to improve with the use of ultrasonography. Patients having gastroscope can bypass a stringent fasting period by directly evaluating their gastric volume. Furthermore, it's worth noting that solid gastric contents were exclusively observed in patients undergoing gastroscope procedures. This finding may stem from two potential factors. Firstly, patients undergoing gastroscope may have had a shorter fasting duration compared to those undergoing gastroscopy combined colonoscopy procedures. Secondly, recent research suggests that combining upper

endoscopy with colonoscopy may offer a protective effect against increased residual gastric contents. This protective effect is likely due to the residue-free diet routinely prescribed to patients for bowel preparation prior to colonoscopy. [8]

The 7 individuals with solid gastric contents who median fasted solids was 16 (10) h with a median age of 63 (19) years, and possible circumstances that might explain the delayed gastric emptying present in six of these patients. The endoscopy revealed duodenal bulb stenosis in two patients, a condition that hindered the passage of stomach contents into the intestine. One of these patients had undergone gastric perforation repair and had type 2 diabetes mellitus, which could have altered the anatomical and functional aspects of the stomach. Moreover, there were two male patients in the cohort. Prior research has suggested that women are less likely to experience retained gastric food (OR 0.8 [0.8–0.9], $P \leq 0.001$), and there's a correlation between gastric retention and duodenal stenosis (OR 4.1 [3.3–4.9], $P \leq 0.001$) as well as type 2 diabetes (OR 1.4 [1.3–1.5], $P \leq 0.001$) [9]. Another investigation focused on retained food material in individuals with a history of gastric surgery, revealing a prevalence of 19% in these patients compared to 0.3% in a control population [16]. Finally, a 71-year-old patient, who had fasted for only 9 h also presented with a similar issue. Research indicates that elderly patients may retain food in their stomachs after meals due to reduced stomach regulatory response and proximal gastric pressure [17]. No risk factors for delayed gastric solid contents emptying were identified in the last one patient. Additionally, one patient among the group was obese [18], with a gastric fluid contents exceeding 1.5 mL·kg⁻¹. Three patients showed bile regurgitation, and seven had consumed a significant amount of clear fluids 3 to 5 h prior to endoscopy. This highlights the potential risk of increasing gastric volume associated with the consumption of a large quantity of clear liquids before gastrointestinal endoscopy. Consequently, it is important to conduct a preoperative ultrasonographic assessment of the gastric contents in these patients. The other patients with high stomach capacities did not possess any identified risk factors.

The sensitivity and specificity of ultrasound for the qualitative assessment of solid gastric contents were 85.7% and 99%, respectively. This means that during ultrasound qualitative assessment, 14.3% of patients with solid gastric contents were not detected, whereas almost all patients without solid gastric contents were correctly identified. In our study, only seven patients had solid stomach contents. Therefore, the 14.3% discrepancy represented only one patient, whose antrum appeared empty in the semi-sitting position and filled with a small quantity of fluid in the RLD position, leading to

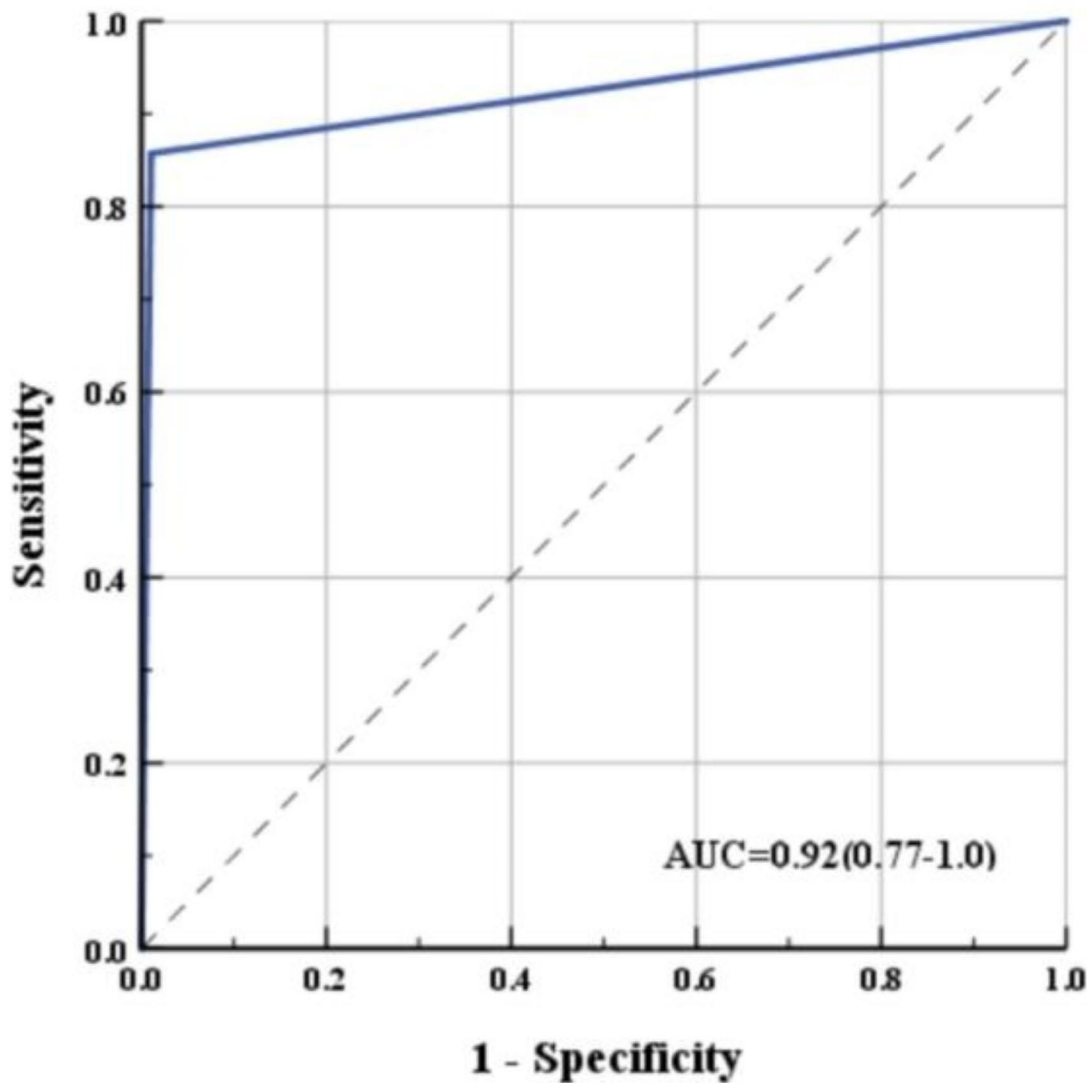


Fig. 1 Receiver operating characteristic curve for the the ultrasonic qualitative assessment of gastric solid contents in patients undergoing endoscopy

Table 4 Diagnostic test result of ultrasonographic qualitative measurement of solid contents

Ultrasound qualitative	Endoscopic examination		AUC	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
	Positive	Negative					
Positive	6	4	0.92	85.7	99	60	99.7
Negative	1	377					

misclassification of having solid stomach contents. This rare condition could be due to the viscosity of the solid contents, making it difficult for them to move toward the antrum in either the semi-sitting or RLD position. Fortunately, this patient did not experience reflux aspiration. Moreover, the positive and negative predictive values of ultrasound for the qualitative evaluation of solid gastric contents were 60% and 99.7%, respectively. This suggests

that while the accuracy of ultrasound in predicting solid contents was relatively low, its accuracy in predicting non-solid contents was high. A positive predictive value of 60% indicates a false positive rate of 40%, which may seem high, but it is important to note that there were only four false positives in our entire study. These patients shared a common characteristic of an expanded gastric antrum and mixed echogenicity in the sinus cavity and

have a median age of 72 (9) years. Our previous research found that patients > 60 year of ages showed a higher gastric antral cross-sectional area than young patients [19]. In addition, the artifacts created by air in the gastric antrum along the anterior wall of the mucosa can create the illusion of solid contents.

Conclusion

In summary, ultrasound exhibits a strong capacity for qualitatively assessing solid stomach contents. For patients undergoing upper endoscopy with potential delayed gastric emptying, ultrasound is recommended to evaluate gastric contents and aid in prompt clinical decision-making.

Limitation

The study possesses several limitations. Primarily, it was conducted at a single center, suggesting that validation of our results may be required in future studies with larger sample sizes or conducted at multiple centers. Second, the small number of patients with conditions such as obesity and diabetes in this study prevented subgroup analysis; therefore, there is a lack of explanation for these specific populations, and further research is needed. Moreover, numerous factors can contribute to delayed gastric emptying, such as gastrointestinal diseases, a history of gastrointestinal surgery, medications, pain, and other factors. However, due to the limited number of independent variables considered in this study, there is insufficient explanation for the causes of delayed gastric emptying in additional patients with full stomachs. Further research is warranted in the future to address this gap. Fourth, unfortunately, we did not evaluate the pH of the stomach contents, particularly in patients undergoing gastroscopy combined colonoscopy, and thus, it is not apparent if high volumes of clear oral fluids have an impact on the pH of the gastric fluid, which would have allowed us to determine the risk of aspiration with greater accuracy.

Author contributions

Jing Wang wrote the main manuscript text. Xuan Yu and Jielei Xu prepared Tables 1, 2, 3 and 4. Ying Wang prepared Fig. 1. Zhao Wang and Yi Zhang revised the manuscript. All authors reviewed the manuscript.

Funding

This project was funded by the Guizhou Provincial Health Commission (gzwkj2022-127) and the Second Affiliated Hospital of Zunyi Medical University (SQ-2021-11).

Data availability

All data associated with this study are present in the paper and are available upon request from the corresponding authors.

Declarations

Ethics approval and consent to participate

Ethical approval was granted by the Medical Ethics Committee of the Second Affiliated Hospital of Zunyi Medical University (KYL-2022-010). Informed consent was obtained from all subjects involved in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 23 April 2024 / Accepted: 20 August 2024

Published online: 06 September 2024

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