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Original Article

Ultrasonographic assessment of residual gastric volume in diabetic versus non-diabetic patients following standard preoperative fasting: A comparative observational study

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ABSTRACT

Background: Pulmonary aspiration of gastric contents at induction of anaesthesia is uncommon but carries substantial morbidity and mortality. Standard fasting intervals assume normal gastric emptying, yet diabetes mellitus is among the commonest causes of delayed emptying and diabetic gastroparesis is frequently asymptomatic. Point-of-care gastric ultrasonography permits bedside assessment of residual gastric volume. **Methods:** A prospective comparative observational study enrolled 160 adults undergoing elective surgery under general anaesthesia, in two groups of 80 defined by the presence or absence of diabetes mellitus. After fasting according to American Society of Anesthesiologists guidance, the gastric antrum was imaged with a 2–5 MHz curvilinear probe in the supine and right lateral decubitus positions. Antral cross-sectional area was calculated from orthogonal antral diameters and gastric volume estimated using the validated Perlas model. Perlas gastric grade and the proportion with a volume of 1.5 mL/kg or more were compared between groups. **Results:** Diabetic patients showed a larger mean antral cross-sectional area (7.8 ± 2.2 versus 5.0 ± 1.4 cm^2, $p < 0.001$) and a larger estimated residual gastric volume (70 ± 27 versus 37 ± 18 mL, $p < 0.001$) than non-diabetic patients despite identical fasting protocols. The distribution of Perlas gastric grades differed between groups ($p < 0.001$), with grade 2 antra in 22.5% of diabetic and 5.0% of non-diabetic patients. A gastric volume of 1.5 mL/kg or more was recorded in 23.7% of diabetic patients and 1.2% of non-diabetic patients ($p < 0.001$). Within the diabetic group, residual gastric volume correlated with glycated haemoglobin ($r = 0.42$, $p < 0.001$) and with duration of diabetes ($r = 0.39$, $p < 0.001$). **Conclusion:** Diabetic patients retained greater gastric contents than non-diabetic patients despite recommended fasting durations. Gastric ultrasonography offers a rapid, non-invasive method of individualised aspiration risk assessment and may inform perioperative decision-making in this group.

KEYWORDS: Gastric ultrasonography; Point-of-care ultrasound; Diabetes mellitus; Residual gastric volume; Aspiration risk; Gastric emptying; Preoperative fasting.

Introduction

Pulmonary aspiration of gastric contents is among the most feared complications of induction of anaesthesia. Although the reported incidence is low, ranging in large series from roughly 1 in 2,000 to 1 in 30,000 anaesthetics depending on population and setting, aspiration pneumonitis contributes disproportionately to perioperative morbidity, unplanned critical care admission and anaesthesia-related death [1,2]. Preoperative fasting accordingly remains a cornerstone of aspiration prevention.

Current guidance from the American Society of Anesthesiologists and from European bodies recommends fasting intervals of two hours for clear fluids, six hours for a light meal and eight hours for a fatty or heavy meal [3,4]. These intervals were derived largely from studies of healthy volunteers and rest on the assumption that gastric emptying proceeds at a predictable rate.

That assumption does not hold uniformly. Diabetes mellitus is among the commonest causes of delayed gastric emptying: chronic hyperglycaemia injures vagal and enteric neurons and depletes the interstitial cells of Cajal that generate gastric pacemaker activity, producing diabetic gastroparesis [5,6]. Delayed emptying has been demonstrated in a substantial proportion of patients with long-standing diabetes, and an important subset remain entirely asymptomatic [5]. For these patients a conventional fasting interval may not reliably deliver an empty stomach.

Bedside gastric ultrasonography offers a means of resolving this uncertainty at the point of care. Real-time ultrasonographic measurement of the gastric antrum was first described as a means of tracking gastric emptying four decades ago [7], but its adaptation to preoperative risk assessment is more recent. Perlas and colleagues established that antral cross-sectional area measured in the right lateral decubitus position correlates closely with gastric volume [8], described a three-point qualitative grading system for fasted surgical patients [9], and validated a mathematical model relating antral area and age to volume against volumes recovered at gastroscopy [10]. The technique has since been reviewed extensively [11], compared against alternative antral measurements [12], and shown to have acceptable intra- and inter-rater reliability among trained operators [13,14].

Applied to unselected surgical populations, the method has

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repeatedly identified patients with unexpectedly large gastric volumes despite adequate fasting [15], and it has been applied to obstetric [16] and other special populations. Data from Indian surgical cohorts remain comparatively limited, although the technique has been evaluated in that setting [17]. Systematic comparison between diabetic and non-diabetic patients undergoing identical fasting has been reported less often, and it is that comparison this study addresses.

The present study aim was to compare residual gastric volume measured by bedside ultrasonography between diabetic and non-diabetic patients after standard preoperative fasting. The primary objective was to compare estimated residual gastric volume between groups. Secondary objectives were to compare antral cross-sectional area and the distribution of Perlas gastric grades, to determine the proportion of patients in each group with a gastric volume of 1.5 mL/kg or more, and to examine the correlation of residual gastric volume with glycated haemoglobin and duration of diabetes.

Materials And Methods

Design and setting

This prospective comparative observational study was conducted in the Department of Anaesthesiology, ESIC Medical College and Postgraduate Institute of Medical Sciences and Research, Rajajinagar, Bengaluru, over a period of twelve following approval by the Institutional Ethics Committee. Written informed consent was obtained from every participant before enrolment. The study was conducted in accordance with the Declaration of Helsinki [18] and is reported in line with the STROBE statement for observational research [19].

Participants

Adults aged 18 to 70 years of ASA physical status I to III scheduled for elective surgery under general anaesthesia, fasted according to American Society of Anesthesiologists guidance [3], were eligible. Participants were assigned to a diabetic or non-diabetic group according to a pre-existing physician diagnosis of diabetes mellitus, with 80 recruited to each group.

Exclusion criteria were pregnancy, emergency surgery, previous gastric surgery, known upper gastrointestinal obstruction, body mass index above 40 kg/m^2, receipt of glucagon-like peptide-1 receptor agonists, and declining participation.

Sample size

A total of 160 patients, 80 per group, was studied. On the standard two-sample formula, 80 per group provides 80% power at a two-sided alpha of 0.05 to detect a difference of 15 mL in mean gastric volume assuming a common standard deviation of 25 mL (44 per group required), and to detect an increase in the proportion of patients with a gastric volume of 1.5 mL/kg or more from 8% to 25% (74 per group required). The binary comparison is the binding constraint, and 80 per group satisfies both with allowance for unusable images.

Ultrasound protocol

Scanning was performed with a portable ultrasound machine and a 2–5 MHz curvilinear probe. The gastric antrum was identified in a parasagittal plane in the epigastrium, between the left lobe of the liver anteriorly and the pancreas posteriorly, with the aorta or inferior vena cava as the posterior vascular landmark. Each participant was scanned in the supine position and then in the right lateral decubitus position. Two orthogonal antral diameters, anteroposterior and craniocaudal, were measured at rest between peristaltic contractions. Antral cross-sectional area was calculated as: CSA (cm^2) = π × AP × CC / 4

and estimated gastric volume from the validated Perlas model for the right lateral decubitus position [10]: Volume (mL) = 27.0 + 14.6 × CSA(RLD) − 1.28 × age (years)

Gastric contents were additionally graded using the three-point Perlas scale, and estimated volume indexed to body weight, with 1.5 mL/kg or more taken to denote increased aspiration risk [9,11] (Table 1, Figure 1).

Table 1. Published reference values used for interpretation

Parameter	Value	Interpretation	Source
Antral CSA, right lateral decubitus	< 3.0–3.5 cm^2	Consistent with an empty antrum	[9,11]
Antral CSA	3.5–6.0 cm^2	Small fluid volume	[11]
Antral CSA	> 6.0 cm^2	Larger fluid volume	[11]
Volume indexed to weight	< 1.5 mL/kg	Baseline aspiration risk	[9,11]
Volume indexed to weight	≥ 1.5 mL/kg	Increased aspiration risk	[9,11]
Perlas grade 0	Antrum empty supine and RLD	Empty stomach	[9]
Perlas grade 1	Fluid visible in RLD only	Small volume, usually within fasting range	[9]
Perlas grade 2	Fluid visible supine and RLD	Larger volume; quantify	[9]

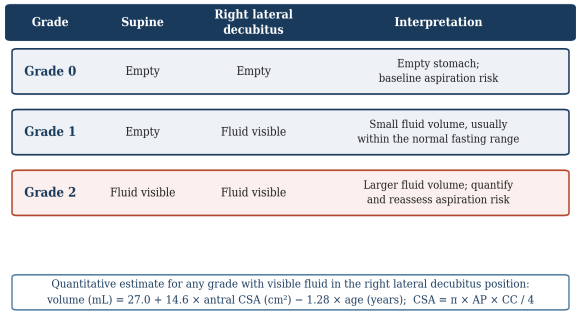

Figure 1. Qualitative gastric grading and the quantitative volume model, after Perlas and colleagues [9,10].

Statistical analysis

Continuous variables are summarised as mean ± standard deviation and categorical variables as counts with percentages. Continuous variables were compared between groups using the independent-samples t test; categorical variables were compared using the Pearson chi-square test. Associations between residual gastric volume and clinical variables were examined within the diabetic group using the Pearson correlation coefficient, with 95% confidence intervals derived by Fisher z transformation. A two-sided p value below 0.05 was taken to denote statistical significance.

Results

Baseline characteristics

Baseline characteristics of the two groups are shown in Table 2. Diabetic patients were on average six years older (55.3 ± 10.8 versus 49.2 ± 11.4 years, p = 0.003) and had a higher body mass index (26.1 ± 3.8 versus 24.6 ± 3.2 kg/m^2, p = 0.02) and glycated haemoglobin (8.1 ± 1.2 versus 5.5 ± 0.4%, p < 0.001). Fasting duration was comparable between groups, at approximately 9.4 hours (p = 0.42), confirming that both groups were fasted to the same standard.

Table 2. Baseline characteristics

Variable	Non-diabetic (n = 80)	Diabetic (n = 80)	p value
Age (years)	49.2 ± 11.4	55.3 ± 10.8	0.003
Male, n (%)	45 (56.3)	46 (57.5)	0.87
Body mass index (kg/m²)	24.6 ± 3.2	26.1 ± 3.8	0.02
Glycated haemoglobin (%)	5.5 ± 0.4	8.1 ± 1.2	< 0.001
Fasting duration (hours)	9.3 ± 1.1	9.5 ± 1.2	0.42
Body weight (kg)	69.4 ± 10.6	73.8 ± 11.2	0.014

Values are mean ± standard deviation unless stated. Continuous variables compared by independent-samples t test, sex by chi-square test.

Antral measurements and gastric volume

Antral dimensions and derived measures are shown in Table 3. Diabetic patients had a larger mean antral cross-sectional area in the right lateral decubitus position (7.8 ± 2.2 versus 5.0 ± 1.4 cm^2, $p < 0.001$), a larger estimated residual gastric volume (70 ± 27 versus 37 ± 18 mL, $p < 0.001$) and a larger volume indexed to body weight (0.95 ± 0.36 versus 0.53 ± 0.22 mL/kg, $p < 0.001$). Both anteroposterior and craniocaudal antral diameters were greater in the diabetic group ($p < 0.001$ for each).

Table 3. Antral measurements and estimated gastric volume

Variable	Non-diabetic (n = 80)	Diabetic (n = 80)	p value
Anteroposterior diameter (cm)	2.1 ± 0.3	2.7 ± 0.5	< 0.001
Craniocaudal diameter (cm)	3.0 ± 0.4	3.6 ± 0.6	< 0.001
Antral CSA (cm^2)	5.0 ± 1.4	7.8 ± 2.2	< 0.001
Estimated gastric volume (mL)	37 ± 18	70 ± 27	< 0.001
Gastric volume (mL/kg)	0.53 ± 0.22	0.95 ± 0.36	< 0.001

Values are mean ± standard deviation; independent-samples t test. Mean estimated volumes reproduce exactly from the Perlas model applied to the mean antral CSA and mean age of each group.

Qualitative gastric grading

The distribution of Perlas gastric grades differed between groups (chi-square test, $p < 0.001$; Figure 2). A grade 0 antrum, indicating an empty stomach in both positions, was recorded in 70.0% of non-diabetic patients but in only 37.5% of diabetic patients, while grade 2 antra were recorded in 22.5% of diabetic patients against 5.0% of non-diabetic patients.

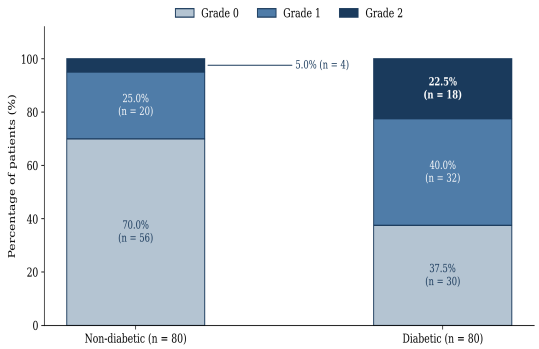

Figure 2. Distribution of Perlas gastric grades

Pearson chi-square test for the distribution across all three grades, $p < 0.001$. The p value applies to the distribution as a whole and not to individual grades.

Aspiration risk category

The proportion of patients with an estimated gastric volume of 1.5 mL/kg or more, the threshold conventionally taken to denote increased aspiration risk, was higher among diabetic patients (23.7% versus 1.2%; chi-square test, $p < 0.001$; Table 4).

Table 4. Aspiration risk category

Category	Non-diabetic, n (%)	Diabetic, n (%)
Gastric volume < 1.5 mL/kg	79 (98.8)	61 (76.3)
Gastric volume ≥ 1.5 mL/kg	1 (1.2)	19 (23.7)
Total	80 (100)	80 (100)

Pearson chi-square test, $p < 0.001$.

Correlation analysis

Within the diabetic group, residual gastric volume correlated positively with glycated haemoglobin and with duration of diabetes, and showed weaker associations with body mass index and age that did not reach conventional significance (Table 5).

Table 5. Correlation between clinical variables and residual gastric volume, diabetic group (n = 80)

Variable	Correlation coefficient (r)	95% CI	p value
Glycated haemoglobin	0.42	0.22 to 0.59	< 0.001
Duration of diabetes	0.39	0.18 to 0.57	< 0.001
Body mass index	0.18	−0.04 to 0.38	0.11
Age	0.15	−0.07 to 0.35	0.18

Pearson correlation; 95% confidence intervals by Fisher z transformation. The confidence interval widths for all four coefficients correspond to n = 80,

Discussion

In this comparison of 160 fasted adults, patients with diabetes had a larger gastric antral cross-sectional area and a larger estimated residual gastric volume than non-diabetic patients despite identical fasting protocols, and a greater proportion fell into the higher Perlas grades and above the 1.5 mL/kg threshold. The direction and magnitude of these differences are consistent with the established pathophysiology and with previous work.

The mechanism is well characterised. Chronic hyperglycaemia produces vagal and enteric neuropathy with depletion of the interstitial cells of Cajal, the pacemaker cells that generate the gastric slow wave, slowing antral contraction and delaying emptying [5,6]. Because this process is frequently silent, a patient may have materially delayed emptying without symptoms that would prompt any change in fasting instruction.

The methodological foundation for the measurements is secure. Perlas and colleagues established the correlation between antral cross-sectional area in the right lateral decubitus position and gastric volume [8], described the three-point qualitative grade used here [9], and validated the mathematical model against volumes recovered at gastroscopy [10]. Comparative work has supported antral area as the measurement of choice [12], and reliability among trained operators is acceptable [13,14]. The right lateral decubitus position is preferred for quantitative

estimation because dependent pooling improves the correlation between antral area and true volume [8,11].

The present findings sit alongside a literature showing that a minority of adequately fasted surgical patients have gastric volumes that would ordinarily prompt a change in airway management. Van de Putte and colleagues, reviewing fasted patients retrospectively, found such volumes in a clinically relevant proportion [15], and comparable observations have been made in Indian practice [17]. The contribution of the present study is to attribute a substantial share of that residual risk to a single identifiable group.

The correlation of residual volume with glycated haemoglobin and with duration of diabetes is the more practically useful finding, since it suggests a gradient of risk within the diabetic population rather than a uniform elevation. That points towards selective rather than universal preoperative scanning: in patients with long-standing or poorly controlled disease, established autonomic neuropathy, or symptoms suggestive of gastroparesis. These analyses are correlational and the study was not sized for them, so they should be regarded as hypothesis-generating.

The proportion of diabetic patients exceeding 1.5 mL/kg (23.7%) is substantially higher than the reported mean and standard deviation for that group (0.95 ± 0.36 mL/kg) would predict under a normal distribution, which would place the expected proportion near 6%. This indicates that indexed gastric volume is right-skewed, and parametric summary and testing may therefore misrepresent the spread. Ultrasonographic measurement is operator-dependent, and no assessment of inter-observer reliability was made within the study. No reference standard such as gastric scintigraphy or suctioning was used, so estimated volumes rest on the accuracy of the Perlas model rather than on direct measurement in this cohort. The effect of individual antidiabetic agents was not examined, and symptomatic and asymptomatic gastroparesis were not formally distinguished.The study measures gastric volume, not aspiration.

Conclusion

Adults with diabetes mellitus had larger antral cross-sectional areas and greater estimated residual gastric volumes than non-diabetic adults after identical standard fasting, with a higher proportion exceeding the conventional 1.5 mL/kg threshold for increased aspiration risk. Within the diabetic group, residual volume increased with poorer glycaemic control and longer disease duration. These observations support the view that fasting duration alone is a weaker guarantee of gastric emptiness in diabetic patients than current uniform guidance implies, and that bedside gastric ultrasonography has a role in individualised preoperative risk assessment in this group.

Declarations

Ethics approval and consent to participate: Approved by the Institutional Ethics Committee Written informed consent was obtained from all participants.

Data availability: The de-identified participant-level dataset will be provided from corresponding author upon requested.

Conflicts of interest and funding: Nil.

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