Original Article

Determinants of gastric residual volume before elective surgery in diabetic patients: An observational study

ABSTRACT

Background: We investigated factors affecting the low- and high-risk groups for aspiration by measuring gastric volume with ultrasound in diabetic patients who fasted for elective surgery.

Methods: The study was conducted as an observational study. Sixty-five patients scheduled for elective surgery, aged 18–86 years, with American Society of Anesthesiologists (ASA) scores II–III, and who have diabetes were included after local ethics committee approval. Written informed consent was obtained from all participants. Demographic data of cases were recorded. Patients whose gastric residual volume (GRV) was calculated using the pupils equal, round, reactive to light, and accommodation (PERLA) formula following gastric antrum measurement in the right lateral decubitus and supine position by ultrasound were categorized as low or high risk for aspiration.

Results: Thirty-one patients were in the low-risk group, and 34 patients were in the high-risk group. Sex, weight, body mass index (BMI), hemoglobin A1c (HbA1c) values, and duration of diabetes were not statistically significant ($p > 0.5$). Age ($p = 0.006$) and fasting blood glucose (FBG) ($p = 0.005$) were statistically significant. The risk of aspiration decreases with age. Hyperglycemia is related to delayed gastric emptying and a high risk for aspiration. The duration of fasting, GRV, and cross-sectional area (CSA) were statistically significant ($p = 0.017$, $p = 0.000$, and $p = 0.000$, respectively).

Conclusion: Gastric emptying might be delayed in diabetic patients resulting in a high risk for aspiration pneumonia. The risk of aspiration increases in young diabetic patients, and preoperative FBG measurements can provide an idea about gastric emptying in diabetic patients. Gastric ultrasound (USG) may contribute to guidelines for determining more appropriate fasting times for other patient populations, such as obese, pregnant, or child patients.

Key words: Diabetes mellitus, fasting, residual volume, respiratory aspiration, ultrasound

Introduction

Aspiration of gastric contents before an operation is a preventable threat that poses a serious risk of mortality and morbidity; for this reason, fasting periods for elective operations are determined by American Society of Anesthesiologists (ASA) guidelines and food restriction hours (clear liquid–breast milk–formula, cow's milk, and light food–oily solid food) are applied. This is summarized as 2–4–6–8 hours of fasting for clear liquids/breast milk/formula, cow's milk, solid food, and oily solid, respectively. The aim was to provide gastric emptying and avoid aspiration. Adequate gastric emptying may not be observed in some patients even if they follow the

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recommended fasting periods. Delayed gastric emptying is a major risk factor contributing to aspiration of gastric contents. Diabetic patients often experience prolonged gastric emptying times. In a healthy adult, 10–100 ml of gastrointestinal system secretion remains in the stomach, but the amount of the secretion remaining in the stomach increases in patient groups with slowed motility, such as diabetes. Although it is known that gastric emptying is delayed in diabetic patients, the guidelines do not provide clear information regarding the fasting period before elective surgery for this patient group.[1] Some studies have used gastric ultrasound (USG) to evaluate gastric content and volume.[2,3]

In this study, we aimed to determine the risk groups for aspiration by evaluating gastric contents and residual volumes with gastric USG in diabetic patients who were scheduled for elective surgery. We compared the fasting times between the high-risk and low-risk groups and identified factors that affect the preoperative fasting time needed for adequate gastric emptying. Our goal was to contribute to the literature by identifying risk factors for aspiration and determining more appropriate preoperative fasting times for diabetic patients.

Methods

This study was approved by the Non-Invasive Clinical Research Ethics Committee of University (26.12.2019, 2019/18-39). This trial was registered at Australian New Zealand Clinical Trials Registry (ACTRN12622001385730). The current study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines and the Helsinki Declaration. A STROBE flow diagram was used for patient enrollment [Figure 1].

Sixty-five ASA II–III patients older than eighteen years with type 2 diabetes scheduled for elective surgery and who gave consent to participate in the study were included in the study. Patients who had a history of previous gastric and esophageal surgery, neuromuscular disease, end-stage chronic kidney disease (CKD), gastroesophageal reflux disease (GERD), pregnancy, prokinetic agent use, inappropriate mental capacity, and drug use that may delay gastric emptying were excluded. The patients were interviewed the night before the operation and were told to record the time and the type of the last preoperative oral intake. The last laboratory values of the patients registered in the system were recorded. The patients were instructed not to smoke for at least 8 hours before the gastric residual volume (GRV) measurement with USG, which was performed within 15 minutes before the induction of anesthesia. Gastric antrum measurement was performed by USG in the supine and right lateral decubitus positions guided by the anatomical reference points just before the commencement of the anesthesia induction. Fasting blood glucose (FBG) levels were measured from the fingertips of the patients at the time of GRV measurement. This procedure is routinely applied for all diabetic patients who will be operated in our hospital.

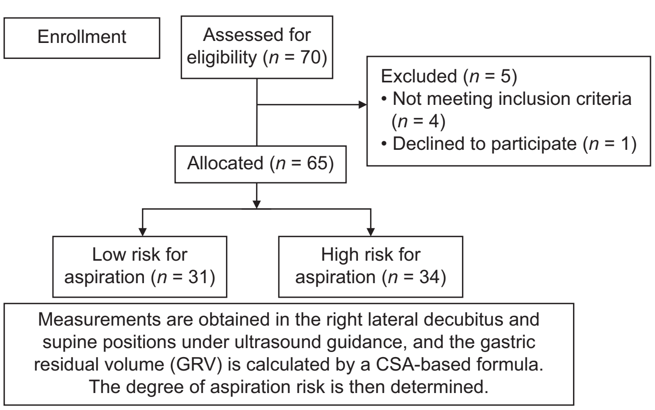

Figure 1: Patient flow

Ultrasound evaluation of GRV was performed by an experienced USG operator on all participant patients, who were trained by the senior radiologist with 40 patients for GRV measurement. An evaluation was performed using the SonoSite® M-Turbo USG system with a 4 Hz curved probe (Washington, USA). Qualitative and quantitative evaluations were made by placing the patients in supine and right lateral decubitus positions. The gastric antrum was visualized in the epigastric region in the sagittal plane.

Cross-sectional area (CSA) was determined by measuring gastric antral volume between two peristaltic contractions in the resting state after determining the anatomical positions (liver in cephalic position and aortic pulsation in posterior position). Measurements were made three times, the median value was taken, and CSA (CSA = anteroposterior × craniocaudal × π/4, where π = 3.14) was recorded. Qualitative evaluation was made according to the type of antral content (clear, liquid particulate, and solid) and graded as follows: grade 0: The antrum appeared empty and small, grade 1: Only clear fluid content was visible in the right lateral decubitus position, and grade 2: Clear fluid was present in both the right lateral and supine positions. A heterogeneous appearance was recorded as solid content. Quantitative assessment was determined using the pupils equal, round, reactive to light, and accommodation (PERLA)'s gastric residual formula (volume (ml) = 27.0 + [14.6 × CSA in the right lateral position]- [1.28 × age in years]) with the measured CSA. If the measured GRV threshold value was equal to or higher than 1.5 ml/kg in patients containing liquid particles or solid content, the patient was considered as having a risk for gastric content aspiration.[4]

Sample size estimate and statistical analysis

To determine the sample size for this study, we conducted a pilot study with the first 30 patients, since we could not find any study in the literature comparing fasting times in diabetic patients. The groups were compared with the independent-samples t-test, and we found the mean fasting time as 7.78 ± 2.24 hours in the high-risk group and 9.57 ± 2.76 hours in the low-risk group for aspiration. The effect size was calculated as 0.71; α error as 0.05; and the power as 0.8. We determined the sample size as 50 patients. We included 65 patients in the study for possible dropouts. When the post hoc analysis was made at the end of the study, we determined the effect size as 0.63; α error as 0.05; and the power as 0.81.

Results

Sixty-five patients were included in the study. The demographic data of the patients are shown in Table 1. The mean age of the cases was 56.77 ± 13.34, the mean weight was 79.55 ± 11.21 kg, the mean height was 166.12 ± 7.39 cm, and the mean body mass index (BMI) was 28.84 ± 4.11. Twenty-nine (44.6%) of our cases were female, and 36 (56.4%) were male [Table 1].

The mean duration of diabetes was 131.60 ± 130.41 months, the mean hemoglobin A1c (HbA1c) level was 7.73 ± 1.69, the mean FBG level was 137.32 ± 49.04 mg/dL, and the mean fasting time was 9.05 ± 2.33 hours. The mean CSA was 11.07 ± 4.06, the mean GRV was 115.06 ± 63.95 mL, and the mean GRV threshold value was 119.35 ± 16.74 ml [Table 2].

According to the calculated GRV levels, the patients were divided into two groups: low risk for aspiration (empty stomach) and high risk for aspiration (full stomach). The effective factors for these two groups were statistically analyzed. Among 65 diabetic patients, 31 were at low risk for aspiration and 34 were at high risk for aspiration.

Demographic data statistical analysis revealed that only the age was statistically significant (p = 0.006) between the groups. While the mean age was 62 ± 12.65 years in the low-risk group, it was 52 ± 12.26 in the high-risk group. The risk for aspiration decreased with increasing age [Table 3].

As a result of the measurement made in the low-risk group for aspiration, the mean CSA was 8.21 ± 2.37, the GRV level was 63.62 ± 27.79 ml, and the GRV threshold value was 119.85 ± 14.75 ml. In the high-risk group, CSA was 13.66 ± 3.50 cm^2, GRV was 161.96 ± 49.78 ml, GRV threshold was 118.88 ± 18.58 ml, and the difference in CSA and GRV values was statistically significant between groups (p = 0.00). This is expected since CSA and GRV parameters are used in the formula determining the risk for aspiration [Table 4].

When we examined the correlation of increased risk of gastric content aspiration with the laboratory findings, duration of diabetes, HbA1c levels, creatinine levels, and glomerular filtration rate (GFR) values in both groups, none was statistically significant.

The mean fasting time was 9.79 ± 2.24 hours in the low-risk group and 8.37 ± 2.24 hours in the high-risk group (p = 0.017). As the fasting time increases, the risk of aspiration decreases.

The mean FBG was 118.68 ± 24.33 mg/dL in the low-risk group and 154.32 ± 59.18 mg/dL in the high-risk group. A statistically significant difference was found in terms of FBG in both groups (p = 0.005). A high FBG is associated with a higher risk for aspiration.

The number of women in the low-risk group for aspiration was 17 (55%), and the number of men was 14 (45%). No statistically significant difference was found (p > 0.05).

Table 1: Demographic characteristics of all cases

	Mean±SD	Median (IQR)	Min-Max
Age (year)	56,77±13,34	56,00 (19,00)	19-86
Weight (kg)	79,55±11,21	80,00 (18,50)	52-105
Height (cm)	166,12±7,39	165,00 (10,00)	150-185
BMI (kg/m²)	28,84±4,11	28,96 (6,42)	20,56-38,20
Gender			
Female *n* (%)	29 (%44,6)		
Male *n* (%)	36 (%56,4)		

BMI: Body Mass Index

Table 2: Additional features and laboratory findings of all cases in terms of diabetes

	Mean±SD	Median (IQR)	Min-Max
Diabetes duration (months)	131,60±130,41	90 (156,00)	1-480
Fasting time (hour)	9,05±2,33	8,00 (2,75)	6-14
HbA1c	7,73±1,69	7,30 (2,15)	5,10-13,90
CSA (cross sectional area)	11,07±4,06	10,24 (16,29)	5,51-21,79
GRV (gastric residual volume)	115,06±63,95	101,48 (96,91)	2,70-277,29
FBG (Fasting blood glucose)	137,32±49,04	129,00 (45,50)	78-341
UREA	38,11±16,33	35,00 (15,00)	17-98
GRV Thershold value	119,35±16,74	120,00 (27,75)	78-157
Creatinine	1,01±0,37	0,90 (0,32)	0,56-3
GFR (Glomerular filtration rate)	79,71±23,36	80,64 (35,45)	16,26-133

When the ASA classification of the patients was examined for both groups, the number of ASA II patients was 21 (68%), the number of ASA III patients was 10 (32%) in the low-risk group for aspiration, and no statistically significant difference was found. In the high-risk group, the number of ASA II patients was 23 (68%), the number of ASA III patients was 11 (32%), and no statistically significant difference was found.

The cutoff values for FBG, fasting duration, age, and risk assessment were determined by receiver operating characteristic (ROC) curves [Figure 2].

Discussion

The effect of age on GRV estimation is challenging. In PERLA's study, the right lateral CSA for any given gastric fluid volume

Table 3: Demographic characteristics (mean±SD), median (IQR), *P* value of the cases according to low and high risk groups for aspiration

	Low risk for aspiration (*n*:31)		High risk for aspiration (*n*:34)		
	Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	*P*
Age (year)	62±12,65	63 (23,00)	52±12,26	53,50 (19.00)	0.006
Weight (kg)	79,90±9,84	80 (14,00)	79,24±12,47	77,50 (18,25)	0.645
Height (cm)	164,61±6.96	164 (10,00)	167,5±7,60	167,0 (13,50)	0.116
BMI (kg/m^2)	29,57±4,11	29,74 (7,00)	28,18±4,05	27,46 (5,81)	0.15
Gender					0.113
Female	17 (%54,8)		12(%35,3)		
Male	14(%45,2)		22(%64,7)		

BMI: body mass index

Table 4: Additional features and laboratory findings for diabetes in low-risk and high-risk groups for aspiration Mean±SD, Median (IQR), *P* value

	Low risk for aspiration (*n*: 31)		High risk for aspiration (*n*: 34)		*P*
	Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	
CSA	8,21±2,37	7,27 (2,88)	13,66±3,50	14,33 (4,47)	0.00
GRV	63,62±27,79	66,45 (41,56)	161,96±49,78	157,76 (62,93)	0.00
GRV (threshold value)	119,85±14.75	120,00 (21,00)	118,88±18,58	116,25 (27,38)	0.673
Diabetes duration (month)	134,65±133,70	90,00 (156,00)	128,82±127,38	105,00 (159,00)	0.942
HbA1C	7,36±1,42	7,00 (1,60)	8,07±1,86	7,45 (2,13)	0.083
FBG	118,68±24,33	119,00 (41,00)	154,32±59,18	139,00 (58,25)	0.005
Fasting time (hour)	9,79±2,23	9,00 (4,00)	8,37±2,24	8,00 (4,00)	0.017
Urea	40,10±14,45	39,00 (18,00)	36,29±17,89	33,00 (13,50)	0.110
Creatinine	1,03±0,46	0,90 (0,32)	0,99±0,28	0,90 (0,33)	0.953
GFR	73,71±20,13	77,24 (29,58)	85,19±25,01	85,64 (32,33)	0.50

CSA: Cross Sectional Area; GRV: Gastric residual Volume; FBG: Fasting Blood Glucose; GFR: Glomerular Filtration Rate

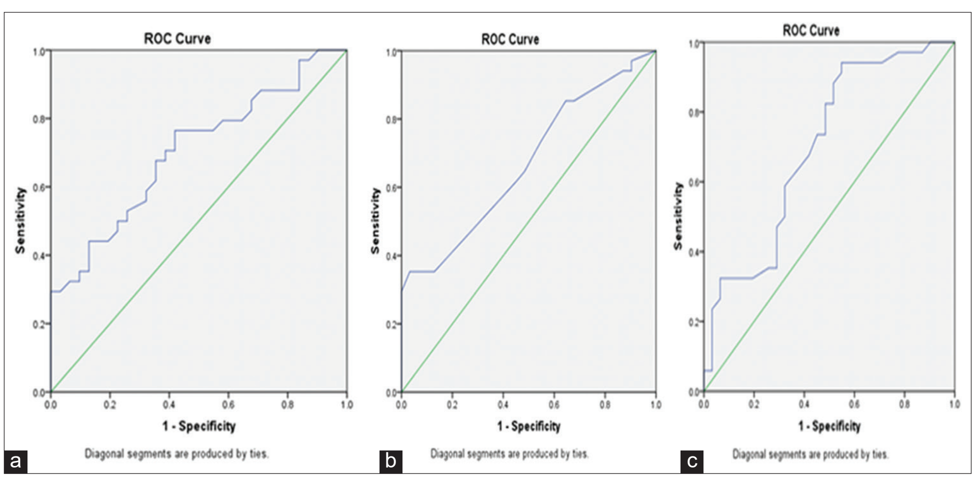

Figure 2: The ROC curves (a) Fasting glucose cutoff: 128.5; 65% sensitivity/specificity; AUC: 0.703, p: 0.005, 95% CI: 0.577–0.828. (b) Fasting duration cutoff: 8.25; 62% sensitivity/55% specificity; AUC: 0.670, p: 0.019, 95% CI: 0.54–0.80.(c) Age cutoff: 56.5; 64% sensitivity/62% specificity; AUC: 0.70, *P*: 0.006, 95% CI: 0.57–0.82

was higher in the elderly than in their younger counterparts. Similarly, a given right lateral CSA corresponds to a lower gastric fluid volume in the elderly than in the young. As an example, a 10-cm² CSA corresponds to 147 ml in a 20-year-old patient, while it corresponds to 71 ml in an 80-year-old patient. This can be explained by the fact that the gastric wall is more adaptable/flexible in the elderly than in the young.[5] Our study found a statistically significant difference in mean age between the low-risk and high-risk groups, with mean ages of 62 and 52, respectively. GRV decreased with increasing age ($p < 0.05$), and the risk for aspiration decreased with age. Our result is in accordance with the literature.

Diabetic gastroparesis is more common in young women of reproductive age.[6] In a single-center study, the mean age for gastroparesis was found to be 34 and 82% of the patients were female.[7] In previous literature, it is stated that gastric emptying is delayed in women compared with men in nondiabetic patients.[8] It has been predicted that this may occur due to differences in estradiol and progesterone levels.[9,10] In our study, 54.8% of the low-risk group were female and 45.2% were male, whereas 35.3% of the high-risk group were female and 64.7% were male. Gender had no statistically significant effect on gastric emptying and aspiration risk according to our results. The mean age of the female patient population in our study was 57, which limited the effect of gender on gastric emptying time due to decreased hormone levels.

In the study conducted by Darwiche *et al*. including 33 patients, 14 of whom were diabetic and 19 were healthy, the mean CSA value of healthy patients was found to be 2.14 cm² after 8 hours of fasting, and the mean CSA value of diabetic patients was found to be 3.29 cm². Diabetes has been shown to be a major risk factor for delayed gastric emptying. No relationship was found between gastric emptying rate, age, and gender.[11]

Chiu *et al*.[12] compared the CSA measurements between type 2 diabetes mellitus (DM) and the control group and showed that the gastric emptying time was significantly longer and less antral contractions occurred in diabetic patients according to the control group (46.3 minutes vs. 20.8 minutes).

In the study conducted by Sabry *et al*. in diabetic and nondiabetic patients who fasted for 8 hours preoperatively, the mean right lateral CSA was found to be 16.7 cm² in diabetics and 9 cm² in nondiabetics and the mean GRV of these patients was 200 ml, higher than nondiabetics (80 ml). 60% of patients in the diabetic group are at high risk for aspiration.[13] In our study, the mean CSA was 11.06 cm² and the mean GRV was 115 ml; the mean CSA was 13.66 cm² and the mean GRV was 161 ml for 34 (52% of all patients) patients in the high-risk group.

In some studies, it has been suggested that rapid changes in blood glucose concentrations affect gastric emptying and that gastric emptying time is prolonged during hyperglycemia.[14] In studies conducted with scintigraphy in the 1990s, it was shown that hyperglycemia prolongs gastric emptying time in diabetic patients.[14] In diabetic patients, this is thought to occur to prevent swings in serum glucose levels. With the increase in glucose concentration, gastric emptying is delayed to prevent the gastric contents from reaching the intestinal tract, thereby reducing glucose absorption. On the contrary, faster gastric emptying in hypoglycemia will allow the contents to reach the duodenum rapidly, thus providing faster glucose absorption.[15] Russo *et al*.[16] showed that 50 mg/dL glycemic value increases gastric emptying rate in their study with type 1 DM patients. Lyrenås *et al*.[17] demonstrated that long-term continuous hyperglycemia was effective in the development of diabetic gastroparesis. Rayner *et al*. showed that hyperglycemia delays gastric emptying in patients with a diabetes history of more than 5 years.[18]

In the study by Lysy *et al*.,[19] it was stated that since insulin use may cause frequent hypoglycemic attacks, it could accelerate gastric emptying to keep the serum glucose level constant, but there may be inconsistency between postprandial insulin level and delayed gastric emptying in individuals due to individual differences.[20] In our study, no statistically significant difference was found between the groups for aspiration in terms of insulin use. This may be attributed to the fact that our patients had a minimum FBG level of 78 mg/dL (hypoglycemic blood glucose level is <70 in diabetic patients).[21]

In the study of Darwiche *et al*.[11] in which gastric emptying rate in diabetic patients was measured by USG, FBG levels were between 65 and 170 mg/dL, and they showed that while gastric emptying rate increased with hyperglycemia, it decreased with hypoglycemia. In our study, blood glucose values above 128.5 mg/dL (cutoff value) posed a high risk for aspiration. While the mean FBG for aspiration was 118 mg/dL in the low-risk group, it was 154 mg/dL in the high-risk group, which is statistically significant. The relationship between hyperglycemia and the high-risk group for aspiration is consistent with the literature. The blood glucose level measured on the morning of the operation may warn us about the risk of aspiration.

The limitations of our study were that it was designed as a single-center study and participants had prolonged fasting periods. Fasting periods lasting a minimum of 6 hours and a maximum of 14 hours were included in the study. Thirty-five (54%) of the patients had a fasting period of ≤8 hours, and 30 (46%) of them had a fasting period of >8 hours. Although there is no clear information on whether such a fasting period paradoxically increases gastric secretions, Tekgul *et al*.[22] showed that a prolonged fasting period causes an increase in GRV. In our study, the fasting duration was found to be 9.79 hours in the low-risk group ($p = 0.017$) and 8.37 hours in the high-risk group. This difference may be because we only studied diabetic patients.

Conclusion

Gastric emptying may be delayed in diabetic patients even if the fasting periods determined in the classical guidelines are followed, and this may pose a risk for aspiration pneumonia. When evaluating patients, bedside measurement with ultrasound is advantageous in terms of being both easily accessible and noninvasive. USG may contribute to the determination of more appropriate fasting times in guidelines for other patient populations (obese, pregnant, and child). Ultrasound can guide the anesthesiologist in determining patients who have risk factors for gastric content aspiration, especially for patients undergoing emergency surgery. It should also be taken into account that diabetic patients who are young may be at increased risk for aspiration. We think that the measurement of fasting blood glucose levels of diabetic patients before the operation can give us an idea in terms of gastric emptying. Although parameters such as HbA1c level and duration of diabetes were not found to be associated with aspiration risk in our study, studies conducted with larger patient populations are needed to precisely predict the risk of gastric aspiration in diabetic patients.

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Conflicts of interest
There are no conflicts of interest.

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