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Original Article

Effects of a carbohydrate loading on gastric emptying and fasting discomfort: an ultrasonography study

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Abstract: Background: Intake of clear liquids 2 h preoperatively is recommended by many anesthesiology societies. A novel carbohydrate-rich drink (CHO) has been developed for this purpose; however its effects on gastric empty and fasting discomfort have not yet been elucidated. The present study examined the effects of this CHO on gastric emptying and fasting discomfort in healthy volunteers. Methods: Thirty healthy volunteers received 400 mL CHO or 10% glucose solution after fasting overnight for at least 8 hours. Each participant randomly ingested one drink and one week later took the other drink. Gastric emptying was examined via ultrasonography of cross-sectional areas (CSA) of the gastric antrum. The degrees of hunger, thirst, and mouth dryness were recorded over 180 minutes shortly before and after fluid intake. Results: Gastric CSA immediately increased after the ingestion of the CHO or glucose solution and returned to baseline by 60 min after ingestion ($P > 0.05$ vs 0 min). There were no differences in gastric CSA when comparing intake of the CHO and glucose solutions. Thirst and hunger were relieved at the time points measured after ingestion of both solutions vs before ingestion ($P < 0.01$). However, mouth dryness was still relieved 180 minutes after intake of the CHO, whereas the glucose solution had no such effect. Conclusion: Rapid gastric emptying and relief of fasting discomfort occurred with intake of both the glucose and the new CHO solutions. Thus, intake of the new CHO solution 2 hours preoperatively appears to be safe prior to anesthesia.

Keywords: Carbohydrate loading, carbohydrate-rich drink, overnight fasting, outfast

Introduction

Over the past 100 years, overnight fasting has been routinely recommended before elective surgery to ensure that the patient has an empty stomach during anesthesia. However, this procedure has been questioned in the last decade due to possible detriments caused by the depletion of carbohydrate reserves and the ensuing fluctuation of metabolism during fasting [1, 2]. Currently intake of clear liquids 2 h before surgery is recommended by many anesthesiology societies [3, 4]. Compared with clear water, intake of a carbohydrate rich beverage is a more natural and efficient way to supply energy during surgery. This notion has been supported by many studies [5, 6]. Patients given preoperative oral carbohydrates have alleviated insulin resistance, anxiety, vomiting, and nausea and have better wellbeing after surgery compared to patients that have fasted overnight [7-11].

A novel carbohydrate drink (CHO) containing various nutrients was developed for the metabolic optimization of patients in order to improve perioperative care and postoperative recovery. However, gastric emptying of this CHO has not yet been determined. In actual practice an overnight fast is still routinely considered to be an indispensable part of the preoperative procedure for patients receiving elective surgery in most Chinese hospitals. This situation mainly originates from the concerns of the possible risk of pulmonary aspiration in patients with unknown delays in gastric emptying, as well as a shortage of methods to simply and efficiently assess individual gastric emptying. Recent studies have shown that bedside sonographic examination is an efficient tool to assess gastric emptying from a full stomach to an empty stomach by measuring the cross-sectional area (CSA) of gastric antrum [12, 13].

The present study was aimed to compare gastric emptying of the new CHO with that of the

Table 1. Subjects characteristics

	Age (yr)	Gender (F/M)	Weight (kg)	Height (cm)	BMI (kg/m^2)
Subjects	26.55 ± 4.60	20/10	50.12 ± 7.58	155.47 ± 6.62	19.88 ± 2.18

same volume of a glucose solution among healthy volunteers using bedside ultrasound. In addition, fasting discomfort, including hunger, thirst and mouth dryness was also assessed after intake of each solution.

Subjects and methods

Subjects

Thirty healthy volunteers were included in this study. None of the volunteers had any history or signs of upper gastrointestinal disorders, metabolic disease, malignancy, kidney or liver disease. All participants were paid a small stipend to cover travelling and parking expenses. The study was approved by the ethics committee of Second Xiangya Hospital of Central South University, and we obtained written informed consent from allenrolled participants.

Before the study began, a random-number table was constructed. For each subject, an envelope containing the beverage sequence assignment was prepared, sealed, and sequentially numbered. On the day of examination, a nurse not involved in the evaluation of the volunteers opened the volunteer's envelope and prepared beverages. Outfast and glucose solution were provided in identical packaging. After 1 week at the time of the second examination, she provided the other beverage based on original records. The person performing ultrasound examinations and another ultrasonographer who analysed the images were blinded to the beverage ingested before the examination. The volunteers and the investigator involved in VAS data collection and data analyses were unaware of any beverage assignment.

Subjects were allowed to eat and drink freely up to midnight prior to the measurement. After an overnight fast of at least 8 hours, subjects randomly received either 400 mL of Outfast, a new carbohydrate-rich drink (285 mOsm/kg, 12.0% carbohydrate, 0.46 mg/mL sodium, 1.93 mg/mL potassium [Renfu Farewell Pharmaceutical Company, China]) or 400 mL of a 10% glucose solution (504 mOsm/kg) randomly. After 1 week, the same fasting protocol above was performed and subjects in each group ingested the opposite solution as the one that had been taken the previous week, such that the subjects who had ingested CHO, now took 10% glucose and visa-versa.

Fasting discomfort evaluation

The degrees of mouth dryness, thirst, and hunger in all subjects were evaluated by an investigator using a 100-mm visual analogue scale (VAS) [14] and recorded over a period of 180 minutes shortly before and after fluid intake.

Gastric emptying measurements

Gastric emptying was examined bymean antral cross-sectional area (CSA) using bedside ultrasonography (M-Turbo, fitted with a probe, 5-2 MHz 30 cm; SonoSite, UN). Measurements in all volunteers were done by the same ultrasound technician and the study was double blind. Volunteers were asked to lie down in a supine position. The measurements of antrum were performed via ultrasonography to record the diameters of the gastric antrum in the sagittal plane passing through the aorta. Longitudinal (D1) and anteroposterior (D2) diameters of a single section of the gastric antrum were measured via the longitudinal scan at the level of the abdominal aorta and the left lobe of the liver. At each observation, three measurements were taken using the mean values of the longitudinal ($D1_{mean}$) and anteroposterior ($D2_{mean}$) diameters to calculate the gastric antral area. At this level, the scan showed that the shape of the gastric antrum was either a circle or an ellipse; thus, the area (A) of the gastric antrum was calculated in all volunteers using the following formula:

$$A = \pi \times \text{longitudinal radius} \times \text{anteroposterior radius} \rightarrow$$

$$A = \pi \times (D1_{mean}/2) \times (D2_{mean}/2) \rightarrow$$

$$A = \pi \times (D1_{mean} \times D2_{mean}/4)$$

Measurements were taken before (0 min), and 10, 60 and 120 min after fluid intake.

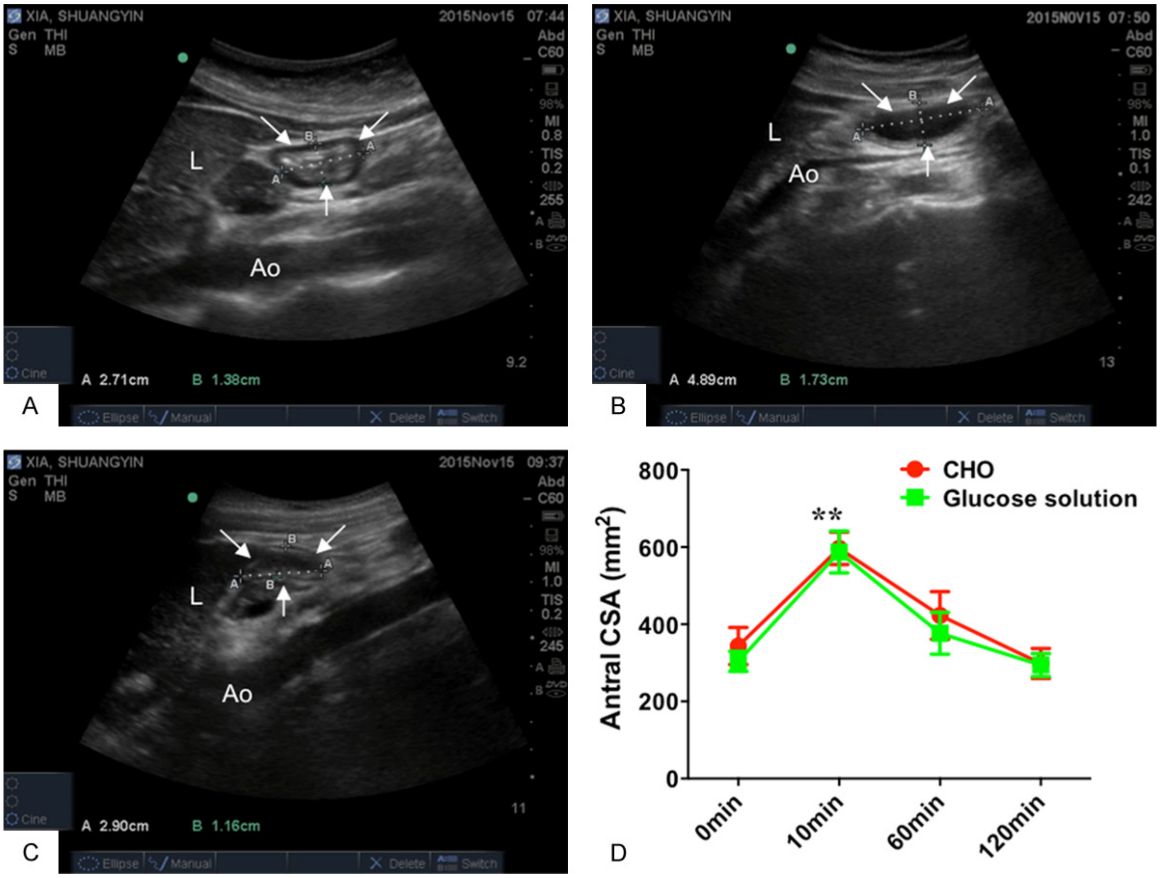

Figure 1. Median gastric antral cross-sectional areas in healthy subjects after ingestion of CHO and glucose solution. (A-C) The Sagittal sonograms of the gastric antrum resembling a "bull's eye" target (arrowheads) at 0 min (A), 10 min (B), 60 min (C) after the morning beverage. Ao = aorta; L = liver. (D) Mean antral cross-sectional area (CSA) ± sd (error bars) versus time for 30 study subjects. $^{**}P < 0.01$ versus 0 min.

Statistical analysis

SPSS 17.0 (SPSS, Inc., Chicago, IL, USA) and Graphpad Prism 5.0 were used for statistical analyses. All means are presented as mean ± SEM or median with 95% confidence limits. Intergroup comparisons were made using the Kruskall-Wallis H test followed by Nemenyi test for pair-wise comparisons. Comparisons between groups were made using the Wilcoxon's signed-rank test. A P value of 0.05 was considered significant.

Results

Demographic characteristics

A total of thirty volunteers completed the trial. Characteristics of the subjects are presented in **Table 1**. The mean age of the subjects was 26.55 ± 4.60 years. Among the volunteers, 10 were male (33.33% of the subjects) and 20 were female (66.66%). Mean BMI of volunteers was 19.88 ± 2.18 kg/m^2.

Gastric emptying measurements

Mean CSA at times 0-120 min after ingestion is shown in **Figure 1**. The median CSA of the gastric antrum was similar in the CHO beverage and glucose solution groups before (0 min) ingestion [306.1 mm^2 (259.0-423.9 mm^2) and 306.1 mm^2 (251.2-332.0 mm^2), respectively]. As compared with the baseline, mean antral CSA at 10 min after administration was greatly increased in the CHO beverage group [600.5 mm^2 (522.0-668.0 mm^2) vs 306.1 mm^2 (259.0-423.9 mm^2)] ($P < 0.01$, vs baseline) and in glucose solution group [571.5 mm^2 (483.5-667.3 mm^2) vs 306.1 mm^2 (251.2-332.0 mm^2)] ($P < 0.01$, vs 0 min), respectively. No significant dif-

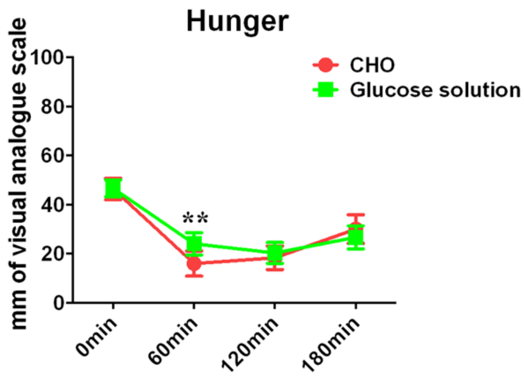

Figure 2. Visual analog scale (VAS) data for hunger. 0 min = before intake of the morning drink; 60, 120 and 180 min = time after the morning drink. $^{**}P < 0.01$ versus 0 min.

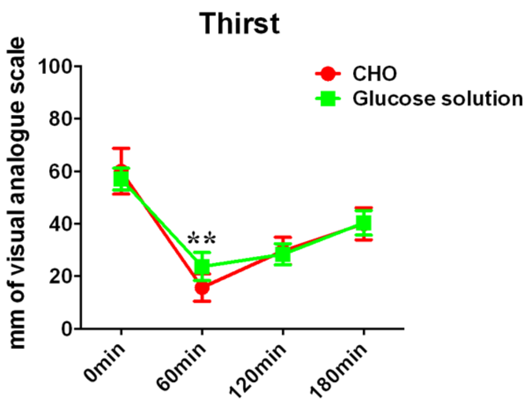

Figure 3. Visual analog scale (VAS) data for thirst. 0 min = before intake of the morning drink; 60, 120 and 180 min = time after the morning drink. $^{**}P < 0.01$ versus 0 min.

ference of CSA at 10 min after ingestion was detected between CHO beverage and glucose solution groups [600.5 mm^2 (522.0-668.0 mm^2) and 571.5 mm^2 (483.5-667.3 mm^2)].

The increased CSA was returned to the baseline at 60 min after ingestion. No significant difference in gastric CSA was detected at 60 min compared to baseline in the CHO beverage group [435.6 mm^2 (306.1-514.9 mm^2) vs 306.1 mm^2 (259.0-423.9 mm^2)] or in the glucose solution group [367.3 mm^2 (273.1-455.3 mm^2) vs 306.1 mm^2 (251.2-332.0 mm^2)] ($P > 0.05$, vs 0 min). At 60 min after ingestion and thereafter, the mean CSA in CHO group was not significantly different from that in glucose solution group ($P > 0.05$, CHO group vs glucose group). This suggested that there are similar gastric emptying in these two solutions.

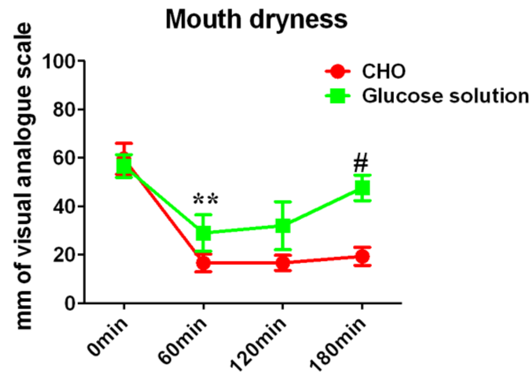

Figure 4. Visual analog scale (VAS) data for mouth dryness. 0 min = before intake of the morning drink; 60, 120 and 180 min = time after the morning drink. $^{**}P < 0.01$ versus 0 min, $^{\#}P < 0.05$ versus CHO.

Analogue scale measurements

Changes in the severity of hunger, thirst and mouth dryness are shown in **Figures 2-4**. The index of hunger, thirst and mouth dryness was recorded during a period of 180 minutes shortly before and after fluids intake. Both the CHO and glucose solution helped to relieve hunger, thirst and mouth dryness at 60 and 120 minutes after the morning ingestion ($P < 0.01$ vs 0 min), and no statistically significant difference in VAS scores was found between the CHO and glucose solution groups at 60 minutes or 120 minutes. Mouth dryness was still reduced 180 minutes after ingestion of CHO whereas the glucose solution had no such effect ($P < 0.05$).

Discussion

In recent years, despite the fact that guidelines have been revised to recommend the intake of clear liquids at least 2 h preoperatively, many anesthetists, especially in China, still feel that it is safer for patients to fast overnight and hesitate to allow patients to ingest energy-rich drinks in order to avoid the risk of aspiration. Another reason for the hesitation is that few studies have determined which types of clear liquids are appropriate for preoperative ingestion in order to relieve preoperative stress, are quantifiable and have been confirmed to be safe. An efficient way to provide energy, as well as a way to quickly monitor preoperative gastric emptying, is of equal importance; however, to date, little research has been done in this area. The current study with the use of bedside ultrasound showed that the stomach had emptied 60 minutes after intake of a carbohydrate-rich beverage or glucose solution. Although both the CHO and glucouse solutions relieved the thirst, hunger and mouth dryness resulting from overnight fasting, the CHO reduced mouth dryness for a longer period of time than did the glucose solution. This study indicates that preparation with CHO preoperatively is a safe procedure and able to alleviate discomfort caused by overnight fasting. CHO may be a more appropriate drink for preparation before an operation compared with glucose solution.

The traditional practice of overnight fasting, against the physiological rhythm and ignores the discomfort of patients. In addition, the difference in gastric emptying between solid foods and fluids has led to an overly-long fasting time, at least in terms of fluids, prior to anesthesia induction. Rigid restrictions on the intake of liquid and/or solid foods in surgical patients (i.e., a 6-8 hours fast before scheduled surgery) have been preferred by anesthesiologists in order to reduce the risk of aspiration pneumonitis. However, this period might be prolonged up to 10-16 h due to unexpected delays in the operating schedule. Numerous studies have shown that overnight fasting can intensify preoperative insulin resistance, lead to metabolic disorders and nitrogen loss [7, 15, 16]. To overcome these adverse effects, intravenous infusion of preoperative carbohydrates has been proposed by some investigators, who found that preoperative carbohydrates administered via intravenous glucose infusion resulted in an obvious reduction in nitrogen loss and improvements in insulin resistance during the postoperative period when compared with overnight fasting [16, 17]. However, intravenous infusion of glucose not only requires concomitant insulin infusion, frequent monitoring of blood glucose levels, but also carries the risk of fluid overload, and does little to alleviate preoperative discomfort, such as thirst and hunger due to overnight fasting. Therefore, finding a more physiological and convenient route of carbohydrate provision, such as oral administration, is urgently needed. Nevertheless, a regular glucose drink may not be appropriate due to its significant hyper-osmolality, which may cause delayed gastric emptying, which could pose an aspiration risk, theoretically. Recently, a specially designed carbohydrate-rich beverage was developed to provide sufficient carbohydrates with low osmolality. The osmolality of this beverage is lower (285 mosmol/kg) than the 10% glucose solution (504 mosmol/kg) because the beverage primarily contains polymers of carbohydrates.

A number of experimental methods have been developed for the assessment of gastric emptying including scintigraphy, gamma camera and orogastric tube [18, 19]. However, few are ideal for quick and efficient evaluations of gastric contents just prior to induction of anesthesia. Furthermore, the methods are either radioactive, are invasive and uncomfortable, and/or cannot be used in an operating room or ward. The lack of an ideal method for measuring gastric content is a critical limitation to the clinical assessment of aspiration risk. Recently, there has been a growing interest in the sonographic measurement of gastric emptying. Sonographic measurement allows for gastric emptying to be monitored in real-time capability, is reproducible and has good correlation with scintigraphy, the gold standard for measurement of gastric emptying. However, to the best of our knowledge, no previous studies have investigated the use of bedside ultrasound for assessing aspiration risk from preoperative intake of drinks prior to anesthetic induction. Sonographic measurements can be easily used to indirectly determine gastric emptying time by measuring the changes in the cross-sectional region or dimensions of the gastric antral area at one selected level. Sonographic measurement of the gastric antral region has been proven to be reproducible and linearly correlated with the amount of ingested or administered liquids [20, 21]. Therefore, this measurement can be used to effectively represent the entire gastric content. In the present study, no significant difference was found in the gastric antrum area, as determined by bedside ultrasound, between 0 and 120 minutes after ingestion of the CHO beverage. In fact, the CHO beverage had already been evacuated from the stomach one hour after ingestion. These results confirm the safety of the CHO beverage and indicates that little aspiration risk exists when 400 ml of the CHO beverage is ingested 2 hours before induction of anesthesia. Considering lower osmolality of CHO with the same calorie content, the remnants in the stomachs were also compared to indirectly assess gastric emptying and no significant difference was found between the two types of drinks. One possible reason is that both of the fluids had been almost emptied 1 hour after ingestion. Future studies that include more frequent measurements of gastric emptying are needed in order to compare differences between the CHO beverage and glucose water.

In addition to the discrepancy in osmolality between the CHO beverage and glucose drinks, a main concern for preoperative patients was the comfortability and nutrient constituents of the drinks. In the current study, the degree of hunger and thirst was significantly alleviated in subjects after intake of CHO or glucose water. However, the new CHO tasted better and attenuated mouth dryness to a greater extent than did the glucose solution. Moreover, various nutrient components have been optimized in the CHO beverage and are specially designed to help relieve the stress state during the perioperative period.

Study limitation

There were several limitations in the current study. First, the study included only a relatively small number of healthy subjects and very little or no data from aged subjects or teenagers. Therefore, findings in this study may not be directly applicable to the general population. Secondly, these results need to be further confirmed in patients undergoing elective surgery, as they are much more likely to be in an anxious state preoperatively. Further studies are needed to investigate the potential effects of CHO on gastric emptying and discomfort in special populations, such as infants, young children, and obese individuals.

Conclusions

In this study, a novel carbohydrate-rich drink, Outfast, was found to be evacuated from the stomach 1 hour after ingestion, suggesting that oral intake of CHO 2 hours prior to induction of anesthesia is safe. The CHO beverage was also very beneficial greatly reducing the thirst, hunger and mouth dryness caused by overnight fasting. In addition, the CHO beverage contained more nutrient components and relieved mouth dryness for a longer period of time compared with the glucose solution.

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Disclosure of conflict of interest

None.

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