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SCIENTIFIC ARTICLE

Use of ultrasound for gastric volume evaluation after ingestion of different volumes of isotonic solution[☆]



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Abstract

Background and objectives: The current preoperative fasting guidelines allow fluid intake up to 2 h before surgery. The aim of this study was to evaluate the gastric volume of volunteers after an overnight fast and compare it with the gastric volume 2 h after ingestion of 200 and 500 mL of isotonic solution, by means of ultrasound assessment.

Method: Eighty volunteers underwent gastric ultrasound at three times: after 8 h of fasting; 2 h after ingestion of 200 mL isotonic saline, followed by the first scan; and on another day, 2 h after ingestion of 500 mL of the same solution after an overnight fast. The evaluation was quantitative (antrum area and gastric volume, and the ratio of participants' gastric volume/weight) and qualitative (absence or presence of gastric contents on right lateral decubitus and supine positions). A p -value < 0.05 was considered significant).

Results: There was no difference in quantitative variables at measurement times ($p > 0.05$). Five volunteers (6.25%) had a volume/weight over 1.5 mL kg^{-1} at fasting and 2 h after ingestion of 200 mL and 6 (7.5%) after 500 mL. Qualitatively, the presence of gastric fluid occurred in more volunteers after fluid ingestion, especially 500 mL (18.7%), although not statistically significant.

[☆] Study performed at the Hospital de Clínicas da Universidade Federal do Triângulo Mineiro (UFTM), Uberaba, MG, Brazil.

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PALAVRAS-CHAVE

Broncoaspiração;
Ultrassonografia
gástrica;
Jejum pré-operatório

Conclusion: Ultrasound assessment of gastric volume showed no significant difference, both qualitative and quantitative, 2 h after ingestion of 200 mL or 500 mL of isotonic solution compared to fasting, although gastric fluid content has been identified in more volunteers, especially after ingestion of 500 mL isotonic solution.

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Uso da ultrassonografia para avaliação do volume gástrico após ingestão de diferentes volumes de solução isotônica**Resumo**

Justificativa e objetivos: As diretrizes recentes de jejum pré-operatório permitem a ingestão de líquidos até 2 horas antes da cirurgia. O objetivo do presente estudo foi, por meio de ultrassonografia gástrica, avaliar o volume gástrico de voluntários após jejum noturno e comparar com o volume gástrico duas horas após a ingestão de 200 e 500 ml de solução isotônica.

Método: Foram submetidos à ultrassonografia gástrica 80 voluntários em três momentos: após jejum de 8 horas; 2 horas após a ingestão de 200 ml de solução isotônica, seguida do primeiro exame; e, em outro dia, 2 horas após a ingestão de 500 ml da mesma solução, após jejum noturno. A avaliação foi quantitativa (área do antro e volume gástricos e relação volume gástrico/peso dos participantes) e qualitativa, pela ausência ou presença de conteúdo gástrico nas posições de decúbito lateral direito e supina. Foi considerado significante $p < 0,05$.

Resultados: Não houve diferença nas variáveis quantitativas nos três momentos estudados ($p > 0,05$). Cinco voluntários (6,25%) apresentaram um volume/peso superior a $1,5 \text{ ml} \cdot \text{kg}^{-1}$ em jejum e 2 horas após a ingestão de 200 ml e seis (7,5%) após 500 ml. Qualitativamente, a presença de líquido gástrico ocorreu em mais voluntários após a ingestão de líquidos, principalmente de 500 ml (18,7%), embora sem significância estatística.

Conclusão: O volume gástrico pela ultrassonografia não apresenta diferença significativa tanto qualitativa quanto quantitativa, 2 horas após a ingestão de 200 ml ou de 500 ml de solução isotônica em comparação com o jejum, embora conteúdo líquido gástrico tenha sido identificado em mais voluntários, principalmente após a ingestão de 500 ml de solução isotônica.

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Introduction

Aspiration of gastric contents is a major cause of morbidity and mortality during general anesthesia, as well as in the intensive care unit.¹⁻³ The risk of mortality is up to 5% and it is involved in over 9% of all deaths related to anesthesia.^{4,5} The presence of gastric contents at the time of anesthesia induction is an important risk factor for its occurrence, which makes the dietary restriction rule before anesthesia essential for patient safety. Although there is a controversy about the gastric residual volume, which is considered critical because this volume itself increases the risk of aspiration, studies have shown that healthy patients under fasting often have residual volume above $1.5 \text{ mL} \cdot \text{kg}^{-1}$ without significantly increased risk for aspiration.⁶⁻⁸

During the 1980s, a patient undergoing extended periods of fasting before elective procedures was a routine practice, which still remains in various institutions. The preoperative fasting recommendations have become increasingly more liberal, so that the current guidelines for preoperative fasting^{9,10} encourage the ingestion of clear liquids in

volumes from 100 mL to unlimited quantities for adults up to 2 h before surgery. This approach aims to reduce patient discomfort and hemodynamic complications during induction of anesthesia, which are often related to dehydration resulting from prolonged fasting.^{11,12} The non-adherence to recommendations may reflect a medical preference or flaws in the guidelines themselves, such as not determining the allowed amount of liquid. The clinical access to the risk of aspiration is limited due to the lack of validated non-invasive tests to assess gastric contents. The increased use of portable ultrasound in surgical centers aroused interest in its use as a diagnostic method for gastric content evaluation. Studies have shown the feasibility of using ultrasound to evaluate the gastric content by measuring the antral cross-sectional area (ACSA).¹³⁻¹⁷ Perlas et al.¹⁵ reported an almost linear relationship between ACSA and gastric volume in healthy volunteers.

The aim of this study was to evaluate by ultrasound the gastric volume of healthy volunteers after an overnight fast and compare it with the gastric volume 2 h after the ingestion of isotonic solution in different volumes.

Method

After obtaining approval from the Ethics Research Committee of the *Universidade Federal do Triângulo Mineiro* – register 1.144.018 of June 19, 2015 – and an informed consent, this prospective cross-sectional study was conducted with 80 healthy volunteers. Inclusion criteria were age between 18 and 60 years, American Society of Anesthesiologists (ASA) physical status I and II, body mass index (BMI) under 30 kg m^{-2} and ability to understand the study protocol and the informed consent. Any condition that might interfere with the gastric emptying time, such as pregnancy, diabetes, or presence of gastrointestinal disease, was considered an exclusion criterion.

The volunteers underwent abdominal ultrasound for quantitative and qualitative analysis of gastric contents measured in three times. The first measurement time (named fasting) was after an overnight period of at least 8 h. The second time (named 200 mL + fasting) was 2 h after ingesting 200 mL of isotonic solution, which was ingested immediately after the ultrasound examination at the first time. The third measurement time (named 500 mL + fasting) was performed on another day. After a minimum period of 8 h of overnight fast, the volunteers ingested 500 mL of isotonic solution and after 2 h underwent ultrasound examination. All isotonic solutions were the same and contained carbohydrates (8.4 g), sodium (57 mg), chloride (49 mg), potassium (46 mg), flavoring and preservatives agents, calorie content of 36 kcal per 200 mL, and were refrigerated. There was no restriction on ambulation after ingestion of solutions.

The ultrasound assessment of gastric content was made by a professional of the Department of Radiology of the institution. Tests were performed using the technique previously described,^{13–18} with a convex probe (2–5 MHz). Volunteers were initially examined in the supine position, followed by the right lateral decubitus (RLD) position. The transducer was placed in the sagittal plane in the epigastric region and then the antrum and gastric body were scanned by moving the transducer from right to left, in order to obtain an overall qualitative impression of the cavity and gastric contents. A better view of the antrum is obtained in parasagittal plane just to the right of the midline. The liver left lobe was taken as reference, previously, and the pancreas, posteriorly. Inferior vena cava is located posterior to the pancreas. The antrum has a wall characterized by multiple layers and its visibility was evaluated in a binary manner (visible or not) in both positions, supine and RLD. The same sonographer performed the qualitative and quantitative assessments of the gastric antrum. The antrum was considered empty when showing the anterior and posterior walls juxtaposed and regarded as containing liquid when showing a cavity view with hypoechoic content inside and its distended walls. The antrum was judged as having a solid content when appearing distended with content with characteristics similar to “frosted glass” or an echogenic image similar to liver parenchyma. Based only on this qualitative analysis of the antrum, the patients were classified as Grade zero: empty antrum in both supine and RLD positions, suggesting an empty stomach; Grade 1: presence of liquid apparent only in RLD, suggesting small amount of fluid in the stomach; Grade 2: presence of liquid contents in both supine

and RLD positions, suggesting the presence of increased gastric volume.

For quantitative analysis, we measured the antral cross-sectional area (ACSA) using the technique described originally by Bolondi¹⁸ and, subsequently, by Perlas et al.^{13–15} using the outer wall of the stomach. ACSA was measured in RLD using two perpendicular diameters of the antrum, from serosa to serosa, longitudinal or craniocaudal (CC), and the anteroposterior (AP) using the ellipse formula developed by Bolondi et al.,¹⁸ in which $ACSA = ((CC \times AP) \times \pi) / 4$, with π -value = 3.14.

After ACSA calculation, the stomach total volume (“expected volume”) was estimated for each subject using a mathematical model previously tested and validated by other authors,¹⁵ in which:

$$\text{Stomach volume (mL)} = 27 + 14.6 \text{ ACSA (cm}^2)$$

$$- 1.28 \text{ age (years)}$$

With the expected volume calculation, was obtained the relationship between the volume and weight (vol/wt) of volunteers were obtained.

Friedman ANOVA was used for statistical analysis. Sample size ($n=80$) was calculated to obtain 95% confidence, 80% power test, and root mean square error (RMSE) = 0.25. Quantitative variables, antral gastric area (cm^2), gastric volume (mL), and the relationship between gastric volume and weight (vol/wt) of subjects (mL kg^{-1}) were initially subjected to a descriptive analysis using measures of centrality and dispersion. These variables comparison between time points (fasting, 200 mL + fasting, 500 mL + fasting) was performed using Friedman’s nonparametric ANOVA, due to the non-normality in data assessed by the Shapiro–Wilk test. Regarding the groups qualitative evaluation of gastric contents, an association analysis using the χ^2 test was performed, followed by a residue analysis when the χ^2 test was significant. The significance level for the inferential procedures was 5%.

Results

The study included 84 volunteers and 80 completed all tests (240 tests), without any adverse event or delay that would undermine the results. Participants’ characteristics are shown in Table 1. The results of gastric content qualitative assessment are shown in Table 2. None of the volunteers had solid content during the examination. Regarding qualitative assessment of gastric contents according to the groups,

Table 1 Demographic data of study participants.

	Mean \pm standard deviation
Age (years)	33.98 \pm 10.73
Weight (kg)	69.82 \pm 12.55
Height (m)	1.67 \pm 0.09
BMI (kg m^{-2})	24.86 \pm 3.85
Sex	
Male	24
Female	56

BMI, body mass index.

Table 2 Distribution of study participants regarding qualitative assessment of gastric contents and groups.

	Grade 0	Grade 1	Grade 2
Fasting	65 (81.25%)	11 (13.75%)	4 (5%)
200 mL + 2 h	55 (68.75%)	14 (17.5%)	11 (13.75%)
500 mL + 2 h	57 (71.25%)	8 (10%)	15 (18.75%)

$p=0.07$, $\chi^2_{stat}=8.8$.

there was a higher number of subjects with Grade zero in fasting group (81.25%), Grade 1 in 200 mL + fasting group (17.5%), and Grade 2 in 500 mL + fasting group (18.75%), suggesting that a larger volume ingested results in increased gastric contents after 2 h of fasting. However, this association was not statistically significant ($p=0.07$).

There was no difference at any time point regarding the results of quantitative assessment, antral area, gastric volume, and volume/weight ratio at the three measurement times ($p>0.05$) (Figs. 1–3). Five volunteers (6.25%) had a volume/weight ratio over 1.5 mL kg^{-1} , both at fasting and 200 mL + fasting periods, and six patients (7.5%) at 500 mL + fasting (Fig. 3). None of them was the same subject in the different situations.

Discussion

The aim of this study was to evaluate the gastric content in healthy volunteers using real-time ultrasound. The qualitative evaluation results showed an increase in the percentage of subjects with liquid content 2 h after the intake of fluids, particularly with 500 mL volume in 15 subjects (18.75%) seen in the supine and RLD positions, which supports an expected gastric volume of $180 \pm 83 \text{ mL}$.¹⁹ In the gastric volume

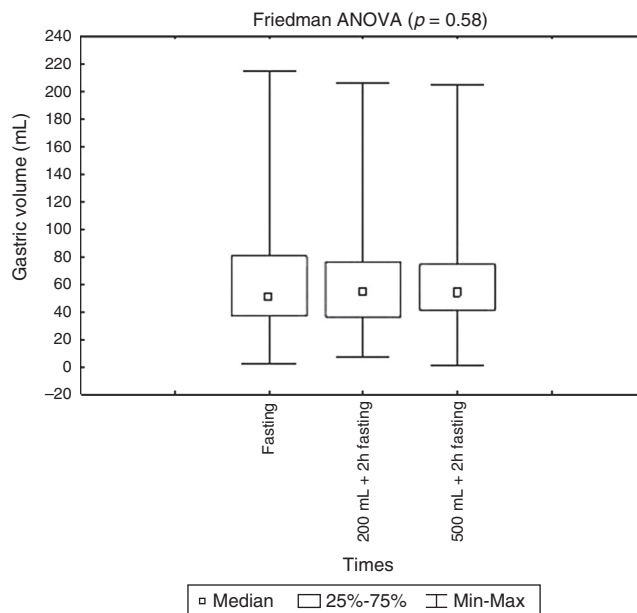


Figure 2 Box-plot showing the median and interquartile range for gastric volume in the three measurement times ($p>0.05$).

(antral area, expected gastric volume, and volume/weight ratio) quantitative evaluation, the results obtained after the overnight fasting period did not differ from those after 2 h of ingesting 200 mL or 500 mL volumes. Additionally, these results also confirmed the existence of variable quantities of gastric volume after the fasting period, which in some subjects was over 1.5 mL kg^{-1} .

Gastric sonography is a novel point-of-care application of diagnostic ultrasound, which allows anesthesiologists to

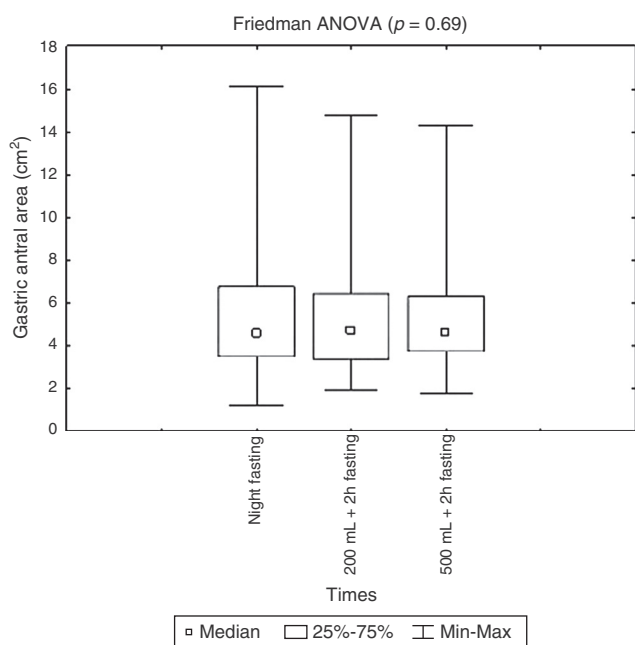


Figure 1 Box-plot showing the median and interquartile range for the gastric antral area in the three measurement times ($p>0.05$).

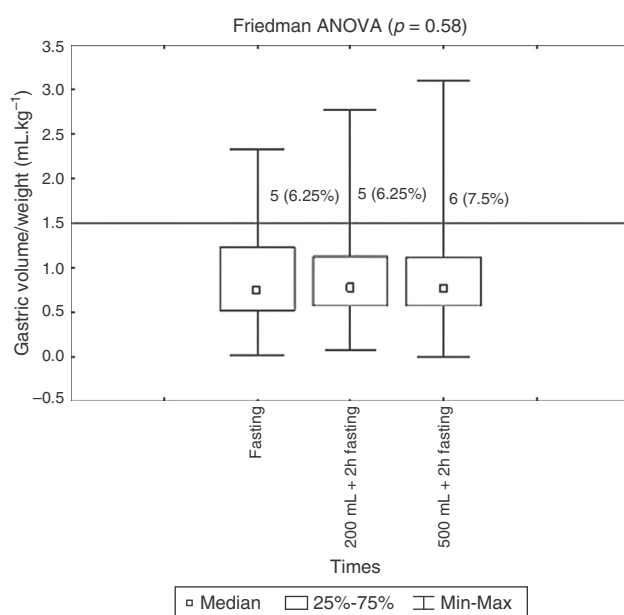


Figure 3 Box-plot showing the median and interquartile range for the gastric volume/weight ratio (vol/wt) in the three measurement times ($p>0.05$). At all times, it is observed that there are volunteers with vol/wt ratio $> 1.5 \text{ mL kg}^{-1}$.

evaluate patients' gastric content and volume and thus the risk of aspiration at bedside, in addition to help decision making for anesthetic and airway management. It has been validated¹⁵ and also considered highly reproducible.²⁰

Aspiration of gastric contents is one of the most feared anesthetic complications and is still considered a major cause of morbidity and mortality related to general anesthesia.²⁰ Described almost 70 years ago in one of the most widely cited articles of the medical literature, Mendelson,^{21,22} who described aspiration in obstetrics, helped in the formation of anesthetic management through generations. And "nothing by mouth" (NPO), empirically, for longer than 8–12 h has become a standard practice in the name of security. The reason why such long periods of liquid fasting were introduced into clinical practice is uncertain. However, at a time in which pulmonary aspiration was one of the main causes of anesthetic mortality, the extrapolation of results of studies with rhesus monkeys to women arbitrarily defined as at risk for aspiration those who presented a gastric volume above 25 mL (0.4 mL kg^{-1}) and $\text{pH} < 2.5$; the concept of critical volume and pH was introduced.²³ That claim later found support in another experiment carried out on rhesus monkeys in which acid solution (0.4 mL kg^{-1}) with $\text{pH} = 1.26$ was instilled into the animal bronchi via tracheotomy, resulting in cardiac arrest.¹⁹ Further studies,^{24,25} also with monkeys, have shown that higher volumes were needed to result in severe pneumonitis and death and, again, extrapolation to humans increased the critical volume from 25 mL to 50 mL (0.8 mL kg^{-1}), which significantly reduced the number of patients considered "at risk". Although this volume is probably considered insufficient by itself to lead to pulmonary aspiration, the combination of this critical volume with other factors, such as hiatal hernia or inadequate anesthesia, may be enough to cause aspiration with lung injury.²⁶ Until then patients were subjected to prolonged fasting periods. And for about 20 years, the approaches related to preoperative fasting began to be reviewed.⁷

Thus, current guidelines^{9,10} recommend clear liquids up to 2 h before surgery, which is a compromise between comfort, cooperation and hydration, on the one hand, and security on the other. And our results of quantitative analyzes supported exactly these guidelines, showing that 2 h after clear fluid intake there was no significant changes in gastric contents compared to fasting over 8 h. Another frequent question of all professionals working with surgery and fast recommendation concerns the volume that can be ingested. Our study found that ingestion of 200 mL or 500 mL showed no difference in gastric residual volume after a period of 2 h fasting, compared to overnight fasting. Although fluid intake is qualitatively associated with the presence of gastric fluid content, the volume was increased after the ingestion of 500 mL.

The stomach has many complex functions. It serves as a reservoir for everything we eat, efficiently macerates food, starts the early stages of digestion and then carefully and slowly, almost methodically, releases its contents into the small intestine. Solids follow a zero-order emptying kinetics. That is, at a constant speed according to the number of calories (about 200 kcal h^{-1}).^{27–29} Clear liquids follow a dramatically different path, emptying quickly from the stomach, following a first order kinetics²⁷ (i.e., a

decline described by an exponential curve). Some liquids such as water and 0.9% saline have a very short half-life of about 10 min, and effectively only have a flush through the stomach.^{27,30} However, high-calorie liquids have a slower emptying rate, such as solid foods. In this study we used an isotonic energy value of 36 kcal per 200 mL. Thus, the number of calories ingested was 36 kcal by subjects who received 200 mL and 90 kcal by those who received 500 mL. All were at the same temperature and there was no rest after ingestion, factors that could alter gastric emptying. Because the same volunteers were tested in the three time points, individual factors did not influence the results obtained. Thus, the volume and the energy value of the ingested solution were the factors that influenced the results. Although there was no significant quantitative difference in the results obtained by statistical comparison of the measurement times, there was an increase in the number of volunteers with gastric volume Grade 2 in the qualitative evaluation after 200 mL and, especially, after 500 mL compared with 8 h fasting. In this qualitative evaluation, the presence of some amount of liquid inside the stomach should be considered even in patients who fasted for more than 8 h. In this study, five volunteers (6.25%) (Fig. 3) had volumes greater than 1.5 mL kg^{-1} in the first evaluation and four of them (5%) were classified as Grade 2. These volumes are considered common in fasting patients, and considered safe.¹⁵ Oral and gastric secretions are constantly added to the stomach, which always contains some amount of liquid. Saliva production occurs at a rate of $0.4\text{--}1.0 \text{ mL kg h}^{-1}$, with endogenous gastric secretion in a similar production rate.³¹ This explains the presence of varying amounts of liquid shown by ultrasonography in fasting volunteers, which were also seen after 2 h of isotonic solution ingestion, irrespective of the volume.

Although there are numerous studies on the safety of drinking clear liquids up to 2 h before surgery and establishment of preoperative fasting guidelines, many anesthesiologists and surgeons are still unsure of the practice. Therefore, noninvasive assessments at the bedside that could determine the volume of gastric contents in the perioperative period would be of interest to assist in assessing the risk of pulmonary aspiration. Until recently there was a lack of a non-invasive diagnostic method that could promptly assess gastric content and be applied perioperative. Ultrasound is the first non-invasive technique that provides both quantitative and qualitative validated information of gastric contents at bedside.^{12–15} Several studies suggest that the gastric antrum is the stomach region that is more amenable to ultrasound examination.^{13,17,32} It can be identified in 98–100% of cases.^{14,16,33} Several mathematical models were developed for gastric volume calculation using the gastric antrum image and calculating its cross-sectional area.^{14–16} This method can predict volumes of 0–500 mL and applies to adult patients with body mass index under 40 kg cm^{-2} . The margin of error in measurements is only $\pm 6 \text{ mL}$.¹⁵ There are other methods to assess gastric emptying, but are not applicable to the perioperative period.^{34,35} Gamma scintigraphy is a noninvasive method considered a gold standard.^{35,36} It has the drawbacks of cost, use of radiation, and is not a practical exam. Ultrasonography is a very interesting technique. In addition to measuring the gastric antrum, which allows the calculation of gastric volume through the formula used, a simple graduation of 0–2 may also be used for content eval-

uation. Perlas et al.,¹³ in a study that evaluated the gastric volume in fasting patients, found 3.5% of subjects examined with the stomach classified as Grade 2, while in the present study we found 5%. The portability and convenience of these devices, combined with the low cost, allow its use at bedside and various types of diagnostic approaches, such as gastric evaluation. After years of uncertainty, studies have shown sufficient evidence of its accuracy and reproducibility.

Although it has some limitations, as with all ultrasound techniques, which is dependent on the equipment quality and also the operator, the antrum is not identifiable in all patients and several steps need to be performed systematically to obtain reliable results, besides not having the ability to evaluate the pH. The present study was conducted with healthy volunteers and, thus, the results may not be extrapolated to patients with chronic diseases or taken medications that alter the digestive system motility. For such patients, the fasting recommendations should be tailored.

We conclude that in fasting healthy volunteers after receiving 200 mL or 500 mL of isotonic solution and remaining 2 h fasting, the gastric antral area, stomach expected volume, and gastric volume/weight show no significant differences compared to the same data after a minimum fasting period of 8 h in the sonographic evaluation. However, qualitatively, there is an increase in the percentage of subjects with detectable liquid contents in both supine and right lateral decubitus positions 2 h after ingesting both 200 mL and especially 500 mL compared to fasting.

Conflicts of interest

The authors declare no conflicts of interest.

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References

- Ng A, Smith G. Gastroesophageal reflux and aspiration of gastric contents in anesthetic practice. *Anesth Analg*. 2001;93:494–513.
- Neelakanta G, Chikyarappa A. A review of patients with pulmonary aspiration of gastric contents during anesthesia reported to the Departmental Quality Assurance Committee. *J Clin Anesth*. 2006;18:102–7.
- Metzner J, Posner KL, Lam MS, et al. Closed claims' analysis. *Best Pract Res Clin Anaesthesiol*. 2011;25:263–76.
- Shime N, Ono A, Chihara E, et al. Current status of pulmonary aspiration associated with general anesthesia: a nationwide survey in Japan. *Masui*. 2005;54:1177–85.
- Schwartz DE, Matthay MA, Cohen NH. Death and other complications of emergency airway management in critically ill adults. A prospective investigation of 297 tracheal intubations. *Anesthesiology*. 1995;82:367–76.
- Agarwal A, Chari P, Singh H. Fluid deprivation before operation: the effect of a small drink. *Anesthesia*. 1989;44:632–4.
- Phillips S, Hutchinson S, Davidson T. Preoperative drinking does not affect gastric contents. *Br J Anesth*. 1993;70:6–9.
- Harter R, Kaelly W, Kramer M, et al. A comparison of the volume and pH of the gastric contents of obese and lean surgical patients. *Anesth Analg*. 1998;86:147–52.
- Smith I, Kranke P, Murat I, et al. Perioperative fasting in adults and children: guidelines from the European Society of Anaesthesiology. *Eur J Anaesthesiol*. 2011;28:556–69.
- Practice guidelines for preoperative fasting, the use of pharmacologic agents to reduce the risk of pulmonary aspiration: application to healthy patients undergoing elective procedures. An updated report by the American Society of Anesthesiologists Committee on Standards, Practice Parameter. *Anesthesiology*. 2011;114:495–511.
- Read MS, Vaughan RS. Allowing pre-operative patients to drink: effects on patients' safety and comfort of unlimited oral water until 2 hours before anaesthesia. *Acta Anaesthesiol Scand*. 1991;35:591–5.
- Srinivasa S, Taylor MH, Singh PP, et al. Randomized clinical trial of goal-directed fluid therapy within an enhanced recovery protocol for elective colectomy. *Br J Surg*. 2013;100:66–74.
- Perlas A, Davis L, Khan M, et al. Gastric sonography in the fasted surgical patient: a prospective descriptive study. *Anesth Analg*. 2011;113:93–7.
- Perlas A, Chan VW, Lupu CM, et al. Ultrasound assessment of gastric content and volume. *Anesthesiology*. 2009;111:82–9.
- Perlas AM, Nicholas M, Lui L, et al. Validation of a mathematical model of ultrasound-determined gastric volume by gastroscopic examination. *Anesth Analg*. 2013;116:357–63.
- Bouvet L, Mazoit JX, Chassard D, et al. Clinical assessment of the ultrasonographic measurement of antral area for estimating preoperative gastric content and volume. *Anesthesiology*. 2011;114:1086–92.
- Fujigaki T, Fukusaki M, Nakamura H, et al. Quantitative evaluation of gastric contents using ultrasound. *J Clin Anesth*. 1993;5:451–5.
- Bolondi L, Bortolotti M, Santi V, et al. Measurement of gastric emptying time by real-time ultrasonography. *Gastroenterology*. 1985;80:752–9.
- Roberts RB, Shirley MA. Antacid therapy in obstetrics. *Anesthesiology*. 1980;53:83.
- Kruisselbrink R, Arzola C, Endersby R, et al. Intra- and inter-rater reliability of ultrasound assessment of gastric volume. *Anesthesiology*. 2014;121:46–51.
- Lienhart A, Auroy Y, Pequignot F, et al. Survey of anesthesia-related mortality in France. *Anesthesiology*. 2006;105:1087–97.
- Mendelson CL. The aspiration of stomach contents into the lungs during obstetric anesthesia. *Am J Obstet Gynecol*. 1946;52:191–205.
- Roberts RB, Shirley MA. Reducing the risk of acid aspiration during cesarean section. *Anesth Analg*. 1974;53:859–68.
- Raidoo DM, Rocke DA, Brock-Utne JG, et al. Critical volume for pulmonary acid aspiration: reappraisal in a primate model. *Br J Anaesth*. 1990;65:248–50.
- Engelhardt T, Webster NR. Pulmonary aspiration of gastric contents in anaesthesia. *Br J Anaesth*. 1999;83:453–60.
- Kluger MT, Short TG. Aspiration during anaesthesia: a review of 133 cases from the Australian Anaesthetic Incident Monitoring Study (AIMS). *Anaesthesia*. 1999;54:19–26.
- Hunt JN. Mechanisms and disorders of gastric emptying. *Ann Rev Med*. 1983;34:219–29.
- Hellström PM, Grybäck P, Jacobsson H. The physiology of gastric emptying. *Best Pract Res Clin Anaesthesiol*. 2006;20:397–401.
- Splinter WM, Schreiner MS. Preoperative fasting in children. *Anesth Analg*. 1999;89:80–9.
- Erskine L, Hunt JN. The gastric emptying of small volumes given in quick succession. *J Physiol*. 1981;313:335–41.
- Splinter WM. From the journal archives: gastric fluid volume and pH in elective patients following unrestricted oral fluid until three hours before surgery. *Can J Anaesth*. 2014;61:1126–9.

32. Cubillos J, Tse C, Chan VW, et al. Bedside ultrasound assessment of gastric content: an observational study. *Can J Anaesth*. 2012;59:416–23.
33. Bouvet L, Miquel A, Chassard D, et al. Could a single standardized ultrasound measurement of antral area be of interest for assessing gastric contents? A preliminary report. *Eur J Anesthesiol*. 2009;26:1015–9.
34. Naslund E, Bogefors J, Gryback H. Gastric emptying: comparison of scintigraphic, polyethylene glycol dilution and paracetamol tracer techniques. *Scand J Gastroenterol*. 2000;35:375–9.
35. Hillyard S, Cowman S, Ramasundaram R, et al. Does adding milk to tea delay gastric emptying? *Br J Anaesth*. 2014;112:66–71.
36. Willems M, Quartero AO, Numans ME. How useful is paracetamol absorption as a marker of gastric emptying? A systematic literature study. *Dig Dis Sci*. 2001;46:2256–62.