Clinical Assessment of the Ultrasonographic Measurement of Antral Area for Estimating Preoperative Gastric Content and Volume

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ABSTRACT

Background: This prospective observational study aimed to assess the feasibility and performance of the ultrasonographic measurement of antral cross-sectional area (CSA) for the preoperative assessment of gastric contents and volume in adult patients and for the diagnosis of *risk stomach* (defined by the presence of solid particles and/or gastric fluid volume >0.8 ml/kg).

Methods: A preoperative ultrasonographic measurement of the antral CSA was performed for each patient by a physician (L.B.) blinded to the history of the patient. Immediately after tracheal intubation, an 18-French multiorifice Salem tube was inserted and gastric contents were aspirated in five different patient positions; during this time, the patient's epigastrium was massaged and the tube was moved backward and forward in the stomach. The relationship between the antral area and the volume of aspirated gastric contents was analyzed, as was the performance of ultrasonographic measurement of antral area for the diagnosis of risk stomach.

Results: The measurement of antral CSA was performed on 180 of 183 patients. A significant positive relationship between antral CSA and aspirated fluid volume was found. The cutoff value of antral CSA of 340 mm^2 for the diagnosis of risk stomach was associated with a sensitivity of 91% and a specificity of 71%. The area under the receiver operating characteristic curve for the diagnosis of risk stomach was 90%.

Conclusions: The ultrasonographic measurement of antral CSA could be an important help for the anesthesiologist in minimizing the risk of pulmonary aspiration of gastric contents due to general anesthesia.

What We Already Know about This Topic

- In animal experiments, stomach contents of 0.4–0.8 ml/kg are associated with a high risk of pulmonary aspiration; therefore, estimating stomach content volume may be useful clinically.

What This Article Tells Us That Is New

- In 183 patients, ultrasonographic measurement of antral cross-sectional area related positively to the volume of gastric contents.

PULMONARY aspiration of gastric contents is one of the most feared complications of anesthesia, which was reported to be the first cause of mortality related to general anesthesia in France in 1999.[1] One of the risk factors for the occurrence of pulmonary aspiration and mainly for the onset of its clinical consequences is the volume of the aspirated gastric content. Extrapolation of the results of previous studies[2,3] conducted on monkeys reported that the critical volume for severe aspiration in adult humans could be classically between 25 and 50 ml (0.4–0.8 ml/kg). This volume is probably insufficient to lead to pulmonary aspiration in itself.[4,5] However, the combination of this risk volume with other risk factors, such as hiatus hernia or inadequate anesthesia, may be sufficient to cause aspiration of gastric content leading to pulmonary damages.[2,6,7] Therefore, it would be of interest to perform an easy noninvasive bedside test to determine the gastric content volume during the preoperative period to help the physician in the assessment of pulmonary aspiration risk.

The ultrasonographic measurement of antral cross-sectional area (CSA) is used for the assessment of gastric emp-

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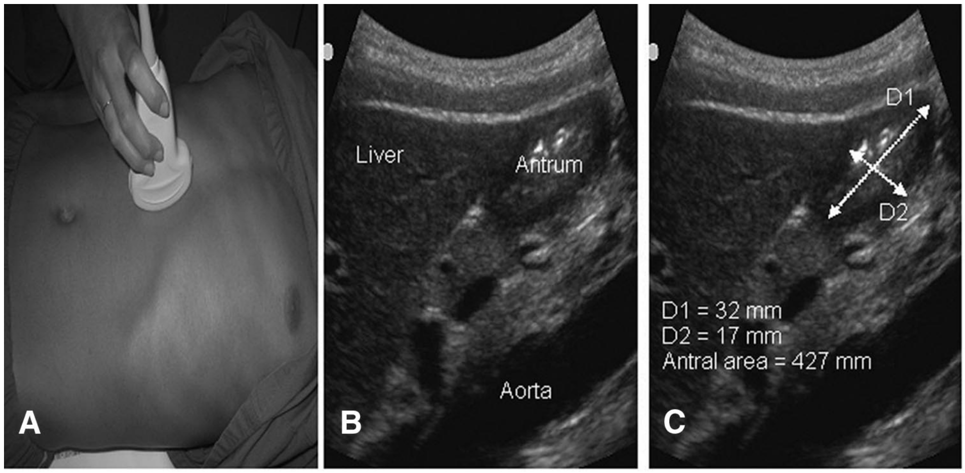

Fig. 1. (*A*) Transducer position to scan the gastric antrum. (*B*) Example of a gastric ultrasonographic image. (*C*) Example of measurement of the antral area.

tying in diabetic or dyspeptic patients and for clinical investigations in obstetrical anesthesia.[8–12] In a recent preliminary study[13] performed on volunteers, it was reported that a bedside two-dimensional ultrasonographic measurement of antral area could be of interest for the diagnosis of preoperative gastric vacuity. Another preliminary study[14] performed on volunteers suggested that the measurement of antral CSA could be a useful noninvasive test to determine gastric contents and volume, with significant potential implications for perioperative aspiration risk assessment.

The aims of this prospective blinded observational study performed in patients were as follows: (1) to confirm the feasibility of the ultrasonographic measurement of CSA in a large population of patients; (2) to determine a relationship between CSA measured before the induction of anesthesia for emergency or elective surgery and the aspirated volume of gastric contents obtained through a gastric tube in these patients; and (3) to assess whether ultrasonographic measurement of antral CSA could be used easily for the diagnosis of *risk stomach* during the preoperative period, defined by a gastric content volume at risk of clinical consequences for pulmonary aspiration (*i.e.*, presence of solid particles and/or gastric fluid volume >0.8 ml/kg). The ability of the ultrasonographic measurement of antral CSA to diagnose the presence of solid particles and/or gastric fluid volume greater than 0.4 ml/kg was also assessed.

Materials and Methods

After approval for the design of this observational study by the local ethics committee (Comité pour la Protection des Personnes Île de France, France) and informed consent were obtained, adult patients undergoing elective or emergency surgery under general anesthesia were included consecutively. As necessary, an antacid prophylaxis (sodium citrate in 100 ml water) could be given to the patient in the surgery ward 1 h before his or her arrival in the operating room.

A preoperative measurement of antral area was performed for each patient by a physician (L.B.) blinded to the status and history of the patient. Patients were asked to lay down in a semiupright position, with the head of the bed increased to 45°[8]; measurements were performed using real-time ultrasonography (Logiq® e, fitted with a probe, 2–5.5 MHz; GE Healthcare, Piscataway, NJ), as described previously in a recent preliminary study (fig. 1).[13]

Immediately after the measurement of antral area, the patient was lying in the supine position on the operating table and general anesthesia was induced by another physician, according to the history of the patient, as usually performed in our unit. This physician was blinded to the result of preoperative ultrasonographic measurement of antral CSA.

After the trachea was intubated, an 18-French multiorifice Salem tube (Kendall; Tyco Healthcare, Mansfield, MA) was inserted. The position in the stomach was confirmed by auscultation over the gastric area of an injected air bolus through the gastric tube and by aspiration of typical gastric contents. Gastric contents were gently aspirated for at least a 15-min period, into 60-ml syringes, while moving the tube backward and forward and massaging the patient's epigastrium. In addition, the position of the operating table was changed so that the patient was placed in the following positions successively: supine, supine with head up, Trendelenburg, and supine with the left lateral tilt and then the right lateral tilt. The volume and consistency (*i.e.*, the presence of macroscopic solid particles) of the aspirated gastric contents were recorded.

Demographic variables (*i.e.*, age, sex, weight, height, and body mass index) were investigated with a descriptive analysis using computer software (SPSS, version 16.0; SPSS Inc., Chicago, IL).

Antral CSA values according to the type of surgery (emergency or elective) and the aspirated volume of gastric contents (≤0.4 or >0.4 ml/kg and ≤0.8 or >0.8 ml/kg) were compared using independent two-tailed Student *t* tests, after

Table 1. Patients Characteristics

Characteristics	Frequency
Male–Female Ratio	1.07
Age, yr	49 ± 18
Height, cm	168 ± 9
Weight, kg	67 ± 12
BMI, kg/m^2	23 ± 3
Emergency Surgery*	76 (42)
ASA Physical Status*	
1	101 (56.1)
2	61 (33.7)
3	13 (7.2)
4	5 (2.8)

Data are given as mean ± SD unless otherwise indicated.
* Data are given as number (percentage of patients).
ASA = American Society of Anesthesiologists; BMI = body mass index.

assessment of the normality of the distribution of data using a Shapiro–Wilk W test. χ^2 Tests were performed to compare incidence data.

A linear multiple regression using the procedure lm from a statistical software program** was used to model the relation between the volume of the gastric contents and the logarithm of the gastric area. The following covariates were used: age, height, weight, American Society of Anesthesiologists physical status classification (range, 1–4), preoperative ingestion of 100 ml water with nonparticulate antacid prophylaxis, and emergency (yes or no).

To estimate the discriminating power of ultrasonographic measurement of antral CSA for the diagnosis of the presence of solid particles and/or a volume of aspirated gastric contents greater than 0.8 or 0.4 ml/kg, receiver operating characteristic curves were plotted and areas under the curves were calculated. Sensitivity, specificity, and positive and negative predictive values were calculated at the cutoff value of antral area for the diagnosis of risk stomach.

For each test, $P < 0.05$ was considered statistically significant.

Results

A total of 183 patients were consecutively included, allowing 180 measurements of antral area (98.4% of the patients). For three patients, antral CSA could not be measured (because of obesity for two patients and the presence of a significant amount of gas in the stomach for one patient). The analysis was based on the remaining 180 data sets. Demographic variables are presented in table 1. No patient in the cohort regurgitated or aspirated gastric contents.

The mean ± standard deviation aspirated volume was 57 ± 43 ml. The mean ± standard deviation aspirated volume was significantly increased in emergency *versus* elective patients (69 ± 51 *vs.* 23 ± 19 ml; $P < 0.0001$). The rates of aspirated volumes of gastric content greater than 0.4 and 0.8 ml/kg and the rate of risk stomach in emergency and elective patients are summarized in table 2. Two emergency patients received antacid prophylaxis, with 100 ml water given 1 h before the surgery, and one elective patient ingested nonparticulate antacids with 100 ml water because of increased risk of regurgitation (hiatus hernia with gastroesophageal reflux). The aspirated volumes were 72 and 90 ml with solid particles for the emergency patients and 58 ml for the elective patient. For eight patients, the aspirated gastric contents volume was lower than 20 ml because it was thick with solid particles; for these patients, the measured antral CSA ranged from 480 to 795 mm^2. For the other 24 patients in whom solid particles were observed in gastric contents, aspirated volume ranged from 65 to 110 ml and antral CSA ranged from 455 to 1290 mm^2.

Table 2. Aspirated Volume of Gastric Contents According to Type of Surgery

Aspirated Gastric Content Variable	Type of Surgery: Elective (n = 104)	Emergency (n = 76)	*P* Value
>0.4 ml/kg	35 (33.7)	60 (78.9)	0.0006
>0.8 ml/kg	3 (2.9)	52 (68.4)	<0.0001
Risk Stomach*	3 (2.9)	60 (78.9)	<0.0001

Data are given as number (percentage) of each group unless otherwise indicated.
* Defined by the presence of solid particles and/or gastric fluid volume greater than 0.8 ml/kg.

Antral CSA increased proportionally to the aspirated volume of gastric content, as set out in the linear correlation curve (fig. 2). The correlation coefficient obtained was 0.72 ($P < 0.0001$).

The ultrasonographic measured antral CSA was significantly increased in emergency *versus* elective patients, for an aspirated volume greater than 0.8 ml/kg *versus* lower or equal to 0.8 ml/kg, and for an aspirated volume greater than 0.4 ml/kg *versus* lower or equal to 0.4 ml/kg (table 3).

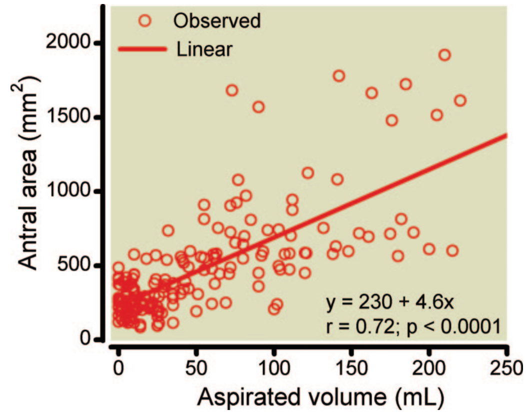

Fig. 2. Correlation of the antral cross-sectional area with aspirated gastric contents.

**R; The R Foundation for Statistical Computing, Vienna University of Technology, Vienna, Austria. Available at: http://www.r-project.org/. Accessed February 18, 2010.

Table 3. Characteristics of Antral Cross-sectional Area

Characteristics	Antral Area, mm²
Surgery	
Elective (n = 104)	280 ± 115
Emergency (n = 76)	581 ± 294
Aspirated Volume, ml/kg	
≤0.4 (n = 85)	278 ± 119
>0.4 (n = 95)	642 ± 293
≤0.8 (n = 125)	303 ± 141
>0.8 (n = 55)	752 ± 315

$P < 0.0001$. Data are given as mean ± SD unless otherwise indicated.

The prediction of gastric content was as follows:

Volume (ml) = −215 + 57 · log (Antral Area [mm²]) − 0.78 · Age (years) − 0.16 · Height (cm) − 0.25 · Weight (kg) − 0.80 · American Society of Anesthesiologists Physical Status Classification (1–4) + 16 ml (in Case of Emergency) + 10 ml (in Case of Preoperative Ingestion of 100 ml Antacid Prophylaxis)

Regression model statistics for the aspirated gastric volume are summarized in table 4. The adjusted R^2 was 0.570.

The receiver operating characteristic curves for the ultrasonographic diagnosis of the presence of solid particles and/or aspirated fluid volume of gastric contents greater than 0.4 ml/kg and for the ultrasonographic diagnosis of risk stomach, as defined by an aspirated fluid volume of gastric contents greater than 0.8 ml/kg and/or the presence of solid particles, are presented in figure 3. At the cutoff values of the antral CSA of 340 and 410 mm² for both the receiver operating characteristic curves, performances of the ultrasonographic measurement of the antral CSA are summarized in table 5.

Discussion

In this observational blinded study performed on 183 patients undergoing elective or emergency surgery, we assessed the antral CSA 98.4% of the time. This result corroborates those of preliminary studies performed in volunteers, reporting that a complete cross-sectional view of the antrum was obtained in 100% of 18 volunteers in the study by Perlas *et al.*[14] and 98.5% of 22 volunteers in the study by Bouvet *et al.*[13] The results of the current study performed in a large population of patients allow the conclusion that the measurement of antral CSA during the preoperative period could be used in clinical practice.

Table 4. Regression Model Statistics for Aspirated Gastric Volume

Variable	Parameter Estimate	SE	t	P Value
Intercept	−215	68	−3.14	0.002
Age	−0.78	0.20	−3.87	0.001
Height	−0.16	0.44	−0.36	0.72
Weight	−0.25	0.30	−0.84	0.40
ASA Physical Status	−0.80	4.40	−0.18	0.86
Emergency Surgery	15.58	6.61	2.36	0.02
Log Area	57.18	4.94	11.57	0.001
Antacid Prophylaxis	9.91	21.24	0.47	0.64

Adjusted R^2 = 0.570.
ASA = American Society of Anesthesiologists.

There is no definitive standard method for the preoperative determination of gastric contents volume. We chose to determine the gastric contents volume by measuring the aspirated gastric contents. This technique was reported to be a good estimate of the current volume in the stomach, highly correlated to the current total volume in the stomach in both adults and children, provided that a multiorificed large tube is used and that aspiration is carefully performed (*i.e.*, with use of a syringe as the tube is withdrawn from the stomach and repeated with the patient in three positions).[15,16] By using such a method of aspiration, Hardy *et al.*[15] reported in 24 fasting adult patients that the correlation with the total gastric fluid volume determined by aspiration ($r = 0.99$) was slightly better than that determined by dye (polyethylene glycol) dilution and that the nonaspirated volume from the total fluid gastric contents ranged from 0 to 13 ml (mean, 4.4 ml) for a total fluid gastric volume ranging from 1.5 to 118 ml (mean, 35.5 ml). In the same way, Cook-Sather *et al.*[16] reported in 17 fasting children that 97 ± 8% (mean±SD) of the gastric fluid volume was removed from the stomach when performing careful aspiration of gastric contents. In the current study, gastric aspiration was gently performed for at least a 15-min period through a multiorifice 18-French Salem tube into a syringe, while moving the tube backward and forward and massaging the patient's epigastrium. Aspiration was repeated with the patient placed in five different positions (supine, supine head-up, Trendelenburg, and left and right lateral decubitus positions). Therefore, the aspirated volume of fluid gastric contents was close to the current total fluid volume in the stomach. Precise estimation of the volume of solid contents was not of great interest because the presence of solid particles was considered sufficient to define a risk stomach in the occurrence of pulmonary aspiration or clinical consequences of this aspiration.

We were able to find a positive relationship between antral CSA and volume of aspirated gastric contents, including age and clinical history (emergency or elective surgery) but not American Society of Anesthesiologists physical status classification or patient demographics. Patient's age was reported previously as being a significant variable in the relationship between volume and antral area measured in the supine position in the study by Perlas et *al.*[14] In the current study, the preoperative ingestion of antacid prophylaxis did not significantly enter the model because only three patients had ingested this prophylaxis before the surgery. Nevertheless, several factors may be involved in the increase in gastric contents in case of emergency surgery, such as nonapplication of preoperative fasting, gastroparesis related to acute

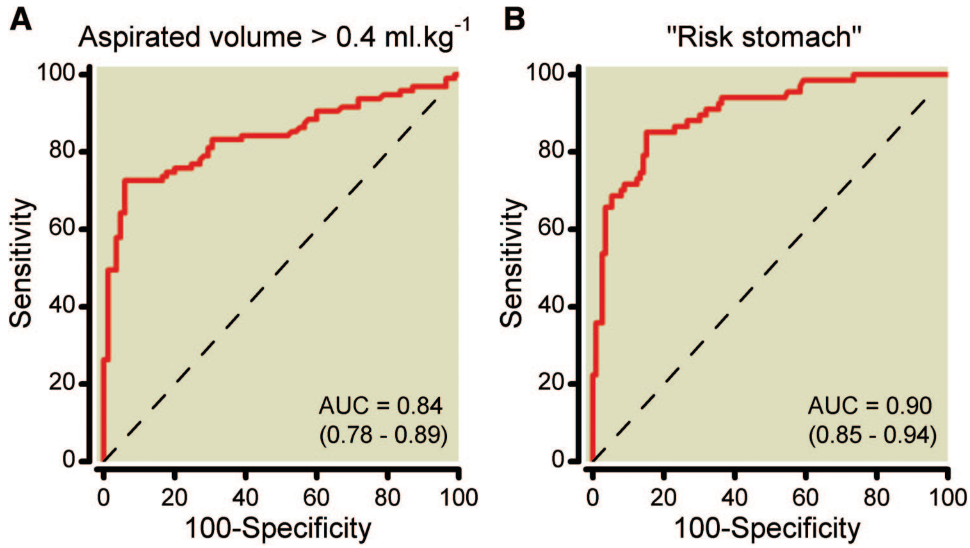

Fig. 3. Receiver operating characteristic curves for the ultrasonographic diagnosis of the presence of solid particles and/or aspirated fluid volume of gastric contents greater than 0.4 ml/kg (*A*) and for the ultrasonographic diagnosis of *risk stomach*, as defined by an aspirated fluid volume of gastric contents greater than 0.8 ml/kg and/or the presence of solid particles (*B*). AUC = area under the receiver operating characteristic curve, with 95% CI. *P* = 0.0001 for both curves.

pain or preoperative administration of opioids, and gastrointestinal obstruction related to the surgical disease.[17,18]

In the current study, the adjusted regression R^2 value was similar to the one calculated by Perlas *et al.*[14] for CSA measured in the supine position. However, these researchers reported an increased R^2 value when antral CSA is measured with the subject in the right lateral decubitus position. This is probably because fluids move toward the antrum when a subject moves to the right lateral decubitus position, leading to a better correlation between antral CSA measurement and volume of fluid. In the current study, antral CSA was measured according to the classic technique described previously in the literature (*i.e.*, with the patients lying in a semiupright position and the head of the bed increased to 45°).[8,9,19] Thus, our method could probably be improved by placing the patient in the right lateral decubitus position while ultrasonography is performed; therefore, further study would be required to compare the relationship between aspirated volume and ultrasonographic measurement of antral CSA in the supine and right lateral decubitus positions during the preoperative period.

Ultrasonographic measurement of the antral CSA performed in 180 patients was able to discriminate the risk stomach, as defined by aspirated gastric contents with solid particles and/or aspirated fluid gastric volume greater than 0.8 ml/kg, from an "empty" stomach. The performance for the diagnosis of aspirated gastric contents greater than 0.8 ml/kg was better than for the diagnosis of aspirated gastric contents greater than 0.4 ml/kg, mainly because this low threshold value (*e.g.*, 24 ml for a 60-kg patient) is close to the mean ± SD value of the aspirated volume recorded in fasting patients (23 ± 19 ml). However, the area under the receiver operating characteristic curve of the ultrasonographic measurement of antral CSA for the detection of volumes greater than 0.4 ml/kg was significant, allowing us to suppose that the measurement of antral CSA is sensitive enough to detect the presence of fluid volumes of approximately 25 ml. For the choice of the cutoff value of antral CSA in the diagnosis of gastric fluid contents greater than 0.8 ml/kg and/or presence of solid particles, a high sensitivity (>90%) of the test must be guaranteed because of the relative uncertainty about the measurement of the fluid volume, as discussed previously. The cutoff value of antral CSA of 340 mm^2 for the diagnosis of risk stomach is associated with a sensitivity of 91%, a negative predictive value of 94%, an acceptable spec-

Table 5. Ultrasonographic Measurement of Antral CSA for Preoperative Diagnosis of the Presence of Solid Particles and/or Gastric Volume Contents

	Solid Particles and/or Aspirated Volume, ml/kg							
	>0.4				>0.8			
Cutoff of Antral CSA, mm^2	Sensitivity, %	Specificity, %	PPV, %	NPV, %	Sensitivity, %	Specificity, %	PPV, %	NPV, %
340	78	74	77	75	91	71	63	94
410	73	88	87	74	85	80	70	90

CSA = cross-sectional area; NPV = negative predictive value; PPV = positive predictive value.

ificity of 71%, and a positive predictive value of 63%; therefore, it could be proposed for clinical practice.

We believed that it was relevant to assess whether ultrasonographic measurement of antral CSA was able to detect the risk stomach (*i.e.*, stomach containing solid particles or at least a fluid gastric volume of >0.8 ml/kg).[2,3] This volume is probably insufficient to lead to pulmonary aspiration in itself because a minimum of 200 ml fluid gastric volume must probably be current to induce passive regurgitation and pulmonary aspiration.[4,5] However, previous studies[2,3] conducted on animals let us suppose that a gastric volume of 50 ml (or 0.8 ml/kg) can be considered a critical volume for severe aspiration in adult humans. In fact, the pathophysiological features of aspiration of gastric contents during general anesthesia are complex and involve several other risk factors, such as difficulties in airway management or inappropriate anesthetic technique, that can lead to blowing air into the stomach, bucking, and coughing; these factors may all cause episodes of gastroesophageal reflux.[2,6,7,20] The combination of a gastric volume greater than 0.8 ml/kg with such risk factors may be sufficient to cause significant aspiration of gastric content, with pulmonary damages.[2,3,6,7] In the current study, a risk stomach was found in 60 out of 76 (78.9%) of emergency patients and in 3 out of 104 (2.9%) of elective patients. In elective patients, increased gastric contents may be the result of a known or unknown gastrointestinal motility disorder or a lack of compliance of the patient with the fasting requirement.[18,21] Thus, the preoperative ultrasonographic diagnosis of a risk stomach can be of interest in both emergency and elective patients to avoid the practice of inadequate anesthetic techniques and, consequently, to reduce the incidence of pulmonary aspiration due to general anesthesia. By using the noninvasive bedside ultrasonographic measurement of antral CSA, further studies performed on more patients will probably make it possible to define critical values of gastric volume and antral CSA correlated to the risk of pulmonary aspiration of gastric contents.

The performance of all ultrasonographic measurements by a single operator constituted a limitation of this study. Standardized measurements of antral area were performed in the same sagittal plane using the same internal landmarks as those described previously by Bolondi *et al.*[8] and Darwiche *et al.*[9] In the study by Darwiche *et al.*, the reproducibility of the repeated ultrasonographic measurements of antral area for determining gastric emptying in both healthy subjects and diabetic patients was assessed. These researchers reported that measurements of gastric emptying rate gave highly reproducible results from different observers, with an interobserver systematic measurement error of 0.3% and a random measurement error of 10.9% between different observers.[9] They also reported that intraobserver variability was similar to interobserver variability.[9] However, the reproducibility of a single measurement of antral CSA was not assessed; it would be of interest in further studies to assess the part of interobserver variability in the estimate of the reliability and reproducibility of the method.

In conclusion, for most of the patients, a preoperative ultrasonographic measurement of antral CSA was feasible. This measurement allowed the diagnosis of risk stomach, as defined by the presence of solid particles and/or a gastric fluid volume greater than 0.8 ml/kg before the induction of anesthesia, which could lead to symptomatic pulmonary aspiration of gastric contents in cases of regurgitation. Further studies are required to assess whether the measurement of antral CSA could be improved when performed in patients lying in the right lateral decubitus position and to assess the usefulness of the ultrasonographic measurement of antral CSA in the prevention strategy of pulmonary aspiration of gastric contents.

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