



ORIGINAL INVESTIGATION

Reinforcing the valuable role of gastric ultrasound for volume and content assessment: an observational study



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Abstract

Background: Pulmonary aspiration is one of the most important complications in anesthesiology. Assessment of gastric content by ultrasound is a good method to quantify gastric volume and to determine the risk of intraoperative pulmonary aspiration. The aim of this study is to determine the accuracy of the gastric ultrasonography in the qualitative analysis of gastric content, mainly in the analysis of small amounts of liquid content.

Methods: Gastric ultrasound was performed to 36 patients before upper gastrointestinal endoscopy (UGI), making two longitudinal scans at the epigastric level, one in supine position and the other in right lateral decubitus position, measuring two diameters and the area of the gastric antrum and assessing the content characteristics determining whether it was an empty stomach or contained fluid or solid content. Subsequently, the ultrasound findings were compared with UGI findings.

Results: Gastric areas were analyzed by the trace and the lengths of the craniocaudal and anteroposterior axes concluding that there are no significant differences between the two methods. No statistically significant difference was found between UGI and US assessment technics. No statistically significant difference was found between the estimated volume by UGI and US.

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Conclusions: Though our study has some limitations, qualitative analysis of gastric content using ultrasound followed by endoscopy enabled the conclusion that there are no differences in the qualitative assessment regarding these two techniques, supporting the important role of point-of-care gastric ultrasound (POCGUS) in the assessment of pulmonary aspiration risk by the anesthesiologist in the perioperative period.

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Introduction

Pulmonary aspiration, defined as the entry of liquid or solid content in the trachea and lungs,¹ is one of the most important complications in anesthesiology.² Several studies have shown that the evaluation of gastric content by ultrasound is a good method to qualitatively and quantitatively assess the gastric volume and thus determine the risk of perioperative pulmonary aspiration.^{3–6} Occasionally, small volumes of clear fluid are identified in a gastric ultrasound, being difficult to discriminate if they are clinically irrelevant or there may be a risk of aspiration.⁵

The aims of this study, performed in patients undergoing upper gastrointestinal endoscopy (UGI), were as follows: (1) determine the accuracy of the gastric ultrasonography in the qualitative analysis of gastric content, mainly in the analysis of small amounts of liquid content; (2) to quantitatively determine gastric volume after a period of fasting.

Methods

After Institutional Research Ethics Board approval and informed consent, we conducted this observational prospective study, which took place between March and June 2019 at two different clinics. Two different raters, all with experience in gastric ultrasound, had variable proficiency level: first rater, a certified sonographer with more than 15-year clinical experience and second rater, a clinical anesthesiologist with more than 7 years in ultrasound clinical application.

A convenience sample of 40 patients was recruited. Inclusion criteria were scheduled for elective UGI with age greater than 18 years and American Society of Anesthesiologists (ASA) physical status I to III. Exclusion criteria were presence of preexisting abnormal anatomy of the upper gastrointestinal tract and pregnancy. Patients subjected to treatments with opioids, octreotides or tricyclics were also excluded from the study. All patients followed institutional guidelines for UGI. No medication that would alter gastric emptying was administered to the patient between the ultrasound examination and the endoscopies.

Ultrasound examination was performed with a low-frequency (2 to 6 MHz) curvilinear array transducer using a Samsung RS60 or Sonoscanner U-lite ultrasound machines. Patients were scanned in the supine position (SP) and subsequently in the right lateral decubitus position (RLDP). The transducer was placed in a sagittal plane in the epigastric region in order to see gastric antrum between the left lobe of the liver and the pancreas, at the level of the aorta. The cross-sectional area of the gastric antrum

(CSA) was measured in both positions and was determined using two methods, the first one based on the two-diameter method formula (TDM), the craniocaudal (CC) and anteroposterior (AP) diameters as previously described⁷ ($CSA = (AP \times CC \times \pi) / 4$) and the second one using the free-tracing method (FTM) (Fig. 1).

Primarily, gastric content was qualitatively evaluated in both patient's position by the sonographer as: (1) empty if it appeared flat with anterior and posterior walls juxtaposed; (2) fluid content when a hypoechoic content was observed; or (3) solid content if lumen was distended with an internal "frosted-glass appearance".⁸ Second, total gastric fluid volume was estimated using the models suggested by Perlas et al.^{3,5} V1, V2 and V3.

$$V1 = 1199.99 + 483.09 \times \log(\text{supineCSA}) - 5.84 \times \text{age} - 9.94 \times \text{height}^*$$

$$V2 = -372.54 + 282.49 \times \log(\text{right-latCSA}) - 1.68 \times \text{weight}^*$$

$$V3 = 27.0 + 14.6 \times \text{right-latCSA} - 1.28 \times \text{age}^*$$

* age in years, supine CSA and right-lat CSA in cm^2 , height in cm, and weight in kg

V3 model is the most accepted in the literature. The ultrasound measures, obtained by TDM and FTM, were later compared to the volume measured in UGI.

Subsequently, UGI was performed by two gastroenterologists and evaluated the characteristics of the gastric content. It was determining if it was empty stomach or if it had liquid or solid content. The quantitative assessment of gastric volume was performed by measurement of the volume of gastric content in an aspiration container, approximated to nearest 10 mL. This volume was named Measured Volume (VolM).

Individual data was also recorded regarding age, sex, weight, causes of gastroparesis, time between ultrasound and UGI, fasting time of solids and liquids and test period (morning or afternoon).

Statistical analysis

A descriptive analysis of the data was performed using RStudio Version 1.2.5033 running R version 3.6.3. The statistical quantitative variables were summarized through the mean, standard deviation, interquartile range, minimum and maximum and the qualitative statistical variables through count

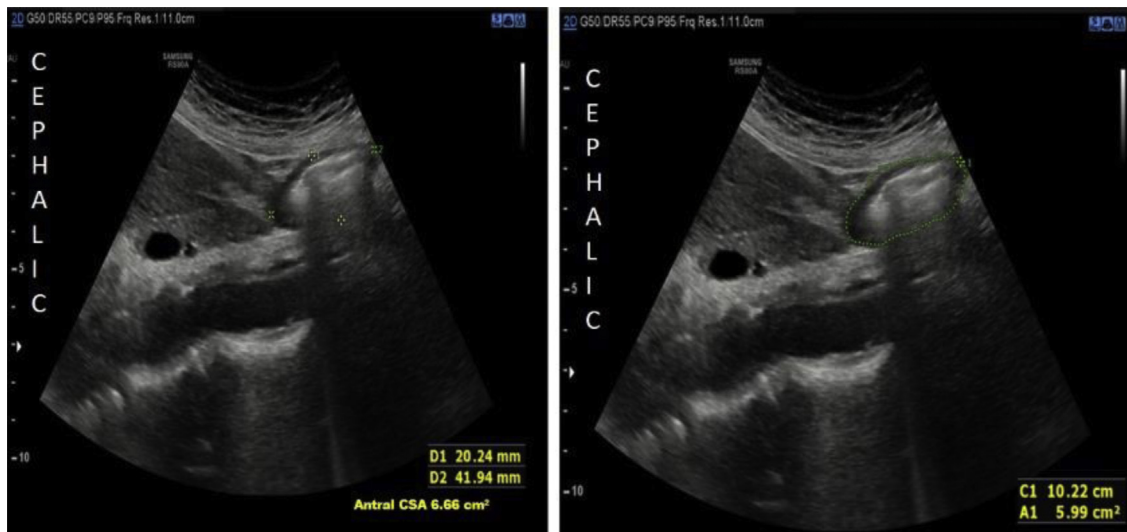


Figure 1 CSA (cross-section area) with TDM (two-diameter method formula) and FTM (free-tracing method) Method.

values. Shapiro-Wilk test was used to assess the normality of the variables. Statistically linear dependence between TDM and FTM measures, fluid fasting time and gastric volume measured, CSA and volumes, CSA and age, different volumes, was tested using Pearson's correlation tests and Spearman's correlation tests. *T*-tests for paired samples were used to compare the area determined by TDM and FTM in the two positions. A Bland-Altman analysis, along with McNemar tests and measures of accuracy, sensitivity, and specificity, was performed to analyze differences between two measurement technics. Quade test and Quade test with Benjamini and Hochberg correction for multiple comparisons of repeated measures were used when comparing volumes calculated by all three models based on areas obtained either by FTM or TDM and the Measured Volume. When applied, a significance level of 0.05 was considered.

Results

A total of 40 patients were included, providing 36 measurements of antral area. Antral CSA could not be measured in two patients due to obesity with Body Index Mass (BMI) over 40, due to the presence of a significant amount of gas in the stomach in one patient and due to error in the registration measures in one patient. Hence, sample was reduced to 36 patients with conditions for the application of V3 model (Fig. 2). Although this is the reference model used in most studies, we also considered two samples of 9 patients each to apply V1 and V2 models to estimate gastric volume.

Demographic variables are presented in Table 1. Not statistically significant difference between demographic variables were evidenced. Patient's fasting time of solids were > 10 hours and liquid fasting period > 4 hours. Not statistically significant difference between fasting time and test period was evidenced.

No significant difference between different sonographer's measures was found.

Information obtained through gastric ultrasound in relation to the antrum area included two diameters method and

free-tracing method. Statistically linear dependence was found between TDM and FTM in supine position ($p < 0.0001$, $r = 0.89$) and in the right lateral decubitus position ($p < 0.0001$, $r = 0.93$). The *t*-tests for differences between the values of TDM and FTM in the two positions allow us not to reject the hypothesis that the differences are equal to zero ($p = 0.9143$ and $p = 0.1740$ respectively).

The difference of measurements in the SP was normally distributed ($p = 0.92$), homoscedastic ($p = 0.90$), with a mean (bias) of -0.015 (CI95% = $[-0.288, 0.259]$). The upper limit of agreement (LOA) was 1.570 (CI95% = $[1.098, 2.042]$) and the lower LOA was -1.599 (CI95% = $[-2.071, -1.127]$). The difference of measurements in the RLDP was normally distributed ($p = 0.67$), homoscedastic ($p = 0.86$), with a bias of 0.259 (CI 95% = $[-0.120, 0.637]$). The upper limit of agreement (LOA) was 2.451 (CI95% = $[1.798, 3.103]$) and the lower LOA was -1.933 (CI95% = $[-2.586, -1.281]$) (Fig. 3).

By endoscopy, no solid content was found with solid fasting period of 11.5 ± 1.68 hours and fluid fasting period of 8.17 ± 3.57 hours. No correlation was found between fluid fasting time and gastric volume measured ($p = 0.8213$, $r = 0.04$). The volume measured in the stomach of 18 individuals was approximately 0 mL. The average gastric antrum FTM area in right lateral decubitus position for these patients was 6.66 ± 3.02 cm² with a minimum of 2 cm². The correlation between FTM area and age was not statistically significant ($p = 0.3251$, $r = 0.25$).

The qualitative assessment of gastric content through ultrasonography identified 22 individuals with no solid or liquid content and 14 individuals with fluid content.

Mean time between the ultrasound and subsequent endoscopic examination was 34.78 minutes.

The McNemar test shows no statistically significant differences between the classification of the presence of gastric content between the two assessment technics ($p = 0.2888$). The US technic, independently of the ultrasound device used showed, an accuracy of 0.78 (CI 95% = $[0.61, 0.90]$), a balanced error of 0.22, a sensitivity of 0.67 and a specificity of 0.89. When considering the 21 patients that used the Samsung RS60 we found an accuracy of 0.67 (CI 95% = $[0.43,$

Table 1 Summary of variables.

		Model V1			Model V2			Model V3		
		Mean ± SD	[Q1:Q3]	min;max	Mean ± SD	[Q1:Q3]	min;max	Mean ± SD	[Q1:Q3]	min;max
Sex (female/male)		4/5			4/5			20/16		
US Empty Stomach (yes/no)		7/2			7/2			14/22		
UGI Empty Stomach (yes/no)		6/3			7/2			18/18		
Test period (morning/afternoon)		6/3						22/14		
Age		43.78 ± 15.02	[32;57]	21;57	45.78 ± 12.97	[41;57]	21;59	59.44 ± 16.13	[50.75;69.25]	21;88
Weight		71.44 ± 13.31	[60;80]	56;94	69.78 ± 13.04	[60;72]	56;94	70.03 ± 11.32	[61.5;78.0]	53;98
Height		1.71 ± 0.15	[1.63;1.84]	1.52;1.90	1.69 ± 0.13	[1.63;1.8]	1.52;1.90	1.66 ± 0.11	[1.6;1.7]	1.47;1.90
BMI		24.22 ± 2.12	[22.40;25.77]	21.08;26.85	24.29 ± 2.06	[23.03;25.77]	21.08;26.85	25.40 ± 3.32	[22.99;26.82]	20.45;34.24
Time between US and UGI		36.33 ± 16.50	[30;47]	5;60	34.11 ± 17.27	[20;47]	5;60	34.78 ± 18.70	[20.0;45.5]	5;90
Fasting time for solids		12 ± 0	[12;12]	12;12	11.33 ± 2.00	[12;12]	6;12	11.50 ± 1.68	[12;12]	6;12
Fasting time for liquids		8 ± 4.03	[4;12]	3;12	8.22 ± 3.83	[5;12]	3;12	8.17 ± 3.57	[5;12]	2;12
Supine position	CSA	4.40 ± 1.03	[3.46;5.35]	3;5.6	4.22 ± 1.33	[3.28;5.35]	1.8;5.6	4.31 ± 1.58	[3.29;5.25]	1.4;8.6
	AP diameter	16.11 ± 4.17	[13;18]	10;22	15.78 ± 4.63	[13;18]	9;22	17.11 ± 5.85	[13;21]	7;35
	CC diameter	30.67 ± 4.56	[28;35]	24;37	32.11 ± 4.23	[29;35]	25;37	32.33 ± 5.86	[28;37]	22;43
Right-lateral position	CSA	8.38 ± 2.92	[6.1;8.8]	5.5;13.3	7.98 ± 3.16	[5.92;8.80]	4.76;13.30	6.66 ± 3.02	[4.59;8.50]	2.0;13.3
	AP diameter	24.33 ± 6.46	[19;28]	16;35	23.56 ± 6.65	[19;28]	16;35	21.86 ± 6.80	[18.5;26.0]	7;38
	CC diameter	43.78 ± 6.08	[41;48]	34;53	42.89 ± 5.44	[41;44]	34;53	39.53 ± 8.47	[33.75;45.25]	23;55

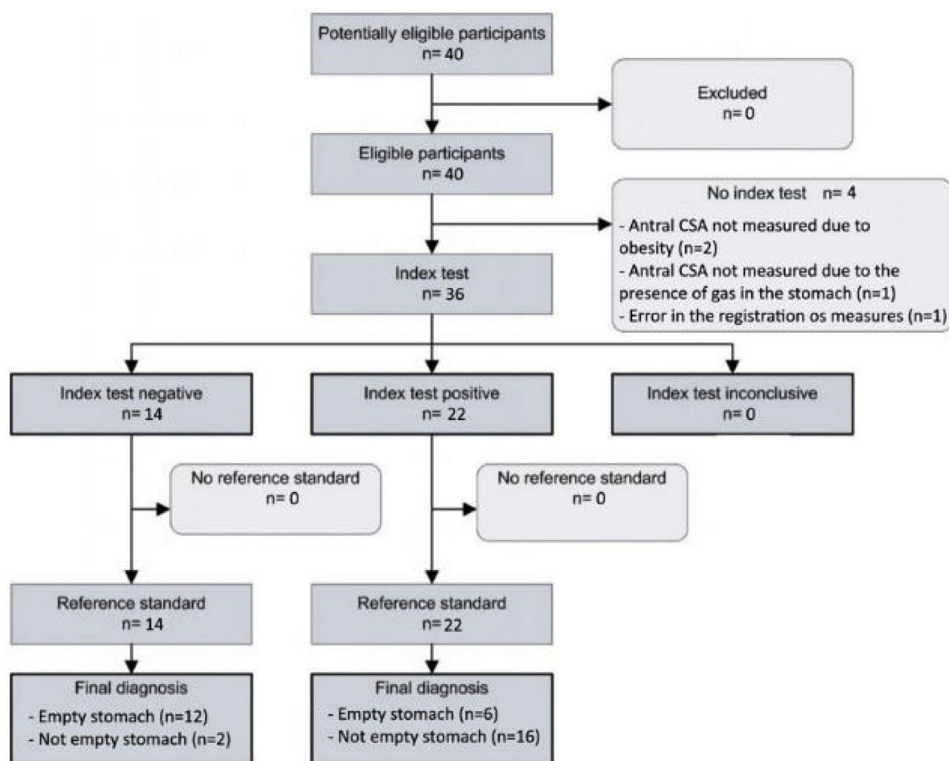


Figure 2 Standards for Reporting of Diagnostic Accuracy (STARD) flow chart of the 40 patients enrolled in the study. Index test – US, Reference test – UGI.

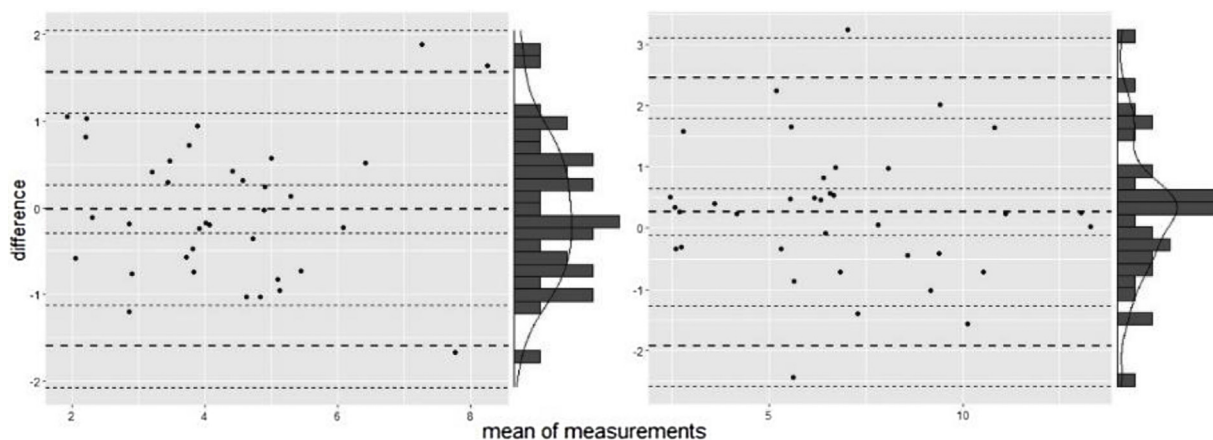


Figure 3 Bland-Altman (B-A) plot for the measurements of the antral CSA in the SP (left) and in the RLDP (right) by the two methods with the representation of the bias) and LOA, with thick dashed lines, and the 95% CI, with thin dashed lines. Histogram and density plot of the difference of the measurements on the right margin of the plot.

0.85]), a balanced error of 0.36, a sensitivity of 0.44, a specificity of 0.83 and a $p=0.45$ in the McNemar's test. For the remaining 15 patients that used the Sonoscanner U-lite we found an accuracy of 0.93 (CI 95% = [0.68, 1]), a balanced error of 0.06, a sensitivity of 0.89, a specificity of 1 and a $p=1$ in the McNemar's test.

No significant correlation was found between the CSA calculated by FTM and the Measured Volume (by UGI) nor between the estimated volume (V3) using the area obtained by FTM and the Measured Volume ($p=0.2673$, $r=-0.19$ and $p=0.9655$, $r=-0.01$ respectively). The difference of the vol-

ume V3 and the Measured Volume in the RLDP was normally distributed ($p=0.07$), with a bias of 35.805 (CI 95% = [18.559, 53.050]). The upper limit of agreement (LOA) was 135.705 (CI 95% = [105.956, 165.453] and the lower LOA was -64.095 (CI 95% = [-93.844, -34.347]).

We found statistically significant positive correlations between: volume calculated based on areas obtained by FTM (VxT) and TDM (VxE) for all 3 models V1, V2 and V3; volume calculated based on areas obtained by FTM in models V2 and V3; volume calculated based on areas obtained by TDM in models V2 and V3; volume calculated based on areas

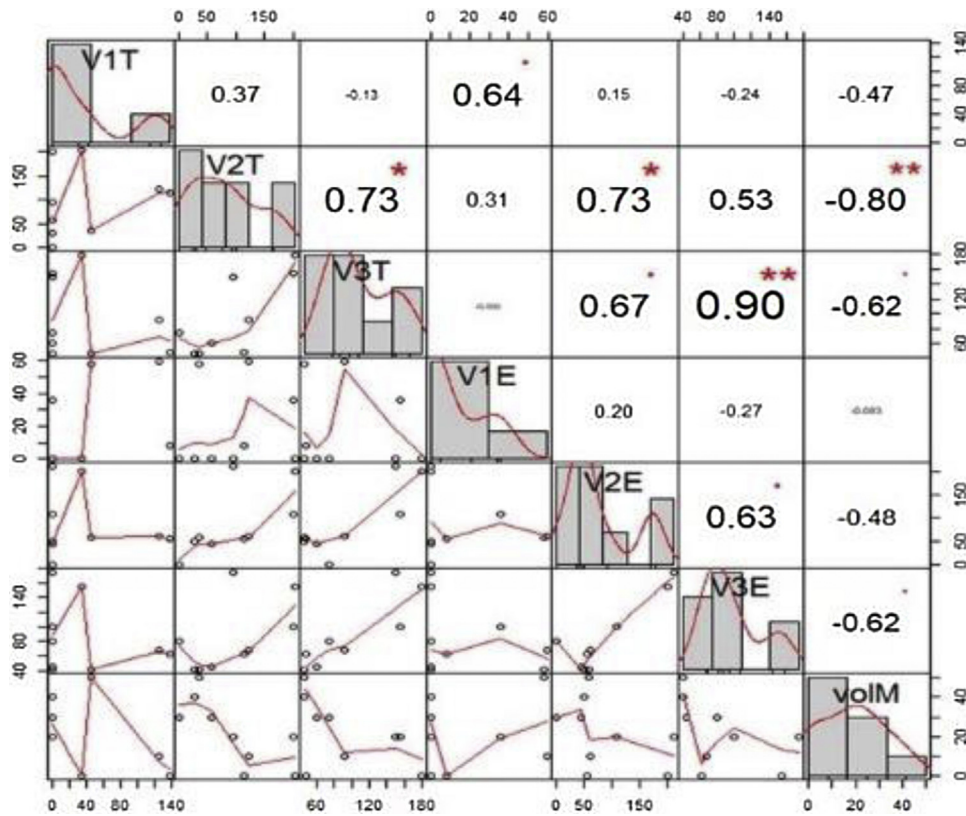


Figure 4 Correlogram. Volume's distribution (diagonal panel), Spearman's correlation coefficients and tests (upper panel; * $p < 0.05$, ** $p < 0.01$) and pairwise scatterplot (lower panel). V_xT , volume calculated based on areas obtained by FTM using model x , where $x = 1, 2, 3$; V_xE , volume calculated based on areas obtained by TDM using model x ; $volM$, volume measured.

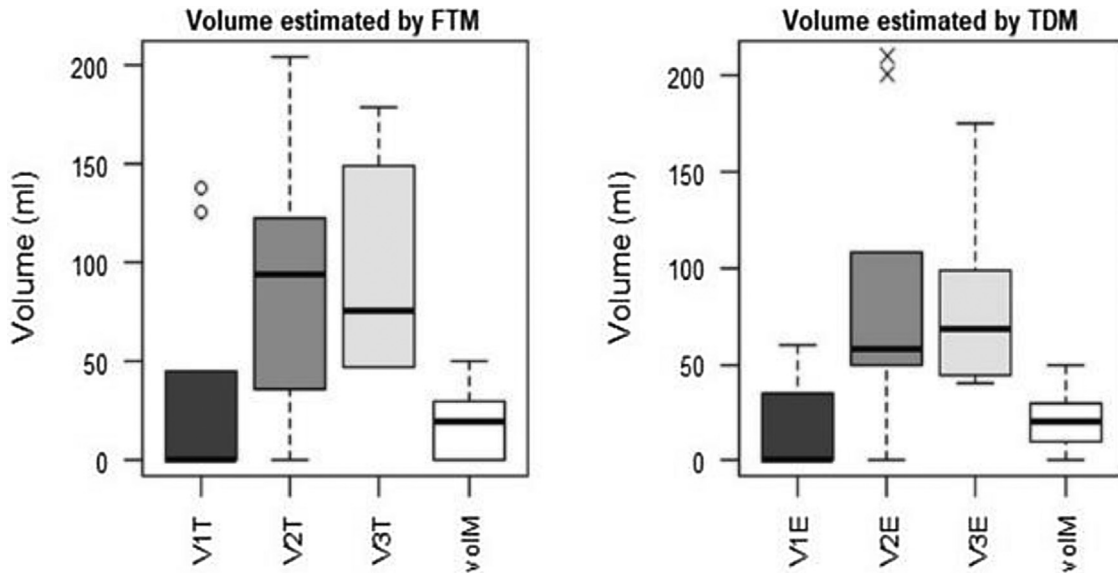


Figure 5 Volumes estimated by different models and differences between these volumes and the measured volume.

obtained by TDM in model V2 and volume calculated based on areas obtained by FTM in model V3.

Although all Spearman's correlation coefficients obtained between the Measured Volume and all the other volumes were negative, only the correlations between the Measured Volume and the volume calculated based on areas obtained

by TDM in model V2, the volume calculated based on areas obtained by FTM in model V3 and the volume calculated based on areas obtained by TDM in model V3 were statistically significant (Fig. 4).

Quade's test returned $p = 0.0317$ when comparing volumes calculated based on areas obtained by FTM in all 3

models and the Measured Volume. The multiple comparison test showed statistically significant differences between the volume estimated by model V2 and the Measured Volume ($p=0.0420$) and the volume estimated by model V3 and the Measured Volume ($p=0.0420$). When comparing volumes calculated based on areas obtained by TDM and the Measured Volume we concluded that there are statistically significant differences between those volumes ($p=0.0006$). The multiple comparison test showed statistically significant differences between the volume estimated by model V1 and model V2 ($p=0.0041$), the volume estimated by model V1 and model V3 ($p=0.0041$), the volume estimated by model V2 and the Measured Volume ($p=0.0041$) and the volume estimated by model V3 and the Measured Volume ($p=0.0047$). Finally, we cannot reject the hypothesis that volumes estimated by models V1 are equal to the measured volumes (Fig. 5).

Discussion

In this study performed on 36 patients undergoing elective gastric ultrasound evaluation before elective UGI, we assessed gastric contents and antrum area. The results verified that the totality of individuals had a gastric volume of less than 1.5 mL.kg^{-1} , which corresponds to a perioperative low risk aspiration according to Perlas et al.⁹

Furthermore, if considering the value of 0.8 mL.kg^{-1} suggested by Bouvet et al.⁶ only 5.56% would have an intermediate risk. This could be because individuals underwent the necessary fasting period for emptying the stomach before UGI. Some studies argument an average time of $248 \pm 39 \text{ min}$ ⁷ and $276.4 \pm 58.9 \text{ min}$ ¹⁰ for emptying the stomach. However, even after an average time of $490.2 \pm 214.2 \text{ min}$, liquid content of about $17 \pm 21 \text{ mL}$ was found in the stomach of 18 patients. However, this residual volume had no correlation with liquid fasting time contrary to the result of Sugita et al.¹ whilst confirming the result of Sadhvi et al.¹¹ This result can be due to the fact that the average fasting time in our study was much higher than the average fasting time considered necessary to clear the stomach.

The Bland-Altman analysis of the areas obtained by the FTM and TDM allowed us to conclude that the two methods are interchangeable, which corroborates the results obtained by Krusselbrink et al.¹²

The V3 model proposed by Perlas et al.⁵ to estimate gastric volume is the most widely used model both in the literature and in practice clinic. Nevertheless, we found no statistically significant correlation with the measured volume. Study limitations or the lack of sensibility of this model to estimate very low gastric volumes ($< 80 \text{ mL}$) could provide explanation regarding this finding. However, these volumes represent low risk for perioperative aspiration and have minor clinical significance.

The analysis of the difference between volumes estimated by the 3 models revealed statistically significant differences between the estimated volume by V2 and V3 models and the Measured Volume. Perlas et al.⁵ had previously described that the V2 model had a tendency to overestimate gastric volume. On the other hand, no statistically significant difference was found between the

estimated volume by V1 model and the Measured Volume, suggesting that this model was better adjusted to our dataset.

The study has other limitations: it was performed with a reduce number of individuals $n_1 = 9$, $n_2 = 9$ and even $n_3 = 36$; the qualitative analysis of gastric content was not based on 3-point grading system;⁵ individuals had high fasting period with small gastric volumes that were difficult to aspirate; no clinically relevant gastric volumes ($> 1.5 \text{ mL.kg}^{-1}$) were found.

Summary

Regarding qualitative and quantitative evaluation of gastric content, we concluded that there is no difference between ultrasound and UGI assessments, even without finding differences in the evaluation of small amounts of liquid content.

There were no differences in the results obtained by the two sonographers with different degrees of experience, which allows us to conclude that gastric ultrasound in the perioperative period can be performed by anesthesiologist in order to evaluate full stomach risk.

Such conclusions support the use of point-of-care gastric ultrasound (POCGUS) in the evaluation of perioperative aspiration risk. Different clinical algorithms have been suggested by Van de Putte and Perlas A.⁴ and Bouvet et al.¹³ to accomplish this.

Conflicts of interest

The authors declare no conflicts of interest.

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