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SCIENTIFIC ARTICLE

Comparative ultrasound study of gastric emptying between an isotonic solution and a nutritional supplement

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KEYWORDS
Bronchoaspiration;
Gastric ultrasound;
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Abstract
Background and objectives: Preoperative fasting may lead to undesirable effects in the surgical patient in whom there is a stimulus to ingesting clear liquids until 2 hours before anesthesia. The aim of this study was to evaluate the gastric emptying of two different solutions using ultrasound.
Methods: In a prospective, randomized, blind study, 34 healthy volunteers ingested 200 mL of two solutions without residues in two steps: an isotonic solution with carbohydrates, electrolytes, osmolarity of 292 mOsm.L^{-1}, and 36 kcal; and other nutritional supplementation with carbohydrates, proteins, electrolytes, osmolarity of 680 mO.L^{-1}, and 300 kcal. After 2 hours, a gastric ultrasound was performed to assess the antrum area and gastric volume, and the relation of gastric volume to weight (vol.w^{-1}), whose value above 1.5 mL.kg^{-1} was considered a risk for bronchoaspiration. A p-value <0.05 was considered statistically significant.
Results: There was a significant difference between all parameters evaluated 2 hours after the ingestion of nutritional supplementation compared to fasting. The same occurred when the parameters between isotonic solution and nutritional supplementation were compared 2 hours after ingestion. Only one patient had vol.w^{-1} <1.5 mL.kg^{-1} 2 hours after ingestion of nutritional supplementation; and only one had vol.w^{-1} >1.5 mL.kg^{-1} after ingestion of isotonic solution.

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Conclusion: This study demonstrated that gastric emptying of equal volumes of different solutions depends on their constitution. Those with high caloric and high osmolarity, and with proteins present, 2 hours after ingestion, increased the gastric volumes, which is compatible with the risk of gastric aspiration.

PALAVRAS-CHAVE
Broncoaspiração;
Ultrassonografia gástrica;
Jejum pré-operatório

Estudo comparativo do esvaziamento gástrico entre uma solução isotônica e um suplemento nutricional por meio da ultrassonografia

Resumo
Justificativa e objetivos: O jejum pré-operatório pode levar a efeitos indesejáveis no paciente cirúrgico, em que há um estimulo à ingestão de líquidos sem resíduos até 2 horas antes da anestesia. O objetivo deste estudo foi avaliar o esvaziamento gástrico de duas soluções diferentes por meio da ultrassonografia.
Métodos: Em um estudo prospectivo, randomizado, cego, 34 voluntários saudáveis ingeriram 200 mL de duas soluções sem resíduos, em duas etapas: uma solução isotônica com carboidratos, eletrólitos, osmolaridade de 292 mOsm.L^{-1} e 36 kcal; e outra suplementação nutricional, com carboidratos, proteínas, eletrólitos, osmolaridade de 680 mOs.L^{-1} e 300 kcal. Após 2 horas, fez-se ultrassonografia gástrica com avaliação da área do antro e volume gástrico e relação do volume gástrico sobre o peso (vol.p^{-1}), cujo valor acima de 1,5 mL.kg^{-1} foi considerado risco para broncoaspiração. Considerou-se $p < 0,05$ como estatisticamente significativo.
Resultados: Houve diferença significativa entre todos os parâmetros avaliados 2 horas após a ingestão de suplementação nutricional em relação ao jejum. O mesmo ocorreu quando foram comparados os parâmetros entre solução isotônica e suplementação nutricional 2 horas após a ingestão. Apenas um paciente apresentou vol.$p^{-1} < 1,5$ mL.kg^{-1} 2 horas após a ingestão de suplementação nutricional; e apenas um apresentou vol.$p^{-1} > 1,5$ mL.kg^{-1}, após a ingestão de solução isotônica.
Conclusão: Este estudo demonstrou que o esvaziamento gástrico de volumes iguais de diferentes soluções depende de sua constituição. Aqueles com alto valor calórico e alta osmolaridade, e com proteínas presentes, 2 horas após a ingestão, aumentaram os volumes gástricos, compatíveis com o risco de aspiração gástrica.

Introduction

Preventing bronchoaspiration has been the focus of anesthetic practice since the beginning of the specialty. For its occurrence it is necessary that there is enough volume in the stomach to be regurgitated. Therefore, the objective of preoperative fasting is to ensure that the stomach is relatively empty during the induction of and awakening from general anesthesia, thus minimizing the risk of aspiration, which, although currently rare, has a high morbidity and mortality.[1-3] In recent years, the fundamentals of the preoperative fasting period have been questioned.[4] Strong evidence shows that ingestion of clear liquids, such as water, coffee, tea, and juices without pulp, can be done up to 2 h before the anesthetic-surgical procedure with no increased risk for patients, including imaging studies that show complete gastric emptying of clear liquids ingested up to 2 h prior to induction of anesthesia.[5] Based on evidence and studies, early surgery recovery programs have introduced high-energy solutions in the preoperative period and advocate that patients receiving these nutrients have a faster recovery as opposed to those who remain fasted for an extended period of time.[6-8]

The emptying of non-caloric liquids begins immediately after ingestion and is directly proportional to the volume present in the stomach in a first-order exponential process with an average emptying time of 15-20 min in which the gastroduodenal pressure gradient is the main driving force.[9] In the presence of different liquids, factors other than volume are involved in the regulation of gastric emptying, of which the properties of ingested food are one of the most important. Several studies have identified different characteristics of food, such as pH, temperature, high osmolality, fiber content and caloric content, with the slowing down of gastric emptying. With the increase in nutrient and calorie content of the liquid, there is a deceleration of the exponential phase to a more linear emptying.[10]

Table 1 Composition of solutions used in this study.

	IS	NS
Caloric content	36 kcal/200 mL	300 kcal/200 mL
Carbohydrates	8.4 g	67 g
Sucrose	4%	12%
Fructose	2%	–
Maltodextrin	–	88%
Sodium	57 g	12 g
Chlorides	49 g	–
Potassium	46 g	14 g
Aromatizers/preservatives	+	+
Osmolarity	292 mOsm.L^{-1}	680 mOsm.L^{-1}

Considering that the solutions proposed for use in the preoperative period have different compositions compared to those commonly considered safe, the objective of the present study was to compare the gastric emptying of a preoperative nutritional supplement solution with that of an isotonic drink using ultrasonography.

Methods

After approval by the Research Ethics Committee of the Universidade Federal do Triângulo Mineiro (UFTM), Trial Number: 1.144.018 of June 19, 2015, and obtaining written informed consent, this cross-sectional and prospective study was conducted with 34 volunteers. The inclusion criteria were age between 18 and 60 years, physical status classification by the American Society of Anesthesiologists (ASA) PI, body mass index (BMI) lower than 30 kg.m^{-2}, and ability to understand the study protocol and informed consent. Exclusion criteria were any condition that could interfere with gastric emptying time, such as gestation, diabetes, or the presence of gastrointestinal tract diseases. The study consisted of two phases, in which ultrasound was used to assess gastric emptying after the ingestion of 200 mL of two different solutions. The solutions used were an isotonic solution (IS) and a nutritional supplement solution (NS), whose composition is shown in Table 1.

In the first phase, the volunteers underwent two ultrasound examinations of the stomach. The first ultrasound examination was performed after an overnight fasting period of at least 8 h and, after this initial examination, the volunteer was randomly selected through sealed envelopes to receive one of the two solutions (IS or NS). Two hours after taking the selected solution, a new gastric ultrasound examination was performed.

In the second phase, the volunteer underwent another gastric ultrasound examination after a minimum of 8 h fasting, and after this examination he received the other solution under study, different from the solution ingested in the first phase. And again, 2 h later a new gastric ultrasonography was performed.

Ultrasound evaluation of gastric emptying was done blindly by a trained professional of the anesthesiology department of the same institution. The examinations were performed with a previously described technique,[11–15] with a convex probe (2–5 MHz). The volunteers were initially examined in dorsal decubitus (DD) followed by right lateral decubitus (RLD) position. Gastric emptying was assessed qualitatively and quantitatively by gastric antrum analysis. The stomach was considered empty if the antrum appeared with the anterior and posterior walls juxtaposed. It was considered to contain liquid if it had an endocavity with hypoechoic content inside and distended walls. Based only on this qualitative analysis, the volunteers were identified as having a stomach classified as Grade 0: when the antrum appeared empty in both supine and RLD positions, suggesting an empty stomach; Grade 1: when the presence of liquid was only apparent in RLD position, suggesting a small volume of liquid in the stomach; and Grade 2: presence of liquid content in both the supine and RLD positions, suggesting the presence of a greater gastric volume.

Quantitative analysis was performed by measuring the cross-sectional gastric antral area (AA), using the technique described initially by Bolondi,[16] and later by Perlas et al.[11,12] using the outer wall of the stomach. This was performed in the RLD position using two perpendicular diameters of the antrum, from serosa to serosa, the longitudinal or craniocaudal (CC) and the anteroposterior (AP) diameter, through the ellipse formula developed by Bolondi et al.,[16] where $AA = (CC \times AP \times \pi)/4$. With the value of $\pi = 3.14$.

After AA calculation, the total volume of the stomach (''predicted volume'') was assessed in each volunteer with a mathematical model previously tested and validated by other authors,[13] in which: Stomach volume (mL) = 27 + 14.6 AA (cm^2) − 1.28 age (in years).

With the calculation of the predicted volume, the ratio between the predicted volume and the weight of the volunteers (vol.weight^{-1}) is obtained.

The qualitative and quantitative data (gastric antrum area, gastric volume) of the stomach were evaluated and the fasting results were compared with the results obtained 2 h after taking the two solutions (IS and NS). The ratio vol.weight^{-1} > 1.50 mL.kg^{-1} was considered a risk of aspiration.[13] For statistical analysis, the Kolmogorov–Smirnov test for normality of differences and Student's *t*-test for paired samples were used with a significance level of 5%.

Results

Thirty-four volunteers were included in the study and all completed the proposed protocol. Each volunteer underwent four ultrasound examinations of the stomach, totaling 136 examinations. Females were 61.8% and males 38.2%. The mean age and standard deviation, weight, height, and body mass index of the volunteers were 27 ± 7 years, 69.4 ± 13.9 kg, 167 ± 4 cm, and BMI 24.9 ± 4.9 kg.m^{-2}. None of the participants presented with medical problems that could alter gastric emptying. All exams started at 7:00 a.m., after an 8-h fasting period.

The stomach was identified in 100% of the tests, and there was a strong association between the technique used and the identification of the gastric image by the examiner when the chi-square test was applied ($p < 0.001$).

Qualitative analysis showed that all fasting volunteers had their stomach considered empty, in both DD and RLD positions (Grade 0). Two hours after taking the isotonic solution (IS), only one volunteer had gastric contents in

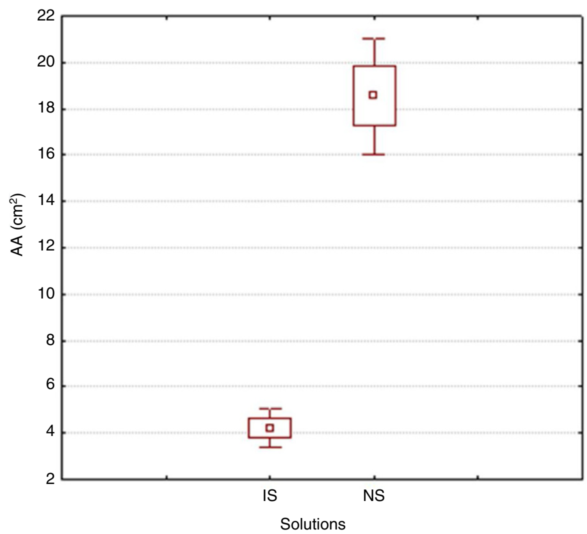

Figure 1 Gastric antral area (AA – cm^{-2}) 2 h after taking the isotonic solution (IS) and nutritional supplement solution (NS) ($p < 0.001$).

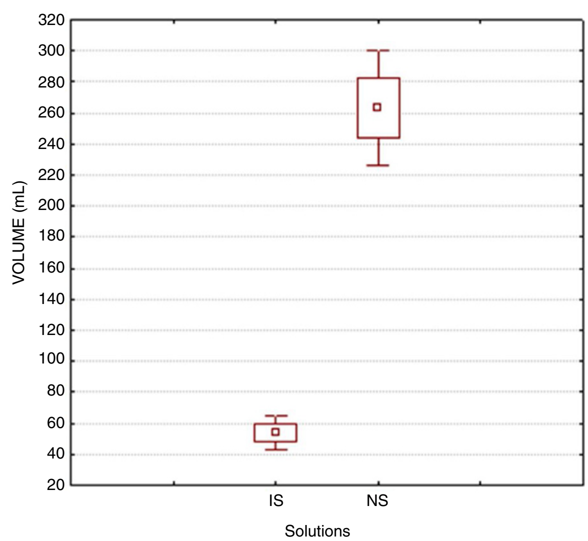

Figure 2 Total volume (mL) 2 h after taking the isotonic solution (IS) or nutritional supplement solution (NS) ($p < 0.001$).

RLD (Grade 1), while those who ingested the nutritional supplement solution (NS) had gastric contents in both DD and RLD (Grade 2).

As for volumetric analysis, the antral area (AA) and total gastric volume showed a significant difference between volunteers in Group IS and Group NS after 2 h of solution ingestion ($p < 0.001$) (Figs. 1 and 2). No fasting volunteer had a volume-weight (vol.w^{-1}) ratio higher than 1.5 mL.kg^{-1}. Two hours after IS ingestion, one volunteer had a vol.w^{-1} ratio >1.5 mL.kg^{-1}; while after NS ingestion, only one volunteer had a vol.w^{-1} ratio <1.5 mL.kg^{-1}. All other volunteers had a vol.w^{-1} ratio >1.5 mL.kg^{-1}; which represented a gastric volume of risk for aspiration ($p < 0.001$) (Fig. 3).

Other findings were that one volunteer had nausea after NS ingestion and another had liquid diarrhea within a few hours of ingestion. The vast majority of volunteers had gastric discomfort, described as a feeling of unpleasant

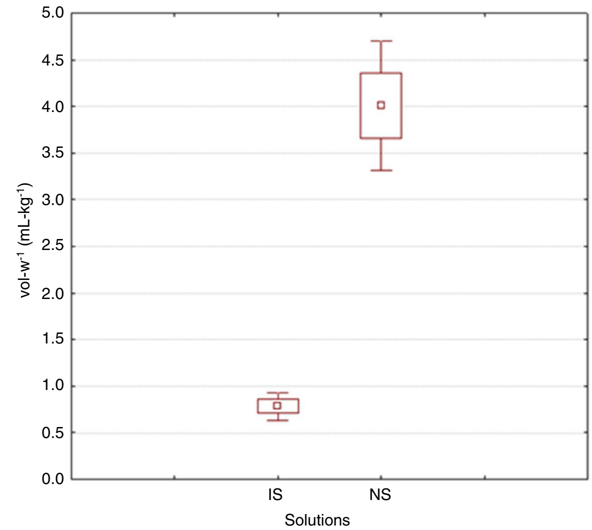

Figure 3 Volume.weight^{-1} (mL.kg^{-1}) ratio 2 h after taking the isotonic solution (SI) or nutritional supplement solution (NS) ($p < 0.001$).

tenderness after NS ingestion. No complication or unpleasant sensation was reported after IS ingestion.

Discussion

The present study showed that ingesting two solutions with the same volume but with different caloric content and osmolarity resulted in different gastric emptying. The high calorie and high osmolarity solution showed delayed emptying, and thus, a significant difference of volunteers with gastric contents compatible with high risk for aspiration was seen 2 h after taking the nutritional supplement solution.

In the last decades, international guidelines have shortened the preoperative fasting period.[17,18] From the old nil per os (NPO) routine after midnight, the ingestion of clear liquids is now allowed 2–3 h before induction of anesthesia. This was based on the assumption that these fluids emptied the stomach rapidly, although no strict formula for such liquids or even the maximum safe volume for preoperative administration has been determined. A study with volunteers comparing gastric volume using ultrasound examination 2 h after the ingestion of 200 mL and 500 mL of isotonic solution with low caloric content (36 kcal.200 mL^{-1}) showed no significant difference in the results. However, an increase in gastric volume above 1.5 mL.kg^{-1} was found in a greater number of volunteers who ingested 500 mL.[19]

A beverage containing carbohydrate supplemented with electrolytes or proteins may have additional benefits for patient satisfaction. In addition to providing greater comfort, minimizing hemodynamic changes during anesthetic induction, and reducing the incidence of insulin resistance, it contributes to an improvement in overall postoperative results.[20–26] Although venous glucose infusion is able to partially reduce insulin resistance,[27–29] oral carbohydrate is a more convenient form of administration. It promotes an insulin secretion stimulus, corresponding to a regular meal, which changes the patient's metabolism from a fasting to a non-fasting state. Studies involving preoperative venous glucose administration or the ingestion of carbohydrate-rich beverages have shown that insulin resistance can be reduced by up to 50%.[27–29] Following the ERAS protocol,[6] a nutritional supplement volume of 400 mL and 12.5% carbohydrates has been used preoperatively and its administration is considered safe in patients undergoing abdominal surgeries.[5,30–33] In a recent Cochrane review,[34] the effects of preoperative administration of carbohydrate were evaluated. Based on 27 controlled trials involving 1976 patients it was concluded that this treatment leads not only to postoperative reduction of insulin resistance, but also to a significant reduction in hospital stay. Animal and human studies suggest that the benefits of feeding prior to the onset of surgical stress, as opposed to carbohydrate depletion during fasting, are related to a carbohydrate intake. Although drinking water before surgery is safe, it has no effect on carbohydrate reserve or metabolism.

Several previous studies have already shown that gastric emptying of liquids is mainly determined by their caloric content.[35–40] This study compared two substances, the isotonic solution, previously studied,[19] and concluded that gastric emptying occurred in 2 h, as it presents reduced caloric content (36 kcal.200 mL^{-1}). As for the nutritional supplement solution, it has a high caloric content and osmolarity, equivalent to 1.5 times the recommended value as safe and feasible by the ERAS group.[6,7]

Beverages which are indicated for this purpose are composed primarily of polymers (maltodextrins), which have lower osmolality than pure glucose or other monomer solutions.[20]

The gastric emptying rate into the duodenum is reported as 1.5–3 $kcal.min^{-1}$,[10,41–43] and the amount of calories in supplement solution (2.75 $kcal.min^{-1}$) is within that range. Maerz et al.[44] demonstrated that the gastric emptying rate of sugar, proteins, and fats, with the same caloric equivalent, was the same in rats. Maughan et al.[38] evaluated gastric changes after ingestion of glucose and soy protein solution in healthy volunteers and concluded that the gastric emptying time was the same when the amount of calories was the same. Okabe et al.[36] evaluated the gastric emptying of several solutions and concluded that the ingestion of 500 mL of liquid solution with a caloric content equal to 200 kcal is equivalent to the ingestion of 500 mL of water after 120 min. However, if this same volume has a content of 330 kcal, the residual gastric volume increases to values above 100 mL. It was therefore concluded that fluid intake up to 2 h before anesthesia should not exceed 500 mL and caloric content should not exceed 220 kcal.

Although the caloric content of the solution used in this study was 300 kcal, the solution also had high osmolarity, which is a factor known to alter gastric emptying. Vist and Maughan[45] reported a time of 64 ± 8 min (mean and standard deviation) of gastric emptying after the ingestion of 600 mL (8 $mL.kg^{-1}$) of a beverage with 18.8% and lower osmolality (237 $mOsm.kg^{-1}$) and of 130 ± 18 min with higher osmolality (1300 $mOsm.kg^{-1}$) in healthy volunteers. Nakamura et al.[46] evaluated gastric emptying using nuclear magnetic resonance with two solutions, one isotonic and one supplement with arginine and high osmolality. They also observed delay in gastric emptying, whose responsible factors were the solution contents (proteins and carbohydrates) and high osmolality.[46]

In the present study the NS volume was lower than in previous studies, but its caloric content was 300 kcal with high osmolarity (680 $mOsm.L^{-1}$) and with 8 grams of proteins. Caloric contents are released more slowly into the duodenum than non-caloric liquids. This is due to a negative feedback mechanism mediated by duodenal receptors, so that a constant rate of nutrient release to the intestine is maintained,[43] with several gastrointestinal peptide hormones involved. The presence of proteins may stimulate intraluminal gastrin secretion and significantly increase gastric secretion, which may have been caused by the increase in total gastric volume (Fig. 2).

Gastric emptying investigations require precise and well-defined techniques. Several techniques are proposed. Gastric scintigraphy is the most accurate method, but exposes the patient to radiation, and in most centers the patient must be transferred to another sector, which in addition to being time consuming is potentially dangerous. Gastric ultrasound is an emerging technique, which, combined with practicality, has also shown very reliable results.

The present study has some limitations. It was conducted with healthy adult volunteers, so that extrapolation of results must be done with caution to other groups, such as children and the elderly, or people with diseases that affect gastric emptying. Moreover, the volunteers were also not scheduled for surgery because the preoperative situation is associated with increased anxiety and the results could be different in surgical patients. Gastric emptying is affected by body posture; it is significantly slower in the supine position compared to sitting or standing position.[43]

The results of this study, performed with volunteers, showed that gastric emptying of equal volume of solutions depends on their constitution. Isotonic solutions have rapid gastric emptying and are suitable for oral administration up to 2 h before surgery, without increasing the risk of gastric aspiration. However, the solutions with high caloric content, high osmolarity, and presence of proteins did not present the same behavior. High gastric volumes, compatible with the risk of gastric aspiration were observed in the same period of 2 h.

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Conflicts of interest

The authors declare no conflicts of interest.

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