MINIREVIEWS

5934 Development of clustered regularly interspaced short palindromic repeats/CRISPR-associated technology for potential clinical applications
Huang YY, Zhang XY, Zhu P, Ji L

5946 Strategies and challenges in treatment of varicose veins and venous insufficiency
Gao RD, Qian SY, Wang HH, Liu YS, Ren SY

5957 Diabetes mellitus susceptibility with varied diseased phenotypes and its comparison with phenome interactome networks
Rout M, Kour B, Vuree S, Lulu SS, Medicherla KM, Suravajhala P

ORIGINAL ARTICLE

Clinical and Translational Research

5965 Identification of potential key molecules and signaling pathways for psoriasis based on weighted gene co-expression network analysis
Shu X, Chen XX, Kang XD, Ran M, Wang YL, Zhao ZK, Li CX

5984 Construction and validation of a novel prediction system for detection of overall survival in lung cancer patients

Case Control Study

6001 Effectiveness and postoperative rehabilitation of one-stage combined anterior-posterior surgery for severe thoracolumbar fractures with spinal cord injury
Zhang B, Wang JC, Jiang YZ, Song QP, An Y

Retrospective Study

6009 Prostate sclerosing adenopathy: A clinicopathological and immunohistochemical study of twelve patients
Feng RL, Tao YP, Tan ZY, Fu S, Wang HF

6021 Value of magnetic resonance diffusion combined with perfusion imaging techniques for diagnosing potentially malignant breast lesions
Zhang H, Zhang XY, Wang Y

6032 Scar-centered dilation in the treatment of large keloids
Wu M, Gu JY, Duan R, Wei BX, Xie F

6039 Application of a novel computer-assisted surgery system in percutaneous nephrolithotomy: A controlled study
<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
<th>Authors</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>6050</td>
<td>Influences of etiology and endoscopic appearance on the long-term outcomes of gastric antral vascular ectasia</td>
<td>Kwon HJ, Lee SH, Cho JH</td>
<td>Randomized Controlled Trial</td>
</tr>
<tr>
<td>6060</td>
<td>Evaluation of the clinical efficacy and safety of TST33 mega hemorrhoidectomy for severe prolapsed hemorrhoids</td>
<td>Tao L, Wei J, Ding XF, Ji LJ</td>
<td>Randomized Clinical Trial</td>
</tr>
<tr>
<td>6069</td>
<td>Sequential chemotherapy and icotinib as first-line treatment for advanced epidermal growth factor receptor-mutated non-small cell lung cancer</td>
<td>Sun SJ, Han JD, Liu W, Wu ZY, Zhao X, Yan X, Jiao SC, Fang J</td>
<td></td>
</tr>
<tr>
<td>6082</td>
<td>Impact of preoperative carbohydrate loading on gastric volume in patients with type 2 diabetes</td>
<td>Lin XQ, Chen YR, Chen X, Cai YP, Lin JX, Xu DM, Zheng XC</td>
<td></td>
</tr>
<tr>
<td>6091</td>
<td>Efficacy and safety of adalimumab in comparison to infliximab for Crohn's disease: A systematic review and meta-analysis</td>
<td>Yang HH, Huang Y, Zhou XC, Wang RN</td>
<td>META-ANALYSIS</td>
</tr>
<tr>
<td>6105</td>
<td>Successful treatment of acute relapse of chronic eosinophilic pneumonia with benralizumab and without corticosteroids: A case report</td>
<td>Izhakian S, Pertzov B, Rosengarten D, Kramer MR</td>
<td>CASE REPORT</td>
</tr>
<tr>
<td>6119</td>
<td>Hepatic epithelioid hemangioendothelioma after thirteen years' follow-up: A case report and review of literature</td>
<td>Mo WF, Tong YL</td>
<td></td>
</tr>
<tr>
<td>6128</td>
<td>Effectiveness and safety of ultrasound-guided intramuscular lauromacrogol injection combined with hysteroscopy in cervical pregnancy treatment: A case report</td>
<td>Ye JP, Gao Y, Lu LW, Ye YJ</td>
<td></td>
</tr>
<tr>
<td>6136</td>
<td>Carcinoma located in a right-sided sigmoid colon: A case report</td>
<td>Lyu LJ, Yao WW</td>
<td></td>
</tr>
</tbody>
</table>
Overlapping syndrome of recurrent anti-N-methyl-D-aspartate receptor encephalitis and anti-myelin oligodendrocyte glycoprotein demyelinating diseases: A case report
Yin XJ, Zhang LF, Bao LH, Feng ZC, Chen JH, Li BX, Zhang J

Liver transplantation for late-onset ornithine transcarbamylase deficiency: A case report

Disseminated strongyloidiasis in a patient with rheumatoid arthritis: A case report
Zheng JH, Xue LY

CYP27A1 mutation in a case of cerebrotendinous xanthomatosis: A case report
Li ZR, Zhou YL, Jin Q, Xie YY, Meng HM

Postoperative multiple metastasis of clear cell sarcoma-like tumor of the gastrointestinal tract in adolescent: A case report
Huang WP, Li LM, Gao JB

Toripalimab combined with targeted therapy and chemotherapy achieves pathologic complete response in gastric carcinoma: A case report

Presentation of Boerhaave’s syndrome as an upper-esophageal perforation associated with a right-sided pleural effusion: A case report
Tan N, Luo YH, Li GC, Chen YL, Tan W, Xiang YH, Ge L, Yao D, Zhang MH

Camrelizumab-induced anaphylactic shock in an esophageal squamous cell carcinoma patient: A case report and review of literature

Nontraumatic convexal subarachnoid hemorrhage: A case report
Chen HL, Li B, Chen C, Fan XX, Ma WB

Growth hormone ameliorates hepatopulmonary syndrome and nonalcoholic steatohepatitis secondary to hypopituitarism in a child: A case report
Zhang XY, Yuan K, Fang YL, Wang CL

Vancomycin dosing in an obese patient with acute renal failure: A case report and review of literature
Xu KY, Li D, Hu ZJ, Zhao CC, Bai J, Du WL

Insulinoma after sleeve gastrectomy: A case report
Lobaton-Ginsberg M, Sotelo-González P, Ramirez-Renteria C, Juárez-Aguilar FG, Ferreira-Hermosillo A

Primary intestinal lymphangiectasia presenting as limb convulsions: A case report
Cao Y, Feng XII, Ni HX

Esophagogastic junctional neuroendocrine tumor with adenocarcinoma: A case report
Kong ZZ, Zhang L
### Contents

**World Journal of Clinical Cases**

**Thrice Monthly Volume 10 Number 18 June 26, 2022**

<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>6247</td>
<td>Foreign body granuloma in the tongue differentiated from tongue cancer: A case report</td>
<td>Jiang ZH, Xu R, Xia L</td>
</tr>
<tr>
<td>6261</td>
<td>Management of type IIIb dens invaginatus using a combination of root canal treatment, intentional replantation, and surgical therapy: A case report</td>
<td>Zhang J, Li N, Li WL, Zheng XY, Li S</td>
</tr>
<tr>
<td>6277</td>
<td>De novo brain arteriovenous malformation formation and development: A case report</td>
<td>Huang H, Wang X, Guo AN, Li W, Duan RH, Fang JH, Yin B, Li DD</td>
</tr>
<tr>
<td>6283</td>
<td>Coinfection of <em>Streptococcus suis</em> and <em>Nocardia asiatica</em> in the human central nervous system: A case report</td>
<td>Chen YY, Xue XH</td>
</tr>
<tr>
<td>6289</td>
<td>Dilated left ventricle with multiple outpouchings — a severe congenital ventricular diverticulum or left-dominant arrhythmogenic cardiomyopathy: A case report</td>
<td>Zhang X, Ye RY, Chen XP</td>
</tr>
<tr>
<td>6307</td>
<td>Thyroid follicular renal cell carcinoma excluding thyroid metastases: A case report</td>
<td>Wu SC, Li XY, Liao BJ, Xie K, Chen WM</td>
</tr>
<tr>
<td>6314</td>
<td>Appendiceal bleeding: A case report</td>
<td>Zhou SY, Guo MD, Ye XH</td>
</tr>
<tr>
<td>6319</td>
<td>Spontaneous healing after conservative treatment of isolated grade IV pancreatic duct disruption caused by trauma: A case report</td>
<td>Mei MZ, Ren YF, Mou YP, Wang YY, Jin WW, Lu C, Zhu QC</td>
</tr>
<tr>
<td>6325</td>
<td>Pneumonia and seizures due to hypereosinophilic syndrome—organ damage and eosinophilia without synchronisation: A case report</td>
<td>Ishida T, Murayama T, Kobayashi S</td>
</tr>
</tbody>
</table>

**LETTER TO THE EDITOR**

<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>6338</td>
<td>Stem cells as an option for the treatment of COVID-19</td>
<td>Cuevas-González MV, Cuevas-González JC</td>
</tr>
</tbody>
</table>
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https://www.wjgnet.com/bpg/gerinfo/208

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Impact of preoperative carbohydrate loading on gastric volume in patients with type 2 diabetes

Xin-Qiang Lin, Yu-Ren Chen, Xiao Chen, Yu-Ping Cai, Jian-Xin Lin, De-Ming Xu, Xiao-Chun Zheng

**Abstract**

**BACKGROUND**
Enhanced recovery after surgery advocates that consuming carbohydrates two hours before anesthesia is beneficial to the patient's recovery. Patients with diabetes are prone to delayed gastric emptying. Different guidelines for preoperative carbohydrate consumption in patients with diabetes remain controversial due to concerns about the risk of regurgitation, aspiration and hyperglycemia. Ultrasonic gastric volume (GV) assessment and blood glucose monitoring can comprehensively evaluate the safety and feasibility of preoperative carbohydrate intake in type 2 diabetes (T2D) patients.

**AIM**
To evaluate the impact of preoperative carbohydrate loading on GV before anesthesia induction in T2D patients.

**METHODS**
Patients with T2D receiving surgery under general anesthesia from December 2019 to December 2020 were included. A total of 78 patients were randomly allocated to 4 groups receiving 0, 100, 200, or 300 mL of carbohydrate loading 2 h before anesthesia induction. Gastric volume per unit weight (GV/W), Perlas grade, changes in blood glucose level, and risk of reflux and aspiration were evaluated before anesthesia induction.

**RESULTS**
No significant difference was found in GV/W among the groups before anes-
thesis induction ($P > 0.05$). The number of patients with Perlas grade II and GV/W > 1.5 mL/kg did not differ among the groups ($P > 0.05$). Blood glucose level increased by > 2 mmol/L in patients receiving 300 mL carbohydrate drink, which was significantly higher than that in groups 1 and 2 ($P < 0.05$).

**CONCLUSION**

Preoperative carbohydrate loading < 300 mL 2 h before induction of anesthesia in patients with T2D did not affect GV or increase the risk of reflux and aspiration. Blood glucose levels did not change significantly with preoperative carbohydrate loading of < 200 mL. However, 300 mL carbohydrate loading may increase blood glucose levels in patients with T2D before induction of anesthesia.

**Key Words:** Type 2 diabetes; Preoperative; Carbohydrate loading; Gastric volume; Ultrasound assessment; Hyperglycemia

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**Core Tip:** Enhanced recovery after surgery advocates that consuming carbohydrates two hours before anesthesia is beneficial to the patient's recovery. Patients with diabetes are prone to delayed gastric emptying. Different guidelines for preoperative carbohydrate consumption in patients with diabetes remain controversial due to concerns about the risk of regurgitation, aspiration and hyperglycemia. In this study, the preoperative carbohydrate load of type 2 diabetes (T2D) patients 2 h before anesthesia induction was found by ultrasonic gastric volume assessment and blood glucose monitoring. 200 mL does not increase the risk of reflux, aspiration, and hyperglycemia, but 300 mL glucose load may cause hyperglycemia in T2D patients before induction of anesthesia.

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**INTRODUCTION**

Enhanced recovery after surgery (ERAS) is a set of perioperative protocols to reduce complications, facilitate recovery, and decrease the length of hospitalization[1,2]. Insulin resistance is a critical complication of injury or stress. Most patients receiving surgery may develop postoperative insulin resistance. The resulting hyperglycemia is often associated with an increased risk of morbidity and mortality. ERAS recommends preoperative carbohydrate loading to decrease postoperative hyperglycemia by 50%, optimizing recovery[3-5].

More than 10% of the world population is reported to have diabetes[6], and nearly 15% of surgical patients have type 2 diabetes (T2D)[7]. Complications and hospital stays are greater in these patients than in non-diabetic patients[8,9]. Delayed gastric emptying (gastroparesis) is also more frequent in patients with diabetes[10,11]. Therefore, preoperative carbohydrate loading may adversely affect gastric volume (GV) in diabetic patients. Moreover, carbohydrate loading-induced hyperglycemia may outweigh the potential benefits of ERAS protocols in such patients. Laffin et al[12] found no significant difference in the hyperglycemic incidence between the groups with and without carbohydrate loading [12]. However, other studies have reported high rates of adverse outcomes, such as postoperative wound infections, cardiac events, and other complications caused by hyperglycemia, in diabetic patients receiving preoperative carbohydrate loading[13]. It is important to further study the change in blood glucose levels in diabetic patients receiving preoperative carbohydrate loading.

Perlas used ultrasound to grade GV, which was measured in the right decubitus and supine positions to assess the risk of aspiration. The visualization of gastric antrum content was scored using the Perlas grading system: Grade 0, no content visible in the supine or right lateral (RLD) position; grade 1, clear gastric fluid content only in the RLD position, but not in the supine position; and grade 2, clear gastric fluid content visible in both supine and RLD positions[14]. Perlas grade II and GV > 1.5 mL/kg have been reported to be associated with a high risk of reflux and aspiration[15,16]. Therefore, ultrasonography is used to evaluate GV both qualitatively and quantitatively. It is an economical, safe, non-invasive, and repeatable technique to assess the risk of anesthesia before surgery[17]. Data on preoperative carbohydrate loading in patients with T2D are limited[18,19]. In this study, we assessed
GV, the incidence of hyperglycemia, and the risk of gastric reflux and aspiration using ultrasonography. We also evaluated the time and dose of preoperative carbohydrates using stratified analysis. These assessments allowed us to determine the safety and feasibility of preoperative carbohydrate loading in patients with T2D.

**MATERIALS AND METHODS**

**Inclusion and exclusion criteria**

Data of adult patients (age: 40-80 years) who received surgery under general anesthesia were enrolled according to the following inclusion criteria: (1) American Society of Anesthesiologists Physical Status Classification System (ASA) classified as II-III; (2) Definite diagnosis of T2D for > 2 years; (3) Preoperative blood glucose < 10 mmol/L; (4) Glycosylated hemoglobin (HbA1c) < 8.5%; and (5) Body mass index (BMI) of 18–35 kg/m². Patients were excluded from the study if they had any of the following: (1) Pregnancy; (2) Cardiac or renal dysfunction; (3) Hypothyroidism; (4) Obesity (BMI > 35 kg/m²); (5) Digestive system diseases, including gastroesophageal reflux, peptic ulcer, digestive system tumors, cholelithiasis or history of upper gastrointestinal surgery; (6) Receiving anesthetic drugs or other drugs affecting gastrointestinal motility before operation; (7) Preoperative gastrointestinal decompression or nutrition; or (8) Unwilling to participate in the study.

**Patients and study design**

Overall, 80 patients with T2D who received surgery under general anesthesia from December 2019 to December 2020 were enrolled in the study. Of them, 2 patients were excluded due to unclear images of the gastric antrum. Finally, 78 patients with complete follow-up data were included in the study. The flow chart of the study is presented in Figure 1. The day before surgery, patients who fulfilled the study criteria and provided written consent were randomly allocated to 4 groups. Randomization was performed using computer-generated random numbers indicating different volumes of carbohydrate loading. Patients received a clear carbohydrate drink (0, 100, 200, or 300 mL) 2 h before anesthesia induction on the day of surgery. Each group uses the same concentration of carbohydrate drink that contains 14.2 g of carbohydrate per 100 mL (Yichang Human Medical Food Co., Ltd.). Randomization was performed using computer-generated four-digit random numbers indicating the treatment, which were kept in sealed envelopes. An envelope was opened according to the random number from small to large based on the time sequence of inclusion of each subject. The ultrasound examiner was blinded by the study protocol, as was the staff involved in the medical procedures and data collection process. All patients received surgery under general endotracheal anesthesia. Intraoperative fluid management was limited to a glucose-free solution, and no exogenous insulin was administered. Postoperative care was standardized as clinically indicated.

**Data collection and assessment**

Ultrasonography was performed by an experienced investigator certified by the Chinese Health Commission. GV was assessed on the day of surgery before carbohydrate loading (T0, basal value), 2 min after carbohydrate loading (T1), and before anesthesia induction (T2). A standard convex ultrasound probe was used to scan the gastric antrum in the sagittal plane between the liver and pancreas, at first in the supine position and then in the RLD position. The gastric antrum content visualization was scored using the Perlas grading system: Grade 0, no content visible in the supine or RLD position; grade 1, clear gastric fluid content only in the supine position; and grade 2, clear gastric fluid content visible in both supine and RLD positions[14]. The longitudinal (D1) and anteroposterior (D2) diameters of the antrum were determined, which were repeated 3 times and averaged (Figure 2). The gastric antral area (CSA) was calculated using the following formula: CSA = π × D1 × D2/4. A mathematical model was used to measure GV: 27 + 14.6 × CSA - 1.28 × age. In addition, blood glucose levels were monitored before carbohydrate loading (T0) and anesthesia induction (T2). Patients with GV per unit weight (GV/W) > 1.5 mL/kg were regarded as having a high risk of reflux and aspiration. Gastrointestinal decompression was performed before anesthesia induction in these patients. If the blood glucose level was > 10 mmol/L at T2, the surgery was delayed until it normalized.

**Statistical analysis**

The sample size was determined based on the GV/W at different time periods. The average GV/W at T0, T1 and T2 in the control group was 0.66, 0.64, and 0.70 mL/kg, respectively, in our preliminary study. The values at T0, T1, and T2 in groups receiving 100 mL, 200 mL, and 300 mL carbohydrate drink were 0.45, 1.2, and 0.53 mL/kg; 0.70, 3.20, 0.85 mL/kg; and 0.65, 4.67, 0.8 mL/kg, respectively. Based on these values, we found that a sample of at least 20 patients in each group and 80 patients in total would ensure 80% power for the study to evaluate the effect of preoperative carbohydrate loading on GV. The 80% power was calculated considering a two-sided type I error of 0.05 by log-rank test and 20% loss to follow-up.
All statistical analyses were performed in SPSS (version 24.0, IBM, New York, United States). Normally distributed continuous data are presented as mean ± SD. Categorical data are presented as frequency or rate. Age, height, weight, BMI, course of the disease, HbA1c (%), and fasting blood glucose were compared using one-way ANOVA. The ASA scores, gender, and control of blood glucose were the Chi-square test or Fisher exact test. The GV per unit body weight and peripheral capillary blood glucose were examined with the repeated measures analysis of variance. The Bonferroni method was applied for pairwise comparisons in the repeated measures analysis of variance. All statistical analyses were two-sided tests. A $P < 0.05$ indicated a statistically significant difference.
RESULTS

Patient characteristics
A total of 78 patients with T2D were randomly allocated to 4 groups, with the control group receiving 0 mL, group 1 receiving 100 mL, group 2 receiving 200 mL, and group 4 receiving 300 mL carbohydrate drink. All groups were well balanced for characteristics, including gender, age, BMI, height, weight, ASA grade, disease course, HbA1c, fasting blood glucose level, and control of blood glucose (Table 1).

Analysis of GV
GV was assessed at 3 different time points as described above. Gastric content was first evaluated using the Perlas A scale. No difference was observed in patients with Perlas grade II at T0 and T2 among the groups (P > 0.05). GV/W was increased significantly at T1 in groups 1, 2, and 3. At T2, GV/W decreased significantly, with no statistical difference observed between T0 and T2 in all the groups (P > 0.05) (Figure 3). Moreover, the number of patients with GV/W > 1.5 mL/kg was similar among the groups (P > 0.05) (Figure 3).

Analysis of blood glucose levels
The blood glucose level in all patients was tested before carbohydrate loading (T0) and anesthesia induction (T2). In groups 1, 2, and 3, blood glucose levels increased significantly at T2 compared with that at T0 (P < 0.05). In patients receiving 300 mL of the carbohydrate drink (group 3), the blood glucose level at T2 increased by >2 mmol/L, which was significantly higher than that in groups 1 and 2. This finding indicates that a 300 mL carbohydrate load may increase the blood glucose level in patients with T2D before anesthesia induction (Figure 4).

DISCUSSION
Preoperative carbohydrate loading improves glycemic control and postoperative recovery in nondiabetic patients[3,4]. However, the practice of carbohydrate loading in patients with T2D is controversial because of reflux and aspiration concerns due to increased GV and delayed emptying. In our study, no difference was found in GV/W between T0 and T2 in all groups. This finding indicates that GV does not increase with a carbohydrate loading of <300 mL. Our results are in line with those of previous studies, which reported no delay in gastric emptying in patients with T2D compared with healthy control subjects[20]. Our patients drank 14.2% liquid carbohydrates with low osmotic pressure. Delayed gastric emptying seems to affect solids rather than liquids in patients with diabetes, which can possibly explain the similar GV between T0 and T2 in our study[10,21]. Furthermore, in our study, the preoperative fasting blood glucose level was controlled less than 10 mmol/L, which may reduce the incidence of delayed gastric emptying in T2D. Previous studies have shown that severe acute hyperglycemia may lead to delayed gastric emptying[22]. In summary, carbohydrate loading of <300 mL 2 h before anesthesia induction does not significantly affect GV in patients with T2D.

The risk of reflux and aspiration was further evaluated using Perlas grading determined by ultrasonography. Patients with Perlas grade I had <100 mL gastric content, whereas those with grade II had obvious gastric content in both supine and RLD positions[23]. Moreover, GV/W >1.5 mL/kg helps determine the risk of reflux and aspiration[24-26]. In our study, the number of patients with Perlas grade II and GV/W > 1.5 mL/kg did not differ among the groups. This finding further confirms that preoperative carbohydrate loading does not increase the risk of reflux and aspiration in patients with T2D. However, it should be noted that all our patients had with Perlas grade II and GV/W > 1.5 mL/kg. This indicates the importance of performing routine preoperative GV ultrasonography in patients with diabetes.

Change in blood glucose level was another focus of our study. In the control group, group 1 and group 2, blood glucose level increased by <2 mmol/L after carbohydrate loading. However, in patients receiving 300 mL of the carbohydrate drink (group 3), blood glucose levels increased by 3.4 mmol/L after 2 h. Studies have shown that a change in blood glucose level of <2 mmol/L after carbohydrate loading does not increase perioperative complications[12,27,28]. Therefore, our results support a preoperative carbohydrate loading of <200 mL in patients with T2D, although the optimal time for preoperative carbohydrate loading remains unaddressed. Carbohydrate loading 3 h before surgery does not pose a risk for hyperglycemia or aspiration in diabetic patients[12,20]. However, some researchers do not recommend the 2-h interval between carbohydrate loading and surgery due to concerns of delayed gastric emptying[29]. In our study, carbohydrate loading 2 h before anesthesia induction did not affect GV or increase the risk of reflux and aspiration. Future studies are warranted to confirm our results.

Our study has certain limitations. First, the blood glucose level of the enrolled patients was well controlled, and their preoperative FPG was <10 mmol/L. Further stratified analysis must be performed in patients with different levels of blood glucose and HbA1c. Second, data about primary diseases in our patients were lacking. Because primary diseases may affect GV and gastric emptying, the lack of such
Table 1 Baseline characteristics of included patients

<table>
<thead>
<tr>
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<td>18/2</td>
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<td>8/12</td>
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<td>Age (yr)</td>
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</tr>
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<td>HbA1c (%)</td>
<td>7.34 ± 0.37</td>
<td>7.34 ± 0.50</td>
<td>7.49 ± 0.46</td>
<td>7.46 ± 0.56</td>
<td>0.53</td>
<td>0.663</td>
<td></td>
</tr>
<tr>
<td>Fasting blood glucose (mmol/L)</td>
<td>7.35 ± 2.13</td>
<td>7.08 ± 1.21</td>
<td>6.95 ± 0.80</td>
<td>6.56 ± 1.20</td>
<td>1.03</td>
<td>0.386</td>
<td></td>
</tr>
<tr>
<td>Control of blood glucose (oral/injection of insulin)</td>
<td>16/4</td>
<td>14/5</td>
<td>16/4</td>
<td>17/2</td>
<td>1.76</td>
<td>0.568</td>
<td></td>
</tr>
</tbody>
</table>

ASA: American society of anesthesiology; BMI: Body mass index; HbA1c: Hemoglobin A1c.

![Figure 3](https://example.com/figure3.png)

**Figure 3 Comparison of gastric volume per unit weight in four groups of patients at different time points.** Gastric volume per unit weight (GV/W) was increased significantly at T1 in groups 1, 2, and 3. At T2, GV/W decreased significantly, with no statistical difference observed between T0 and T2 in all the groups ($aP < 0.05, T0$ vs $T1, T1$ vs $T2$). NS: Not significant.

CONCLUSION

Preoperative carbohydrate loading < 300 mL 2 h before anesthesia induction in patients with T2D did not affect GV or increase the risk of reflux and aspiration. Blood glucose level did not significantly change with preoperative carbohydrate loading of < 200 mL. However, 300 mL carbohydrate loading may increase blood glucose levels in patients with T2D before anesthesia induction. In conclusion, it is safe for patients with T2D to drink 200 mL 14.2% carbohydrate 2 h before surgery. In the future, we will study whether preoperative consumption of 200 mL of 14.2% carbohydrate can reduce postoperative insulin resistance and promote recovery of patients.
ARTICLE HIGHLIGHTS

Research background
More than 10% of the world’s population and almost 15% of surgical patients are reported to have type 2 diabetes (T2D). Diabetic patients are prone to delayed gastric emptying due to the risk of reflux, aspiration and hyperglycemia.

Research motivation
Different guidelines for preoperative carbohydrate loading in diabetic patients are still controversial.

Research objectives
This study is conducted to evaluate the safety and feasibility of preoperative carbohydrate loading on gastric volume (GV) before anesthesia induction in T2D patients.

Research methods
Patients with T2D were randomly allocated to 4 groups receiving 0, 100, 200, or 300 mL of carbohydrate loading 2 h before anesthesia induction. Gastric volume per unit weight (GV/W), Perlas grade, changes in blood glucose level, and risk of reflux and aspiration were evaluated before anesthesia induction.

Research results
No significant difference was found in GV/W among the groups before anesthesia induction ($P > 0.05$). The number of patients with Perlas grade II and GV/W > 1.5 mL/kg did not differ among the groups ($P > 0.05$). Blood glucose level increased by > 2 mmol/L in patients receiving 300 mL carbohydrate drink, which was significantly higher than that in groups 1 and 2 ($P < 0.05$).

Research conclusions
Preoperative carbohydrate loading < 300 mL 2 h before anesthesia induction in patients with T2D did not affect GV or increase the risk of reflux and aspiration. Blood glucose levels did not change significantly with preoperative carbohydrate loading of < 200 mL. However, 300 mL carbohydrate loading may increase blood glucose levels in patients with T2D before induction of anesthesia.

Research perspectives
Our study illustrates the safety and recommended volume of preoperative carbohydrate loading in patients with T2D.

FOOTNOTES

Author contributions: All authors contributed to the study conception and design; Zheng XC designed the study; Material preparation, data collection and analysis were performed by Lin XQ, Chen YR and Chen X; Cai YP, Lin JX and Xu DM contributed sample collection and intellectual input; The first draft of the manuscript was written by Lin XQ and all authors commented on previous versions of the manuscript; All authors read and approved the final
manuscript; Lin XQ and Chen YR contributed equally to this study.

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**Clinical trial registration statement:** This study is registered at the Chinese Clinical trial registry, No. ChiCTR1900028529.

**Informed consent statement:** All study participants or their legal guardian provided informed written consent about personal and medical data collection prior to study enrolment.

**Conflict-of-interest statement:** The authors declare that they have no competing interests.

**Data sharing statement:** The datasets generated during and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

**CONSORT 2010 statement:** The authors have read the CONSORT 2010 Statement, and the manuscript was prepared and revised according to the CONSORT 2010 Statement.

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