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Preoperative Gastric Emptying

Effects of Anxiety and Oral Carbohydrate Administration

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Background

Overnight fasting is routine before elective surgery. This may not be the optimal way to prepare for surgical stress, however, because intravenous carbohydrate supplementation instead of fasting has recently been shown to reduce postoperative insulin resistance. In the current study, gastric emptying of a carbohydrate-rich drink was investigated before elective surgery and in a control situation.

Methods

Twelve patients scheduled for elective surgery were randomly given 400 mL of either a carbohydrate-rich drink (285 mOsm/kg, 12.0% carbohydrates, $n = 6$) or water 4 hours before being anesthetized. Gastric emptying was measured (gamma camera, $^{99}Tc^{m}$). Each patient repeated the protocol postoperatively as a control. All values were presented as the mean ± SEM by means of a nonparametric statistical evaluation.

Results

Despite the increased anxiety experienced by patients before surgery ($p < 0.005$), gastric emptying did not differ between the experimental and control situations. Initially, water emptied more rapidly than carbohydrate. However, after 90 minutes, the stomach was emptied regardless of the solution administered (3.2 ± 1.1% [mean ± SEM] remaining in the stomach in the carbohydrate group *versus* 2.3 ± 1.2% remaining in the stomach in the water group).

Conclusions

Preoperative anxiety does not prolong gastric emptying. The stomach had been emptied 90 minutes after ingestion of both the carbohydrate-rich drink and water, thereby indicating the possibility of allowing an intake of iso-osmolar carbohydrate-rich fluids before surgery.

For more than 100 years, overnight fasting has been a widely recommended routine before elective surgery. This fasting period was instituted to reduce the risk of aspiration of acid stomach contents during anesthesia.[1] However, this routine has been questioned lately, primarily because fasting is uncomfortable for the patient, and strict fasting results in unnecessary problems with routine oral medication.[2,3] In several studies in which the free intake of water was allowed within 3 hours before surgery in both children[4-6] and adults[7,8] preoperative thirst[8] and anxiety[9] were reduced as compared with the traditional overnight fast. Ingestion of clear fluids did not increases gastric contents[8,9] or risk of aspiration after surgery.[8,10,11]

Investigators studying the risks of allowing late preoperative fluid intake have focused primarily on patient well-being. Less attention has been paid to the fact that the preoperative fasting period also results in a marked alteration in body metabolism. Although strict fasting is usually set to begin at midnight, in clinical practice it often begins earlier (resulting in 10–15 hours of fasting) because the last major meal is usually served in the late afternoon on the day before surgery. It has long been known that even brief fasting results in a marked reduction in hepatic glycogen contents[12–14] and a change in metabolism.[15,16]

Although overnight fasting is part of humans' normal diurnal rhythm, this change in the metabolic setting may not be ideal in preparing patients for surgical stress. Thus, in animal studies of stress, such as hemorrhage[16] and endotoxemia,[17] the loss of hepatic glycogen reserves is closely associated with fatal outcome. Such studies suggest that fasting, even for a shorter duration, may not be the optimal way in which to prepare the body for surgical trauma. This notion was recently clinically supported by the finding that preoperative carbohydrate supplementation given intravenously in the form of glucose infusions (5 mg $\times$ kg^{-1} $\times$ minute^{-1}) overnight, instead of fasting, resulted in a 50% reduction in the development of postoperative insulin resistance in patients undergoing elective abdominal surgery.[18] In glucose-infused patients, the hepatic glycogen content was increased by 65% during surgery when compared with that in the fasting patients.[19] Animal and human data suggest that the benefits of eating before the onset of stress, as opposed to carbohydrate depletion during fasting, is related to carbohydrate loading. Although water intake shortly before surgery has been shown to be safe, it has no effects on carbohydrate reserves or metabolism.

For routine administration of carbohydrates before surgery, oral administration has several advantages over the intravenous route, but it can only be used if shown to be safe. Gastric emptying of glucose has been studied primarily among healthy volunteers.[20–29] However, the preoperative situation is associated with increased anxiety, thus results from these earlier studies of healthy volunteers cannot be extrapolated directly to the preoperative surgical patient. Therefore, we chose to study the gastric emptying rate of a carbohydrate-rich drink that was specifically developed to reduce the osmotic effect on gastric emptying.[29,30] The gastric emptying of this solution was compared with that of the same volume of water among patients on the morning of elective surgery. The same protocol was also used in a control situation among the same patients several weeks after surgery as well as among a separate control group of healthy volunteers. The degree of anxiety, hunger, and thirst as well as the plasma levels of glucose and serum levels of insulin were also measured in all studies.

Table 1. CHARACTERISTICS OF SUBJECTS

Group of Subjects	Age (yr)	Gender (F/M)	Weight (kg)	Height (cm)	BMI (kg/m^2)
Carbohydrate patients (n = 6)	46 ± 3	3/3	76 ± 6	171 ± 4	25.8 ± 1.6
Water Patients (n = 6)	47 ± 7	2/4	83 ± 6	175 ± 4	27.1 ± 1.7
Volunteers (n = 7)	42 ± 5	6/1	68 ± 4	170 ± 3	23.6 ± 1.2

BMI = body mass index.
Values are mean ± SEM.

METHODS

Subjects

Twelve patients scheduled to undergo elective laparoscopic cholecystectomy (n = 11) or parathyroid surgery (n = 1) were included in the study (Table 1). They were graded as ASA I or II and had no history of diabetes mellitus, earlier gastric surgery, or medication known to affect gastric emptying.[31] Patients were randomized to receive 400 mL of a carbohydrate-rich drink (285 mOsm/kg, 12.0% carbohydrate, 0.46 mg/mL sodium, 1.93 mg/mL potassium [Nutricia AS, Zoetermeer, Netherlands]) (n = 6) or the same volume of water 4 hours before the induction of general anesthesia. As a control measure, the protocol was repeated among the same patients 53 ± 7 days (mean ± SEM) after operation.[7] The same protocol was performed among healthy volunteers (Table 1) after ingestion of the carbohydrate-rich drink or water. The study was approved by the local ethical and isotope committees, and the subjects gave their informed consent before entering the study.

Analogue Scale Measurements

All subjects plotted their degree of anxiousness, thirst, and hunger on a 100-mm visual analogue scale[32,33] shortly before fluid intake and repeatedly during a period of 120 minutes after fluid intake.

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Gastric Emptying Measurements

Gastric emptying was assessed by means of a gamma camera (400 AZ Maxicamera, General Electric, Milwaukee, WI) equipped with a low-energy general-purpose collimator and connected to a computer (PDP 11/73, Digital Equipment Corporation, Maynard, MA). Images were presented in a 128 × 128 matrix.

The carbohydrate-rich drink or water was mixed with 20 MBq $^{99}Tc^{m}$-labeled human albumin colloid (Solco Nanocoll, Solco Basle Ltd., Birsfelden, Switzerland). The radiotracer remains uniformly distributed in the carbohydrate-rich fluid and in water for 4 hours.[34] This was first tested by placing glass tubes filled with mixtures of the radiopharmaceutical and fluids in front of the vertically tilted gamma camera. At 8 A.M., after an overnight fast and not less than 4 hours before the initiation of anesthesia, the patients received either the carbohydrate-rich drink or water, drinking in the left lateral position on the examination coach. Both fluids had a temperature of 12 C. when drunk. Thereafter, the patients were gently turned counterclockwise into the supine position, and a 1-minute acquisition with the camera from behind was immediately initiated (time 0). Thereafter, recordings were made during a 120 time period (at 5, 10, 20, 40, 60, 90, and 120 minutes). Between the image acquisitions, the patient rose from the coach and moved freely. Before each acquisition, the patient was placed in the left lateral position for 10 to 15 seconds. Thereafter, the patient was turned supine and a recording identical to the initial one was made. This maneuver causes gastric fluid to accumulate in the fundus, which is the lowest part of the stomach when one is supine.[35] This allowed us to reproduce the position of the stomach for each recording of gastric activity without disturbance from bowel activity. The fundus activity was enclosed in a manually drawn region of interest in the digitized image. The gastric activity thus defined in the initial image (time 0) was usually between 40,000 and 50,000 cpm. After correction for physical decay, the activity at the different recordings was expressed as a percentage of the initial value (time 0).

Blood Sampling and Analysis

Venous blood was taken for analyses of plasma glucose and serum insulin levels before fluid intake and at the same intervals as used for gastric emptying measurements (see above). Among the subjects given water, blood samples were obtained before fluid intake only. All samples were placed on ice, centrifuged for 10 minutes at 4 C. at 3000 rpm, and stored at −20 C. until the batch was analyzed. Plasma glucose was determined by means of a glucose analyzer using the glucose peroxidase method (model 23 AM, Yellow Springs Instruments, Yellow Springs, OH).[36] Determinations of serum insulin levels were made with use of radioimmunoassay techniques.[37]

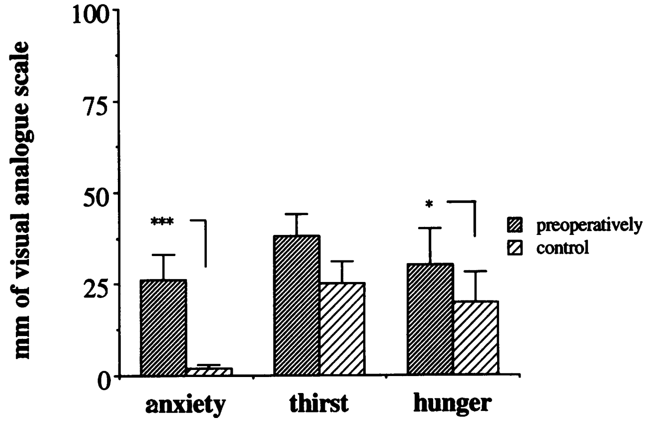

Figure 1. Visual analogue scale measurements (mean ± SEM) of 12 patients shortly before elective surgery as well as in a postoperative control situation. *$p < 0.05$; ***$p < 0.005$, Wilcoxon's signed-rank test.

Statistical Analysis

Results are presented as the mean ± SEM. Statistical significance was accepted at the probability level of <0.05 with the use of nonparametric statistical testing. Intergroup comparisons were made with use of Wilcoxon's signed-rank test. Comparisons between groups were made with the Mann–Whitney *U* test.

In comparing gastric emptying in the preoperative situation *versus* the postoperative situation and with the measurements of separate healthy volunteers, we were able to obtain an index of the area under the curve by adding the levels of radioactivity found in the stomach during the study (5, 10, 20, 40, 60, 90, and 120 minutes after fluid intake) and dividing the sum obtained with the initial value at time 0. The comparison between these groups was made with use of the area-under-the-curve index and through a comparison of the radioactivity levels in the stomach at the separate measuring points with nonparametric testing for each measuring point and with a two-way analysis of variance for repeated measurements over time for the preoperative and postoperative studies.

RESULTS

Analogue Scale Measurements

The levels of anxiety ($p < 0.005$) and hunger ($p < 0.05$) were higher before surgery compared with those measured in the control situation (Fig. 1). Thirst did not

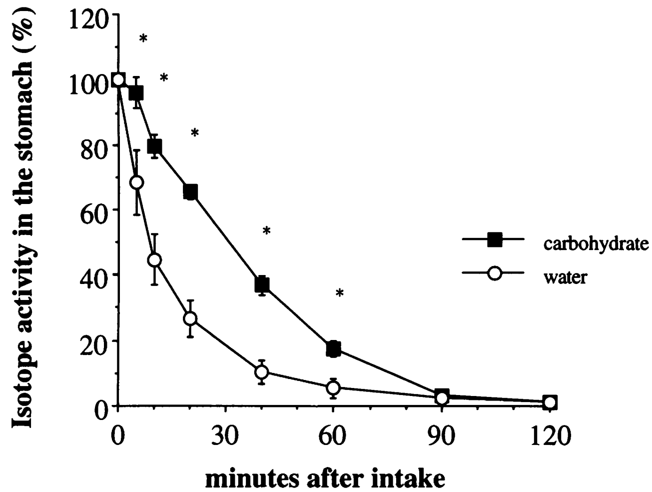

Figure 2. Mean gastric emptying rate of patients given a carbohydrate-rich drink (n = 6) compared with those given water (n = 6) shortly before elective surgery. *p < 0.05, Mann-Whitney *U* test.

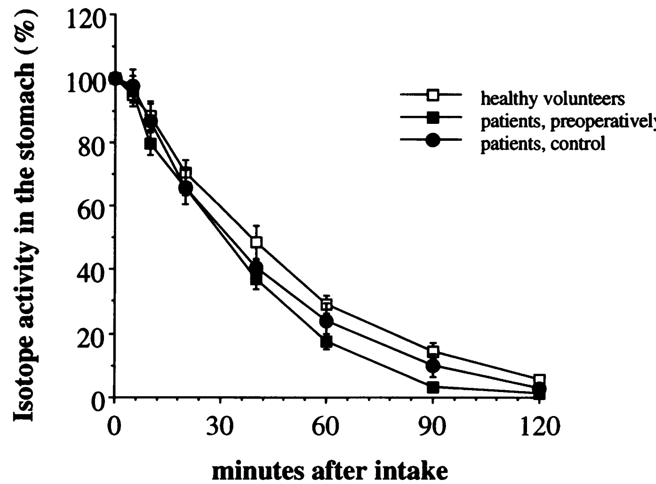

Figure 3. Mean gastric emptying rate of patients given a carbohydrate-rich drink before (n = 6) and after (n = 6) surgery (control situation) and of seven healthy volunteers.

differ significantly between the two situations ($p = 0.06$) (Fig. 1). Thirst was reduced ($p < 0.01$) during the first 60 minutes after the intake of the carbohydrate-rich drink and during the first 40 minutes after the intake of water ($p < 0.05$). Thereafter, no significant changes were observed ($p = 0.06$ and $p = 0.07$; 0 *vs.* 90 minutes; carbohydrate drink and water, respectively; data not shown). Hunger was reduced during the first 20 minutes after the intake of water ($p < 0.05$) but not after intake of the carbohydrate-rich drink ($p = 0.1$, 20 minutes after intake). Anxiety was reduced ($p < 0.05$, 0 *vs.* 90 minutes) after the intake of water. However, this was not observed after intake of the carbohydrate-rich drink ($p = 0.11$, 0 *vs.* 90 minutes; data not shown).

Gastric Emptying Measurements

Before surgery, gastric emptying of water was more rapid than that of the carbohydrate-rich drink during the first 60 minutes after intake ($p < 0.05$). However, after 90 minutes, only a small percentage of activity remained in the stomach regardless of the solution (difference not significant) (Fig. 2). The same pattern was also found among the healthy control subjects (data not shown). There were no differences in gastric emptying rates related to sex ($p = 0.8$) nor any correlation between gastric emptying and body mass index ($p = 0.4$) or age ($p = 0.7$) on assembling all measurements from control studies in patients and healthy volunteers.

Gastric emptying of the carbohydrate drink did not differ before surgery from that after surgery nor from the measurements taken among the healthy volunteers (Fig. 3). Likewise, gastric emptying of water did not differ among all three parallel groups on comparing the area-under-the-curve index (data not shown). However, at 60 and 90 minutes after fluid intake, gastric emptying of water was enhanced before surgery ($p < 0.05$, Wilcoxon's signed-rank test) compared with the control after surgery.

Blood Samples

Basal values of plasma glucose and serum insulin were normal on all occasions, with no difference between the groups. Nearly identical curves were found on all occasions (before and after surgery among patients and among the separate control situations). Data from pa-

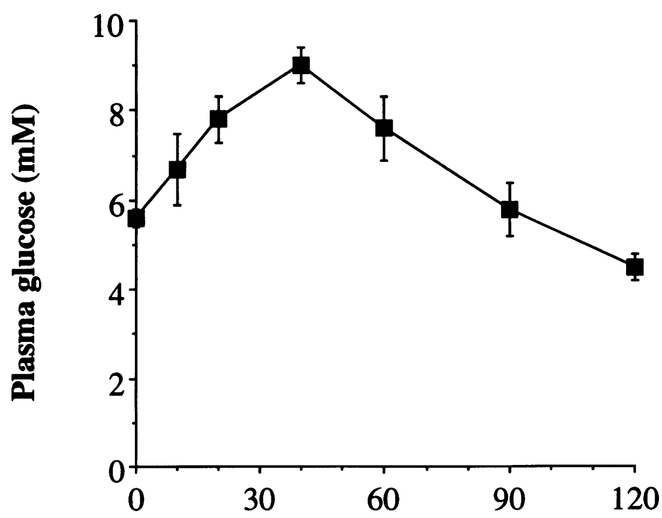

Figure 4. Plasma glucose levels in 6 patients after intake of carbohydrate-rick drink preoperatively. Means ± SEM.

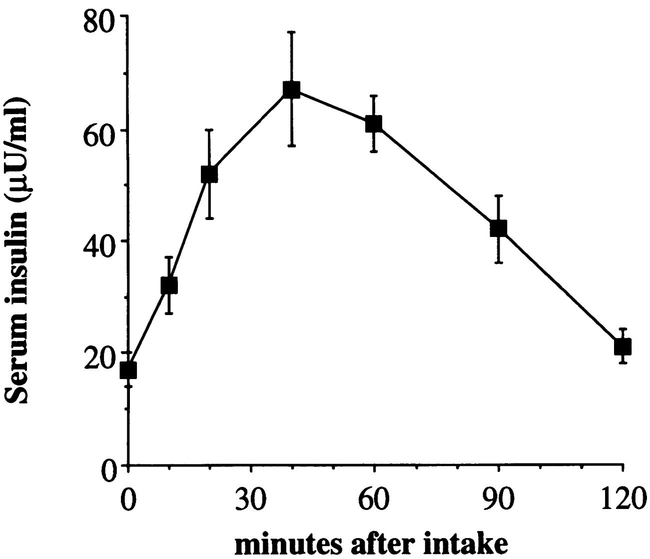

Figure 5. Serum insulin levels in 6 patients after intake of carbohydrate-rich drink preoperatively. Means ± SEM.

tients after intake of the carbohydrate-rich drink before surgery are shown in Figures 4 and 5. In the preoperative study, plasma glucose (Fig. 4) and serum insulin (Fig. 5) levels increased significantly to maximal levels 40 minutes after intake of the carbohydrate-rich drink (9.0 ± 0.4 and 67 ± 10 µU/mL respectively).

DISCUSSION

In the current study, we showed that an oral carbohydrate load leaves the stomach within 90 minutes after ingestion on the morning of surgery despite the presence of increased anxiety and hunger. Gastric emptying of both the carbohydrate-rich drink and water before surgery did not differ from the that found after surgery or compared with that of a group of healthy volunteers (Fig. 2). As was expected, gastric emptying of water occurred more rapidly than of the carbohydrate-rich drink, but only during the first 60 minutes after ingestion (Fig. 3). After 90 minutes, both groups had similar low levels of radioisotopic activity remaining in the stomach, which could be considered emptied.

Several factors are known to affect gastric emptying. The volume of fluid is perhaps the most obvious.[20,21,25,28] The composition of the fluid also affects the gastric emptying rate. Water is emptied rapidly, and gastric emptying is prolonged by additional osmoles.[23,28-30,38] Thus, studies of healthy volunteers have shown that when monomers of carbohydrates are given in increasing doses, gastric emptying is prolonged.[29] A more rapid passage of larger quantities of carbohydrates through the stomach is achieved when polymers are used to reduce the osmolality.[26,27,39] If the fluid contains fat, then gastric emptying is prolonged.[40] These findings were confirmed in our laboratory. Hence, in a pilot study, the same number of calories (200 kcal, n = 4) was given as a commercially available nutritional formula (39% fat, 48% carbohydrate, 13% protein, 490 mOsm, 1.5 kcal/mL [Nutridrink, Nutricia]). Although only 133 mL of Nutridrink was given, the stomach had not been emptied 120 minutes after intake (39.1 ± 5.3% and 18.4 ± 5.6% remained in the stomach after 90 and 120 minutes, respectively). When the same volume of Nutradrink (400 mL, n = 2) was given as in the current study, at least 50% (200 mL) remained in the stomach 120 minutes after ingestion, thus showing that not all solutions used frequently for energy supplementation are safe to administer before surgery.

The carbohydrate-rich drink that is currently used is composed primarily of polymers (maltodextrins), thereby having a lower osmolality than pure glucose or other monomer solutions. Gastric emptying rates of carbohydrate solutions containing polymers, as compared with standard glucose solutions, have been reported to be increased in some studies.[26,39] Perhaps this occurs because the lower osmolality of the polymer solutions cause a reduced gastric secretion. Also, a lower osmolality will cause less activation of osmoreceptors, which reduces gastric emptying rates, contributes to an increased gastric emptying rate. The osmoreceptors are believed to be located in the upper duodenum; hydrolyzation of polymers by oligosaccharidases probably occurs distal to this point.[26,41] The carbohydrate-rich drink used currently also contains small amounts of fructose and electrolytes (e.g., sodium chloride), which also contribute to an increased gastric emptying rate.[23,24,42] These characteristics of the carbohydrate-rich drink explain why gastric emptying of this fairly large dose of carbohydrates (48 g) occurred more rapidly than has been reported in earlier studies using monosaccharides of carbohydrates.[22,29]

The gastric emptying rate showed little variation among the patients and control subjects in the current study, despite a fairly large age range (18–67 years) and the inclusion of both sexes. Although our study population was small, the uniformity of our findings suggest that the broader testing of ingestion of this drink up to 2 hours before the induction of anesthesia will pose little risk, providing that patients with known reduced rates of gastric emptying are excluded.[31]

Ingestion of the carbohydrate-rich drink resulted in higher levels of glucose and insulin. Insulin levels peaked at 67 ± 10 (mean ± SEM) µU/mL 40 minutes after ingestion. These levels are known to fully depress hepatic glucose production[43] and increase the peripheral uptake of glucose among healthy subjects. These levels also result from ingestion of a standard hot meal among healthy volunteers.[44] In response to the intake of 48 g carbohydrate, the body shifts from a fasting state to a metabolic setting associated with energy storage. To ensure this change in metabolism, we developed the drink used in the current study to allow for a maximum intake of energy in the form of carbohydrates and yet to pass rapidly through the stomach.

The change in body metabolism from an overnight fasting state, with reduced glycogen reserves and low basal insulin levels, to that of glycogen loading and insulin release, as seen in the fed state, may be better for preparing the body for stress. This is particularly evident in animal studies[16,17,45] and is probably also of clinical relevance.[18,19] We recently showed that when this metabolic change was achieved through the use glucose infusions administered intravenously in place of fasting, the development of postoperative insulin resistance was reduced by 50%.[18]

It remains unclear whether the reduction in postoperative insulin resistance after intravenously administered glucose[18] is primarily due to glycogen loading, increased insulin levels at the time of the surgical trauma, or both. Nevertheless, in the current study we showed that insulin and glucose level responses as observed with the use of intravenously administered glucose infusions[18] can be mimicked with the use of oral carbohydrates given on the morning of surgery. Regarding the overall stress response, animal data suggest that the state of metabolism at the onset of stress may be a key factor in the reactions to a given form of stress. An animal recently fed or one that has not been fed overnight and given carbohydrates only before the onset of stress will react differently than an animal subjected to the same stress but that has not been fed or that has been given saline intravenously or water orally.[16,45]

We conclude from the current data that not only clear fluids, but also carbohydrate-rich beverages can be given even shortly before elective surgery, provided that the right composition of the solute is used, because gastric emptying was completed within 2 hours. Increased anxiety and discomfort before surgery has little, if any, effect on gastric emptying.

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