

Ultrasound-guided estimation of gastric residual volume using Perlas's formula: A validation study in patients

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ABSTRACT

Background and Aims: Bedside ultrasound (US) is used to evaluate gastric residual volume (GRV) and assess aspiration risk. We examined the accuracy of US-guided measurement of GRV using Perlas's formula, by two trained anaesthesiologists, in patients who had consumed different types and volumes of fluids. **Methods:** Patients with no risk factors for delayed gastric emptying were included. Each assessor independently determined the baseline US-guided GRV. The patients were randomly allocated to receive no drink or 100 or 200 mL of water or milk. US-guided GRV was re-assessed within 5 min after the intervention. Investigators were blinded to the measurements performed by each other and to the randomisation arm. The primary outcome was the agreement between actual volumes consumed and estimated change in GRV. **Results:** Agreement between actual volume consumed and estimated change in GRV was poor [Intra-class correlation coefficient (ICC) 0.46, 95% confidence interval (CI) 0.09 to 0.72; $P = 0.09$ for assessor 1 and ICC 0.37; 95% CI 0.02 to 0.66; $P = 0.03$ for assessor 2]. **Conclusion:** US-guided GRV measurements using Perlas's formula, performed by trained anaesthesiologists may not be a reliable measure of GRV.

Key words: Gastric emptying, pyloric antrum, stomach content, ultrasonography

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INTRODUCTION

Patients receiving sedation or general anaesthesia are at risk of aspiration due to impairment of their lower oesophageal sphincter tone and protective airway reflexes. Previous studies have used bedside ultrasound (US) to evaluate gastric residual volume (GRV) to assess peri-operative aspiration risk and guide anaesthetic management.^[1,2] However, in some of these studies, certified sonographers performed all measurements and, therefore, the results may not be reproducible. A recent study showed poor agreement between GRV measurements made by radiologists and trained anaesthesiologists.^[3] There is very little data on the learning curve for anaesthesiologists to achieve competence in the gastric US.^[4] The purpose of this study was to examine the accuracy of US-guided measurement of GRV using Perlas's formula, by trained anaesthesiologists,

in patients who received two different types and varying volumes of liquids.

METHODS

This was an interventional study initiated at a tertiary-referral cancer institute in India between 12th June 2019 and 8th January 2020 after Institutional Review Board approval and registration at the Clinical

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Trials Registry of India (CTRI/2019/02/017677). The study was initially planned to be carried out with healthy volunteers; however, due to logistic issues with the recruitment of healthy volunteers, we amended the protocol and recruited patients admitted to the hospital. A written informed consent was obtained from all patients. Adult patients with no risk factors for delayed gastric emptying (e.g.; uncontrolled diabetics, morbid obesity (body mass index more than 40 kg/m²), pregnancy, patients on opioids, pyloric stenosis, intestinal obstruction, gastric or oesophageal malignancy or pathology, patients on treatment with antacids, prokinetics or with history of acid peptic disease or gastric reflux) were included. As the patients were randomised to receive various types and volumes of fluids, patients who were not posted for surgery on the day of their GRV assessment were included, so that their anaesthesia management would not be affected. Study assessments were independently performed by two anaesthesiologists, each of whom was trained in US assessment of GRV and had performed at least 70 examinations before commencing the study. At any convenient time of the day (not necessarily fasting), the patients underwent baseline US-guided estimation of GRV independently by each assessor, within 5 min of each other. These patients were then randomly allocated to receive one of the following interventions: no drink, 100 mL of water, 200 mL of water, 100 mL of milk or 200 mL of milk [Table 1]. Each assessor performed a repeat US-guided assessment of GRV within 5 min of the intervention (to minimise the effect of gastric emptying). The assessors were blinded to the measurements performed by each other and to the randomisation arm. Between the baseline and post-randomisation assessments, the assessors were

asked to leave the room, and any glasses of water or milk were cleared away before they returned. To further ensure blinding, assessors were not allowed to communicate with the patients until assessments were completed.

For all GRV measurements, a curved array low-frequency transducer (2–5 MHz) of the same US machine (Sonosite™ M Turbo) was used with standard abdominal settings to identify the relevant anatomic landmarks. With the patient in the right lateral decubitus position, the antrum was imaged in a parasagittal plane in the epigastric area using the left lobe of the liver, the inferior vena cava, and the superior mesenteric vein as internal landmarks. After identifying these vessels, the transducer was rotated slightly clockwise or counterclockwise to obtain a cross-sectional view of the antrum. Measurements were taken including the full thickness of the gastric wall, from serosa to serosa, in between peristaltic contractions. Antral cross-sectional area (ACSA) was measured by using two perpendicular diameters – antero-posterior (AP) and cranio-caudal (CC) of the antrum and the formula of the area of an ellipse:

$$ACSA = (AP \times CC \times \pi) / 4$$

(AP=antero-posterior diameter and CC=cranio-caudal diameter)^[5]

Gastric volume was determined by using the formula based on studies by Perlas *et al.*^[5] - stomach volume (mL) = 27 + 14.6 ACSA (in right lateral position) (cm²) – 1.28*age (years).^[5] This model can predict volumes from 0 to 500 mL and is applicable to non-pregnant adult patients with body mass index less than 40 kg/m².

The primary outcome was to assess agreement between the volume of fluid ingested and the estimated change in GRV. Secondary outcomes included analysing agreement between assessors at each stage of assessment, and the effect of type and volume of fluid on the agreement between ingested volume and estimated change in GRV.

Assuming intra-class correlation (ICC) of 0.5 between readings (null hypothesis), to detect an ICC of 0.8 between the actual and measured volume at a 5% level of significance and 90% power, 40 sets of measurements were needed. We planned to get 50 sets of measurements from 25 participants (each participant had two sets of measurements: actual volume consumed versus estimated change in GRV for

Table 1: Characteristics of study participants

Characteristic	Result
Age (years)	47.3±13.3
Weight (kg)	51.6±10.4
Gender	
Male	4 (16%)
Female	21 (84%)
American Society of Anesthesiologists physical status	
I	23 (92%)
II	2 (8%)
Randomisation arm	
No drink	6 (24%)
100 mL water	7 (28%)
200 mL water	7 (28%)
100 mL milk	2 (8%)
200 mL milk	3 (12%)

Data are represented as mean (standard deviation) for numerical data and absolute numbers (percentages) for categorical data

assessor 1; actual volume consumed versus estimated change in GRV for assessor 2).

The data were entered into a statistical software (Statistical Package for Social Sciences 20.0) for analysis. The categorical data were expressed as percentages and continuous data as means (standard deviation) or median (inter-quartile range). ICC coefficient was used to determine the agreement between continuous variables. *P* value <0.05 was considered significant for all outcomes.

RESULTS

Twenty-five patients were accrued in the study; there were no protocol violations, and all 25 participants were included in the final analysis [Figure 1]. The baseline demographic characteristics of the patients were comparable between the groups [Table 1]. The mean baseline GRV was 177 ± 111 mL and 154 ± 132 mL as measured by assessors 1 and 2, respectively. For each assessor, the estimated change in GRV correlated poorly with actual volume of fluid consumed [ICC 0.46, 95% confidence interval (CI) 0.09 to 0.72; *P* 0.09 for assessor 1 and ICC 0.37; 95% CI 0.02 to 0.66; *P* 0.03 for assessor 2).

There was moderate agreement between baseline measurements made by the two assessors (ICC 0.54; 95% CI 0.20 to 0.77; *P* 0.002) and between post-randomisation GRV measurements made by assessors 1 and 2 (ICC 0.6; 95% CI 0.29 to 0.80; *P* 0.001). No association was found between the type of fluid or volume of fluid on the agreement between measurements made by assessors (*P* 0.67).

As an unplanned sub-group analysis, we looked at the group randomised to receive no drink, in which we would expect pre-and post-randomisation

measurements to be nearly identical. Good agreement was found between pre-and post-measurements for each assessor (ICC 0.94; 95% CI 0.62 to 0.99; *P* 0.001 for assessor 1; ICC 0.76; 95% CI 0.02 to 0.96; *P* 0.023 for assessor 2).

DISCUSSION

In this study, a poor agreement was found between the estimated change in GRV and the actual volume of fluid ingested as assessed by trained anaesthesiologists, and between measurements made by the assessors. There was no effect of type of fluid or volume of fluid on the agreement between measurements.

As shown in previous studies, in some categories of patients, the GRV may be high even after prolonged fasting.^[6-8] Recognition of a high GRV before induction of anaesthesia will allow the anaesthesiologist to take appropriate precautions to minimise the risk of aspiration. Among the various techniques described for assessment of GRV, methods based on US-guided measurement of ACSA have been shown to have good agreement with actual GRV.^[1,2] However, most of the studies on this topic have been done by the same team, with certified sonographers performing the measurements.^[2,5,9] Arzola *et al.*^[4] evaluated the performance of anaesthesiologists using US for qualitative estimation of GRV, and established that the learning curve needed to achieve 95% competence was 33 cases. Kruisselbrink *et al.*^[10] compared the measurements between three types of raters with varying levels of experience in ultrasonography. They found very high inter-rater concordance between sonographers and anaesthesiologists, irrespective of experience. In contrast, another recent study compared US-guided GRV measurements between anaesthesiologists and radiologists and showed poor

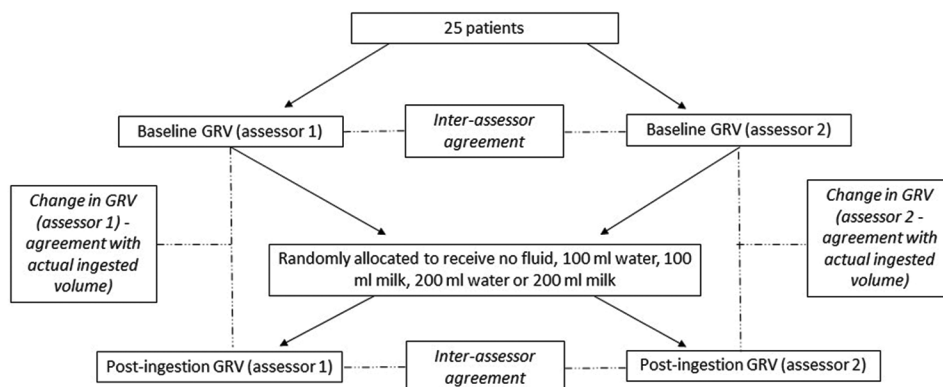


Figure 1: Study schema. GRV: Gastric residual volume

agreement between them despite adequate training (30 assessments) of anaesthesiologists.^[3] As the former studies were from the same team which had initially developed the algorithm for the prediction of GRV based on ACSA, it is possible that the non-sonographers in this team had more experience with the gastric US as compared to non-sonographers in our hospital.^[4,10,11]

The current study showed poor agreement between changes in GRV with actual ingested volume. This is in contrast to the study by Perlas *et al.*^[2], who measured GRV in both supine and lateral positions after ingestion of five different types of fluid. They found a high correlation between ACSA in both the supine and lateral positions and the actual ingested volume; however, this relationship was limited to relatively small volumes (up to 300 mL). Another study by Cubillos also examined GRV after ingestion of different types and volumes of fluid; however, they did not quantify the GRV with respect to the volume of fluid consumed, and only looked at a change in the appearance of gastric contents.^[12] In all these studies, the patients fasted before ingestion of the test fluid. This could explain the discrepancy seen in the current study as patients were recruited regardless of their fasting status, and the volume of drink given was in addition to baseline content, which could have exceeded 300 mL in some patients.

The calorie content is one of the major factors that determine gastric emptying and as milk has higher caloric density than water, it needs a longer abstinence period than water.^[13] From the ultrasound perspective, clear liquids (water) and particulate liquids (milk) provide different sonic-textures, and it is important to recognise these as patients with particulate gastric content will have delayed gastric emptying and more dangerous consequences of aspiration. For this reason, both water and milk were used in the current study.

Burton showed that up to 2 h after a meal, GRV assessed by positron emission tomography was much higher than baseline GRV plus ingested volume.^[14] This has been attributed to swallowed air during meal ingestion and gastric secretions in this period. This is similar to the findings of the current study, where there was poor agreement between measured volume and the ingested volume. This was also seen in the study by Bisinotto *et al.*^[15] where irrespective of the type of food ingested, a mixture of gaseous, liquid and solid contents were seen in the stomach. This suggests

that final gastric volume may not just be the sum of baseline GRV and ingested volume but may include ingested air and gastric secretions.

An interesting finding in the current study is that there was poor agreement between assessors for the pre-randomisation measurements, and the post-randomisation measurements, despite both assessors having adequate experience in US-guided GRV measurement. This suggests that US-guided GRV measurement may be subjective, with inter-assessor variations.

The strength of the study is that it was a pragmatic study. A variety of fluid types and volumes were used (as might be seen in patients presenting for emergency surgery). Bias was minimised by blinding assessors to the volume and type of fluid ingested and to each other's measurements. Quality control was ensured by performing all measurements within 5 min after ingestion, to minimise the effects of gastric emptying. To check the reliability of measurements, a control group that did not receive any fluid was included. The anaesthesiologists involved in the study had each independently performed at least 70 ultrasonographic assessments of GRV to reach the necessary competence.

One of the limitations of the study is that the sample size was small; however, this was calculated based on the expected agreement between measurements. Also, it is known that gastric peristalsis may begin as soon as fluids are ingested, and therefore, minor changes in volumes could be attributed to this. The study did not involve a qualified sonographer and did not compare the findings between anaesthesiologists and radiologists. However, in the setting of emergency surgery, it may not always be possible to have a qualified sonographer to perform gastric ultrasonography; and the study mimicked this situation.

CONCLUSION

The agreement between the US-measured changes in gastric volume and actual ingested volume across various types and volumes of ingested fluid is poor, and there is no association between type of fluid or volume of fluid on the agreement between US measurements made by trained anaesthesiology investigators. These limitations must be recognised during the use of gastric US to measure GRV before anaesthesia, and precautions must be taken to minimise the risk of aspiration.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have/have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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