

Point of Care (POCUS) Gastric Ultrasound to Predict Gastric Volume in Patients Presenting for Emergency Surgeries

Sharma M,¹ Ghimere P,¹ Yadav B,² Dhungel S³

¹Department of Anesthesia,
Kathmandu Medical College Teaching Hospital,
Sinamangal, Kathmandu, Nepal.

²Department of Population Health,
Division of Biostatistics,
King Abdullah Medical Research Centre (KAIMRC),
King Saud Bin Abdulaziz for Health Sciences, Riyadh,
Saudi Arabia.

³Department of Epidemiology, University of
Washington, Seattle, United states of America.

Corresponding Author

Mona Sharma
Department of Anesthesiology,
Kathmandu Medical College Teaching Hospital,
Sinamangal, Kathmandu, Nepal.
E-mail: dr.sharmamona@gmail.com

Citation

Sharma M, Ghimere P, Yadav B, Dhungel S. Point of Care (POCUS) Gastric Ultrasound to Predict Gastric Volume in Patients Presenting for Emergency Surgeries. *Kathmandu Univ Med J.* 2025; 93(5): 72-7. (Special Issue)

ABSTRACT

Background

In emergency surgery, pulmonary aspiration is a significant anesthetic risk. Traditional fasting hours are often unreliable due to physiological stress. This study evaluated the utility of point-of-care gastric ultrasound in assessing gastric volume and content in an emergency Nepalese cohort.

Objective

To determine the volume, content and cross sectional area of gastric antrum in emergency surgeries and to determine if they are correlated with age, fasting hours, comorbidity, pain score, body mass index and opioid.

Method

A prospective cross-sectional study of 145 adult patients was conducted. Gastric antral cross-sectional area was measured in the right lateral decubitus position. Gastric volume was calculated using validated formula. Gastric content was noted. These were correlated with variables using univariate and multivariate regression.

Result

The mean fasting time was 11.05 ± 4.20 hours. However, gastric ultrasound revealed that 42.7% of patients had gastric contents (37.9% clear fluid, 4.8% solids). Furthermore, 21.4% of patients exceeded the high-risk volume threshold of 1.5 mL/kg. In the multivariate analysis, advanced age ($p = 0.003$) and higher visual analogue scale score ($p = 0.03$) were independent predictors of gastric volume and gastric cross sectional area.

Conclusion

Fasting hours are a poor surrogate for gastric emptiness in emergency settings. One in five patients meeting nil per oral criteria remained at high risk for aspiration. We recommend the routine use of preoperative gastric ultrasound, especially in older patients and those with high pain scores, to individualize airway management.

KEY WORDS

Anesthesia, Aspiration pneumonia, Emergency surgery, Gastric ultrasonography, Point-of-care ultrasound

INTRODUCTION

One of the perioperative challenges for emergency surgery is pulmonary aspiration, as it has 7.6-fold increase in patient mortality.¹ While elective surgical guidelines safely rely on standard nil per oral hours to ensure empty stomach. These parameters do not apply in acute care settings. Physiological disruption due to acute trauma such as pain, anxiety, comorbid conditions and administration of opioids can delay gastric emptying.² Consequently, an emergency surgery patient may present with a full stomach, despite reporting hours or even days of oral restriction. Patients with residual gastric volume (GV) of 1.5 ml/kg or more are considered to have a significant risk of aspiration.³

Gastric point of care ultrasound (POCUS) has emerged as a high fidelity diagnostic method that allows rapid quantitative and qualitative assessment of the gastric antrum. By providing image of amount and type of content; Gastric ultrasound enables anesthesiologists to modify the induction technique, use medications or postpone the case depending on the urgency of the surgery.⁴ While gastric ultrasound has gained significant popularity in elective surgeries internationally, its routine application in emergency surgeries remain scarce. Currently, there is a lack of published literature characterizing gastric volume via gastric ultrasound within Nepalese population, where delays in definitive care, prolonged transfer times and unmanaged pre-hospital pain may further compound gastrointestinal motility.

This study aims to provide data by evaluating preoperative gastric volume by point of care ultrasound in an emergency surgery cohort at a tertiary care center and identify the clinical factors associated with a high-risk gastric state.

METHODS

A prospective cross-sectional observational study was conducted at the department of Anesthesiology, Kathmandu Medical College, Kathmandu, Nepal, from December 2024 to November 2025. Ethical approval was obtained from Institutional Review Board (approval number: 16102024/06) and informed and written consent was obtained from all participants. The study was conducted in the preoperative holding area. All adult patients who gave consent before emergency surgery were included in the study. We did not include patients with gastroesophageal reflux disease, hiatal hernia, gastric/duodenal ulcers, history of major gastrointestinal surgeries, cognitive impairment, unable to assume required position (eg Unstable spine fractures, peritonitis) and pregnancy beyond 1st trimester.

Upon recruitment, a detailed history was obtained along with fasting duration; pain was assessed with visual analogue scale (VAS) score, charts were assessed for opioids and comorbid conditions.

Our department had already conducted a study on gastric POCUS, in the previous year. Data collection was performed by anesthesiologist well versed with the technique of Gastric POCUS. The sample size was calculated based on standard deviation from a previous study, 5 where the mean gastric volume in right lateral decubitus (RLD) reported was 42.13 ± 29.06 ml. Using this standard deviation of 29.06, we calculated the sample size using the formula, $Z_{1-\alpha/2}^2 SD^2 / d^2$. Where, $Z_{1-\alpha/2}^2$ is the standard variate at 5% type I error, SD is standard deviation and d is absolute precision. We calculated the sample size to be 130. To counter 10% drop out, we rounded up total sample size to be 145.

The attending anesthesiologists performed all scans in right lateral decubitus position (RLD). After affirmation of the consent and brief explanation of the procedure, we let the patient lie in RLD position for five minutes before measurements. The gastric antrum was measured in anteroposterior and craniocaudal diameters with ultrasound (GE, LOGIQ-e BT 12).

To ensure anatomical consistency, the identification of antrum was standardized using left lobe of the liver as an anterior acoustic window and abdominal aorta or inferior vena cava and superior mesenteric vessel as posterior and medial reference landmarks. A still image of the antrum was obtained. The antral Cross-Sectional Area (CSA) was measured at the level of the aorta by identifying the serosa-to-serosa diameters in between peristalsis. In the RLD position, gastric contents were categorized into three types:

Empty: The antrum appeared small and collapsed (the “bull’s eye” appearance).

Clear Fluid: Anechoic (black) content visible within the antrum.

Solid/Thick Fluid: Hyperechoic (bright) or heterogeneous content with a “frosted glass” appearance.⁴ The CSA of antrum was calculated using the formula, $CSA = (AP \times CC) \times \pi/4$, where AP is anteroposterior diameter and CC is the craniocaudal diameter. The gastric volume (GV) was calculated using Perlas formula, $GV = 27 + 14.6 \times RLD\ CSA - 1.28 \times age$.³ This is the validated Perlas model derived from fasted elective patients undergoing upper gastrointestinal endoscopy; a formula specifically validated in emergency surgical cohorts is not currently available, and this model was used as the best available validated option. When the calculated gastric volume yielded a negative value, it was truncated to zero.

Our primary aim was to examine the gastric contents, volume and CSA in adult patients for emergency surgery to identify high-risk patients with gastric volume > 1.5 ml/kg. Secondary outcome included, correlation with nil per oral hours, pain score, BMI (body mass index), opioid use and comorbid conditions with gastric volume and CSA.

Categorical variables were expressed in frequencies and percentages. Continuous variables were presented as mean with standard deviation (SD) or median with interquartile range (IQR) as appropriate. Since CSA and gastric volume values demonstrated right-sided skewed distributions, separate generalized linear models (GLMs) were fitted for both outcome variables. Univariate GLM analyses were initially performed to evaluate the association of patient characteristics, fasting duration, preoperative pain score, opioid use, ASA physical status, and comorbidity with antral CSA and gastric volume respectively. The variables with $p < 0.10$ in the univariate analysis of the GLM model were considered for multivariate analysis. ASA and comorbidity were significant in the univariate models, but due to multicollinearity and clinical relevance, we included co-morbidity in the multivariate model. Comorbidities, age and VAS score were finally considered in the multivariate analysis for both outcomes. Regression coefficients (β) with 95% confidence intervals (CIs) and p-values were reported. A $p < 0.05$ is considered significant. All analyses were conducted using IBM SPSS Statistics Version 25.

RESULTS

A total of 145 patients who presented for emergency surgery were included in the final analysis. The cohort was predominantly male (57.9%) with a mean age of 34.83 ± 12.83 years. The mean BMI was 23.59 ± 3.46 kg/m², reflecting a largely non-obese population. Abdominal surgeries constituted the majority of cases (46.2%), followed by orthopedic and trauma surgeries (17.9%). The demographic has been tabulated in table 1. Among the participants, Hypertension (HTN) was the most frequent isolated comorbidity. Notably, Diabetes Mellitus (DM), a key variable for gastric motility was present in 8.9% (n=13) of the patients.

Table 1. Descriptive Statistics of the Study Population (N=145)

Variable	Mean \pm SD
Age (years)	34.83 \pm 12.83
Gender (n, %)	
Male	84 (57.9)
Female	61 (42.1)
Body Mass Index (kg/m ²)	23.59 \pm 3.46
ASA Physical Status (n, %)	
I	109 (75.2)
II	22 (15.2)
III	14 (9.7)
Opioid Administration (n, %)	
No	91 (62.8)
Yes	54 (37.2)
Preoperative Pain (VAS Score)	3.52 \pm 2.27
Fasting Profiles:	
Fasting (hours)	11.05 \pm 4.20

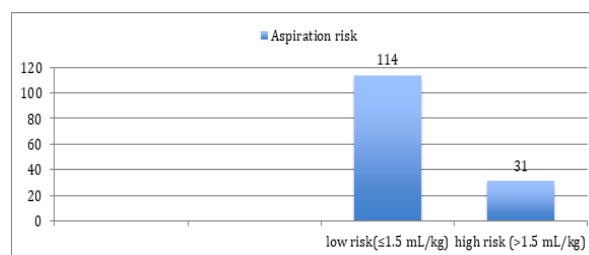


Figure 1. Aspiration risk among patients presenting for emergency surgeries.(N=145)

The primary outcome of aspiration risk was defined as a gastric volume > 1.5 mL/kg. Despite the high mean fasting period of 11.05 ± 4.20 hours, 21.4% (n=31) of patients were identified as high risk via ultrasound (Fig. 1). Notably, the maximum-recorded gastric volume was 957 mL, observed in a patient who had met traditional fasting criteria. The qualitative and quantitative assessment of the gastric antrum in right decubitus position has been depicted in table 2.

Table 2. Qualitative and quantitative ultrasound assessment in the Right Lateral Decubitus (RLD) position

Variable	Median (IQR)	Number (%)
Antral CSA (cm ²)	5.8 (4.90, 7.02)	-
Calculated Gastric Volume (mL)	71 (60, 83)	-
Empty	-	83 (57.2%)
Clear Fluid	-	55 (37.9%)
Solid Content	-	7 (4.8%)

To determine the factors associated with gastric status, univariate and multivariate generalized linear models were constructed. On univariate analysis, age, VAS pain score, ASA physical status and comorbidity were significantly associated with increased antral CSA and gastric volume. On the other hand, gender, BMI, preoperative use of opioid and fasting duration demonstrated no significant association with either outcome (Table 3). On the multivariate result (Table 4) for both outcomes, patient age and preoperative pain (VAS score) were independently associated with higher antral CSA and gastric volume. Specifically, each one-year increase in age was significantly associated with a 0.24 cm² increase in antral CSA (95% CI: 0.12 - 0.35, $p < 0.001$), and a one-unit increase in VAS score was significantly associated with a 0.57 cm² increase in antral CSA (95% CI: 0.04 - 1.10, $p = 0.03$).

Similarly, a one-year increase in age was significantly associated with a 2.53 mL increase in gastric volume (95% CI: 0.87 - 4.20, $p = 0.003$) and an 8.28 mL significant increase in gastric volume (95% CI: 0.85 - 15.89, $p = 0.03$) with a unit increase in VAS score (Table 4).

Table 3. Univariate analysis of patient characteristics with gastric antrum CSA and gastric volume

Variables	Univariate analysis			
	CSA (cm ²)		Gastric volume (ml)	
	beta (95% CI)	p-value	beta (95% CI)	p-value
Gender				
Male	0.78 (-1.90, 3.46)	0.57	13.23(-23.84, 50.31)	0.48
Female	Reference		Reference	
ASA				
1	Reference		Reference	
2	-0.10 (-3.68, 3.49)	0.96	-12.87(-62.11, 36.36)	<0.001
3	8.68 (4.41, 12.95)	<0.001	110.9(51.1, 170.7)	0.61
Comorbidity				
None	Reference		0.88	
HTN	0.91 (-3.62, 5.44)	0.69	0.09	0.88
DM	6.60 (0.58, 12.61)	0.03	75.80(-8.72, 160.3)	0.08
Others	4.45 (0.43, 8.48)	0.03	48.85(-7.70, 105.39)	0.09
Opioid				
Yes	0.77 (-2.0, 3.50)	0.58	13.77(-24.09, 51.62)	0.48
No	Reference		Reference	
Age	0.23 (0.14, 0.33)	<0.001	2.52 (1.14, 3.89)	<0.001
BMI	.11 (-0.28, 0.50)	0.57	0.34 (- 5.00, 5.66)	0.90
Solid fasting (hours)	0.08 (- 0.24, 0.40)	0.62	1.10 (- 3.28, 5.47)	0.62
VAS score	0.63 (0.06, 1.20)	0.03	8.87 (0.89, 16.86)	0.03

Table 4. Predictors of gastric antrum CSA and gastric volume using multivariate analysis

Variables	Multivariate analysis			
	CSA (cm ²)		Gastric volume (ml)	
	beta (95% CI)	p-value	beta (95% CI)	p-value
Comorbidity				
None	Reference		Reference	
HTN	-2.57 (-7.11, 1.98)	0.27	- 32.26 (-97.67, 33.15)	0.33
DM	2.97 (-2.90, 8.83)	0.32	36.68 (-47.68, 121.04)	0.39
Others	-0.20 (-4.60, 4.21)	0.33	- 0.46 (-63.75, 62.83)	0.99
Age	0.24 (0.12, 0.35)	<0.001	2.53 (0.87, 4.20)	0.003
VAS score	0.57 (0.04, 1.10)	0.03	8.28 (0.66, 15.89)	0.03

DISCUSSIONS

In this study, quantitative measurement of the gastric antrum revealed that 21.4% patients presenting for emergency surgery with mean fasting time of 11.05 ± 4.20 hours had > 1.5 ml/kg of gastric volume. This volume has been regarded as high risk for aspiration. Literature shows emergency surgery carries an aspiration risk that is 4.5 times greater than elective surgery.⁶ A recent meta-

analysis indicate that residual gastric content is present in 18 to 56% of emergency surgery patients, which aligns with the overall 42.7% positivity rate seen in this study.²

The nil per oral guidelines applies only to healthy individuals and medically complex patients have different gastric emptying time. Our result shows that chronological fasting interval is poor indicator of gastric emptying (p= 0.62) in acute care settings. Similar to our findings, many studies have concluded that fasting hours do not correlate with gastric content.⁷⁻¹⁰ Additionally, many patients with classical factors for full stomach had empty stomach and seemingly normal patients with no history suggestive for full stomach had gastric content in the preoperative gastric ultrasound.¹⁰

Our multivariate model identified age ($\beta=2.53$, $p=0.003$) as independent predictor of gastric volume and higher antral CSA ($\beta= 0.24$, $p < 0.001$). In our cohort, older age may serve as a surrogate for physiological frailty, making this population vulnerable to aspiration. This is a significant finding especially in aging population presenting for emergency surgery with multiple comorbidity, suggest extra care to prevent aspiration. Recent evidence suggests decline in gastric neuromuscular apparatus due degeneration of interstitial cells of Cajal (ICC), which acts as gastric neuromodulator cells. This leads to disrupted electrical waves and impaired relaxation. Furthermore, there is downregulation of signaling pathways like insulin-like growth factor 1 (IGF1) and extracellular signal-regulated kinase (ERK1/2). Deprivation these signals, lead to gastric cellular aging leading to gastroparesis.¹¹ Reduced motility due to region specific loss of neurons, coexisting condition like diabetes, gastro esophageal reflux disease, chronic kidney disease or even due to drugs like anticholinergics and opioids leads to delayed gastric emptying in advanced age.¹²⁻¹⁴

Our multivariate analysis demonstrated that higher preoperative pain scores on the VAS scale were independently associated with both increased antral CSA ($p = 0.03$) and higher gastric volume ($p = 0.03$). Severe pain may trigger increased sympathetic nervous system response, leading to a catecholamine release that could inhibit parasympathetic- driven gastric motility and antral contractility. A study by Hasuo et al, suggests even tolerable pain leads to effective halt of normal fundic accommodation and antral clearance irrespective of fast duration.¹⁵ In a developing nation such as Nepal, where patients endure long transit time with unmanaged pain, this physiology may significantly delay gastric clearance.¹⁶

Many factors come into play during emergency surgeries, like trauma, preoperative administration of opioids. There is conflicting evidence regarding the effect of preoperative opioids on gastric volume.² In our study, we did not find any correlation between preoperative administration of opioids and gastric volume and cross sectional area of the antrum. High BMI, particularly obesity has been another factor that

has been studied for association with high-risk stomach for aspiration.¹⁷ However, our result shows no association. The reason could be the fact that our cohort had a mean BMI of 23.59 ± 3.46 (range 18.5 – 45.0).

Regarding additional clinical characteristics, the correlation identified in univariate analysis between ASA Class III status and increased volume ($\beta=110.9$, $p < 0.001$) underlines the high risk of aspiration associated with patients with uncontrolled comorbid patients. This association, is often due to metabolic condition such as Diabetes Mellitus, which impacts the autonomic nervous system of the gut.¹⁸⁻²⁰ Diabetes Mellitus was one comorbid condition that achieved univariate significance ($p = 0.03$). There is evidence suggesting that chronic autonomic neuropathy coupled with acute surgical stress delays gastric antrum and therefore, increases the risk of aspiration.²¹ This risk is highlighted by our maximum recorded volume of 957 ml, that occurred in multimorbid patient despite prolonged fasting. Owing to collinearity with ASA class, comorbidity was taken into multivariate analysis. However, comorbidity was not retained within our multivariate analysis ($p = 0.39$). This could be due to relatively low number of patients presenting with confirmed comorbidities like Diabetes Mellitus ($n = 13$) and chronic kidney diseases. Small subgroup reduces statistical power to detect a significant independent effect. Secondly, physiological factors such as acute sympathetic and neuroendocrine disruption due to pain and stress associated with aging may act as more dominant inhibiting factors for gastric motility.²²

One of the other risk factor for increased probability for full stomach was emergency surgery of the abdomen including gynecological. Our study population was 45% were posted for emergency abdominal including gynecological emergency surgeries. This could be the major reason for our median (IQR) CSA to be 5.8 (4.9, 7.02) cm^2 . Some authors have described a threshold of 4.46 cm^2 measured in semi recumbent position.⁷ One of the recent studies have calculated a cut off $> 9.72 \text{ cm}^2$ with a sensitivity of 100% and specificity of 87% calculated in right lateral decubitus position.²³ A recent, study by Perlas suggests using 10 cm^2 as a cut off for aspiration risk.²⁴ Our measurement was all performed in right lateral decubitus. The RLD position is the most sensitive for detecting low-volume fluid and distinguishing between “empty” and “low-risk” stomachs. By utilizing the RLD exclusively, we ensured a high sensitivity for our primary outcome ($> 1.5 \text{ mL/kg}$), providing a more realistic assessment of aspiration risk than supine-only measurements.

The clinical implication of this study is beyond perioperative safety, this represents a paradigm shift in acute surgical

care management. In resource limited setting cost of ultrasound is negligible whereas the morbidity of aspiration pneumonia is immense. In our cohort 21.4% had full stomach despite fasting more than 11 hours necessitates a reevaluation of nil per oral guidelines for unplanned surgery. Integration of gastric POCUS in preoperative evaluation strengthens the medicolegal documentation, anesthesia care and patient outcome.

This study has several limitations. As a single-center, cross-sectional study, our findings may not be generalizable to other settings, and causal relationships between predictors and gastric content cannot be established due to cross sectional design. Gastric ultrasound is operator-dependent, and we did not perform an interobserver reliability assessment; all scans were performed by a single trained operator to minimize variability. We also did not validate our ultrasound-derived volumes against a gold-standard method such as computed tomography, endoscopic aspiration, or direct gastric aspiration. While we identified several independent predictors, the emergency setting involves complex interactions between anxiety, medications and pathology that are difficult to isolate perfectly. The small sample size of specific comorbidities, such as negligible patients with chronic kidney disease, warrants larger multicenter studies in the Nepalese population to refine these sub-group risks. We have not included population such as obstetrics, morbidly obese patients. Finally, we observed an extreme volume in one case which, though necessary to report, can skew our data; however, we utilized multivariate regression to minimize the impact of this outlier.

CONCLUSION

Preoperative gastric ultrasound is a superior tool for aspiration risk stratification compared to the traditional assessment of fasting hours in emergency surgery. In our population, advanced age and preoperative pain score were significantly more predictive of a full stomach. Rather than relying on history of last intake of food, we recommend the integration of gastric POCUS into the standard preoperative evaluation of all emergency surgical patients, particularly those with high pain scores or significant comorbidities, to guide the decision between standard induction and Rapid Sequence Induction (RSI).

ACKNOWLEDGEMENT

I want to thank the preoperative nurses, our residents and faculties who helped in every possible way to complete this study.

REFERENCES

1. Kozlow JH, Berenholtz SM, Garrett E, Dorman T, Pronovost PJ. Epidemiology and impact of aspiration pneumonia in patients undergoing surgery in Maryland, 1999-2000. *Crit Care Med.* 2003 Jul;31(7):1930-7. doi: 10.1097/01.CCM.0000069738.73602.5F PMID: 12847385
2. Godschalx V, Vanhoof M, Soetens F, Van de Putte P, Hadzic A, Van de Velde M, et al. The role of gastric ultrasound in anaesthesia for emergency surgery: A review and clinical guidance. *Eur J Anaesthesiol Intensive Care.* 2023 Aug;2(4):e0027. DOI: 10.1097/EA9.000000000000027 PMID: 39917072
3. Perlas A, Mitsakakis N, Liu L, Cino M, Haldipur N, Davis L, et al. Validation of a mathematical model for ultrasound assessment of gastric volume by gastroscopic examination. *Anesth Analg.* 2013 Feb;116(2):357-63. DOI: 10.1213/ANE.0b013e318274fc19 PMID: 23302981
4. Perlas A, Arzola C, Van de Putte P. Point-of-care gastric ultrasound and aspiration risk assessment: a narrative review. *Can J Anaesth J Can Anaesth.* 2018;65(4):437-48. DOI: 10.1007/s12630-017-1031-9 PMID: 29230709
5. Chaitra TS, Palta S, Saroa R, Jindal S, Jain A. Assessment of residual gastric volume using point-of-care ultrasonography in adult patients who underwent elective surgery. *Ultrasound J.* 2023 Feb 8;15(1):7. DOI:10.1186/s13089-023-00307-8 PMID: 36752856
6. Landreau B, Odin I, Nathan N. [Pulmonary aspiration: epidemiology and risk factors]. *Ann Fr Anesth Reanim.* 2009 Mar;28(3):206-10. DOI: 10.1016/j.annfar.2009.01.020 PMID: 19304443
7. Dupont G, Gavory J, Lambert P, Tsekouras N, Barbe N, Presles E, et al. Ultrasonographic gastric volume before unplanned surgery. *Anaesthesia.* 2017 Sep;72(9):1112-6. DOI: 10.1111/anae.13963 PMID: 28695978
8. Bouvet L, Desgranges FP, Aubergy C, Boselli E, Dupont G, Allaouchiche B, et al. Prevalence and factors predictive of full stomach in elective and emergency surgical patients: a prospective cohort study. *Br J Anaesth.* 2017 Mar 1;118(3):372-9. DOI: 10.1093/bja/aew462 PMID: 28203726
9. Okada Y, Toyama H, Kamata K, Yamauchi M. A clinical study comparing ultrasound-measured pyloric antrum cross-sectional area to computed tomography-measured gastric content volume to detect high-risk stomach in supine patients undergoing emergency abdominal surgery. *J Clin Monit Comput.* 2020 Oct;34(5):875-81. DOI: 10.1007/s10877-019-00438-1 PMID: 31813111
10. Delamarre L, Srairi M, Bouvet L, Conil JM, Fourcade O, Minville V. Anaesthesiologists' clinical judgment accuracy regarding preoperative full stomach: Diagnostic study in urgent surgical adult patients. *Anaesth Crit Care Pain Med.* 2021 Jun;40(3):100836. DOI: 10.1016/j.accpm.2021.100836 PMID: 33753294
11. Zhang Y, Choi EL, Hayashi Y. Cellular and molecular mechanisms underlying aging-related gastric neuromuscular dysfunction. *J Smooth Muscle Res Nihon Heikatsukin Gakkai Kikanshi.* 2025;61:43-50. DOI:10.1540/jsmr.61.43 PMID: 40204454
12. Klingensmith WC, Rhea KL, Wainwright EA, Hopper OW. The gastric emptying study with oatmeal: reference range and reproducibility as a function of age and sex. *J Nucl Med Technol.* 2010 Dec;38(4):186-90. DOI: 10.2967/jnmt.110.077065 PMID: 21078783
13. Shin HJ, Kim H, Han SH, Do SH, Na HS. Ultrasound assessment of residual gastric volume in older adults undergoing staged-bilateral total knee arthroplasty after consuming carbohydrate-containing fluids: a prospective observational study. *Korean J Anesthesiol.* 2023 Apr;76(2):128-34. DOI:10.4097/kja.22378 PMID: 36274254
14. Wang J, Shuai Y, Cheng Y, Zhang Y. Ultrasound assessment of gastric residual volume in patients over 60 years of age undergoing gastroscopy under sedation: a prospective cohort study. *Can J Anaesth J Can Anesth.* 2023 Aug;70(8):1315-22. DOI: 10.1007/s12630-023-02523-1 PMID: 37477770
15. Hasuo H, Kusunoki H, Kanbara K, Abe T, Yunoki N, Haruma K, et al. Tolerable pain reduces gastric fundal accommodation and gastric motility in healthy subjects: a crossover ultrasonographic study. *Biopsychosoc Med.* 2017;11:4. DOI:10.1186/s13030-017-0089-5 PMID: 28163776
16. El-Boghdady K, Wojcikiewicz T, Perlas A. Perioperative point-of-care gastric ultrasound. *BJA Educ.* 2019 Jul;19(7):219-26. DOI:10.1016/j.bjae.2019.03.003 PMID: 33456894
17. Van de Putte P, Perlas A. Gastric sonography in the severely obese surgical patient: a feasibility study. *Anesth Analg.* 2014 Nov;119(5):1105-10.
18. Krishnasamy S, Abell TL. Diabetic Gastroparesis: Principles and Current Trends in Management. *Diabetes Ther Res Treat Educ Diabetes Relat Disord.* 2018 Jul;9(Suppl 1):1-42. DOI:10.1007/s13300-018-0454-9 PMID: 29934758
19. Chiu YC, Kuo MC, Rayner CK, Chen JF, Wu KL, Chou YP, et al. Decreased gastric motility in type II diabetic patients. *BioMed Res Int.* 2014;2014:894087. DOI:10.1155/2014/894087 PMID: 25147821
20. Yan J, Sun X, Liu X, Li X. Gastric filling ultrasound in assessing gastrointestinal motility in type 2 diabetic patients with neuropathy: A clinical study. *J Diabetes Investig.* 2025 Aug;16(8):1518-25. DOI:10.1111/jdi.70059 PMID: 40387634
21. Moningi S, Nikhar S, Ramachandran G. Autonomic disturbances in diabetes: Assessment and anaesthetic implications. *Indian J Anaesth.* 2018 Aug;62(8):575-83. DOI:10.4103/ija.IJA_224_18 PMID: 30166651
22. Sharma G, Jacob R, Mahankali S, Ravindra MN. Preoperative assessment of gastric contents and volume using bedside ultrasound in adult patients: A prospective, observational, correlation study. *Indian J Anaesth.* 2018 Oct;62(10):753-8. DOI:10.4103/ija.IJA_147_18 PMID: 30443057
23. Asokan R, Bhardwaj BB, Agrawal N, Chauhan U, Pillai A, Shankar T, et al. Point of care gastric ultrasound to predict aspiration in patients undergoing urgent endotracheal intubation in the emergency medicine department. *BMC Emerg Med.* 2023 Sep 21;23(1):111. DOI:10.1186/s12873-023-00881-z PMID: 37735359
24. Perlas A, Arzola C, Portela N, Mitsakakis N, Hayawi L, Van de Putte P. Gastric Volume and Antral Area in the Fasting State: A Meta-analysis of Individual Patient Data. *Anesthesiology.* 2024 May 1;140(5):991-1001. DOI: 10.1097/ALN.0000000000004914 PMID: 38241328