Preoperative carbohydrate drink increases glycemic variability in patients with type 2 diabetes mellitus: A prospective randomized trial

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Preoperative carbohydrate drink increases glycemic variability in patients with type 2 diabetes mellitus: A prospective randomized trial

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ABSTRACT

Preoperative carbohydrate drink increases glycemic variability in patients with type 2 diabetes mellitus: A prospective randomized trial

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Background: Preoperative carbohydrate treatment attenuates insulin resistance and improves metabolism to an anabolic state. Despite these benefits, impaired glycemic control and aspiration risk related to gastroparesis represent concerns for patients with diabetes undergoing surgery. This randomized controlled trial investigated the effects of oral carbohydrate therapy on perioperative glucose variability, metabolic responses, and gastric volume in diabetic patients undergoing elective total hip or knee arthroplasty.

Methods: Fifty diabetic patients scheduled to undergo elective total knee or hip arthroplasty during August 2019–October 2020 were randomly assigned to a control or carbohydrate therapy (CHO) group. CHO group patients received a 400-mL carbohydrate drink 2–3 h before anesthesia;

control group patients underwent overnight fasting from midnight, one night before surgery. Blood glucose levels were measured before intake of the carbohydrate drink, before spinal anesthesia, preoperatively, immediately postoperatively, and 1 h postoperatively. Insulin level and gastric volume were measured before spinal anesthesia.

Results: The glucose variability of patients in the CHO group was significantly higher than that of those in the control group (16.5 vs. 10.9 %, P = 0.008). Similarly, insulin resistance was higher in the CHO group than in the control group (8.5 vs. 2.7, P <0.001). The gastric volume did not differ significantly between the groups (61.3 vs. 15.2 ml, P = 0.082).

Conclusions: Preoperative oral carbohydrate therapy increases glucose variability and insulin resistance in diabetic patients. Therefore, carbohydrate beverages should be cautiously administered to diabetic patients, considering metabolic and safety aspects.

Key words: Carbohydrates, diabetes mellitus, glucose, insulin resistance

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I. INTRODUCTION

Surgical stress induces metabolic, inflammatory, and immune reactions [1]. Among them, insulin resistance and catabolism are well-characterized aspects of metabolic responses [1]. Conventional preoperative overnight fasting for reducing aspiration risk and improving bowel preparation also causes insulin resistance and a catabolic metabolic state [1, 2]. Guidelines for recent fasting and enhanced recovery postoperatively suggest that clear fluids may be freely allowed until 2 h preoperatively [2-5]. Furthermore, administrating a preoperative carbohydrate beverage attenuates insulin resistance and improves metabolism to an anabolic state [6-9].

In studies on abdominal and orthopedic surgery, preoperative carbohydrate treatment is associated with improved bowel function return and postoperative pain, and shorter length of hospital stay [10-12]. However, these benefits were observed in non-diabetic patients, and impaired glycemic control and increased aspiration risk related to gastroparesis remain concerns for surgical patients with diabetes. Although few guidelines suggest that preoperative carbohydrate treatment can be routinely used in patients with well-managed diabetes [4], patients with delayed gastric emptying or those undergoing insulin treatment are also recommended to fast overnight or for 8 h preoperatively [5, 13]. Recent

clinical studies exploring the administration of oral carbohydrate therapy to diabetic patients reported no safety issues. Nonetheless, the current evidence remains insufficient for establishing general guidelines based on glucose variability and metabolic stress findings in diabetic patients [14, 15].

We aimed to investigate the effects of oral carbohydrate therapy on perioperative glucose variability and metabolic responses in diabetic patients. Furthermore, we compared the gastric volume and pulmonary aspiration risk in patients who received preoperative carbohydrate drinks and those who fasted overnight.

II. MATERIALS AND METHODS

This randomized controlled trial was approved by the 3rd Committee of the Severance Hospital Institutional Review Board, Seoul, Korea (protocol number: 4-2019-0428) on June 24, 2019 and was registered at ClinicalTrials.gov (No. NCT04013594) on July 9, 2019. This study was conducted in accordance with the Declaration of Helsinki. We enrolled 50 patients with type 2 diabetes mellitus scheduled to undergo elective total hip or knee arthroplasty between August 2019 and October 2020. Written informed consent was obtained from all patients. Patients having clinical signs of autonomic neuropathy, undergoing treatment with insulin, or having glycated hemoglobin (HbA1c) levels >8.5% [16], body mass index >30 kg/m^2, gastroesophageal reflux disease, history of abdominal surgery, chronic renal failure, or absolute contraindications to spinal anesthesia were excluded [17].

Participants were randomly assigned to control and carbohydrate therapy (CHO) groups using a randomization table generated with MedCalc Statistical Software version 18.11.3 (MedCalc Software Ltd., Ostend, Belgium). An anesthesiologist not involved in data collection conducted the randomization and group assignments. The CHO group received a 400-mL carbohydrate drink

(12.8% carbohydrate, 0.5 kcal/mL, 14% monosaccharides, 3% disaccharides, 83% polysaccharides, and 265 mOsm/kg; NO-NPO®, Daesang WelLife, Seoul, Korea) 2–3 h before anesthesia, whereas the control group fasted overnight from midnight, one night before surgery. All patients received diabetes medication according to the study protocol [17].

Perioperative management

Patients were routinely monitored in the operating room, received spinal anesthesia with hyperbaric bupivacaine, and administered 3 L of O_2 via a nasal prong. The attending anesthesiologist administered doses of 0.5% hyperbaric bupivacaine (10–12 mg) at his/her discretion. Patients requesting intraoperative sedation were administered propofol, and a significant decrease in blood pressure (>20% decrease in mean blood pressure compared with baseline) indicated hypotension and was treated with a bolus of ephedrine (4 mg) or phenylephrine (50 μg). Perioperative blood glucose levels were maintained between 90 and 180 mg/dL using intermittent insulin or 50% dextrose in water if blood glucose levels exceeded 250 mg/dL or were less than 70 mg/dL, as appropriate [18]. A continuous adductor canal block was performed after total knee arthroplasty with a pump (Accufuser Plus, Woo Young Medical Co., Ltd., Seoul, Korea) at 6 mL/h using a 4-mL bolus (lockout time: 30 min) of 0.2% ropivacaine. A femoral nerve block was performed after total hip arthroplasty. A 200-mg dose of celecoxib was routinely administered for pain control; if the verbal numerical rating scale (VNRS) score was >4, 50 mg tramadol or 25 mg pethidine was administered intramuscularly. One surgeon (K.K.P.) performed all total hip or knee arthroplasty procedures to maintain a uniform surgical stimulus.

Outcome assessment

Blood glucose levels were measured using a finger stick blood test (Accu-Chek Instant BGMS, Roche Diabetes Care, GmbH, Mannheim, Germany) at five time points: before carbohydrate drink intake (baseline), after carbohydrate drink intake (T1, before spinal anesthesia), preoperatively (T2), immediately postoperatively (T3), and 1 h postoperatively (T4). Blood samples were obtained via an indwelling catheter in the antecubital vein at T1 to measure free fatty acid (FFA), glucagon, activated glucagon-like peptide-1 (GLP-1), insulin, and C-peptide levels. Glucose variability was measured through a variation coefficient (standard deviation [SD]/mean × 100%) and J index ($0.001 \times [\text{mean} + \text{SD}]^2$) [19, 20]. Insulin resistance was calculated using the following formula: Homeostasis Model Assessment Insulin Resistance (HOMA-IR) value = (fasting glucose (mg/dL) × fasting insulin (μU/mL))/405 [21].

Intraoperative variables included anesthesia time, operation time, surgery type, and fluid input/output. Postoperative variables included length of hospital stay; incidence of nausea, vomiting, dizziness, hypotension, and delirium; wound infection; white blood cell (WBC) count; neutrophil-to-lymphocyte ratio; and pain scores. Pain at rest was evaluated on postoperative days 1 and 2 using an 11-point VNRS ranging from 0 (no pain) to 10 (worst imaginable pain).

Gastric ultrasound assessment

Before spinal anesthesia, Y.S.C., while instructed and supervised by an experienced radiologist, assessed the gastric volume of patients using ultrasonography (Sonosite X-Porte, SonoSite Inc., Bothell, Washington, USA) with a 4-MHz convex transducer. Patients were examined in the supine and right lateral positions. The gastric antrum was identified in a sagittal or parasagittal plane between the liver left lobe and pancreas at the aorta or inferior

vena cava level [22]. The transducer was tilted to obtain a true cross-sectional view of the antrum. Anteroposterior (AP) and craniocaudal (CC) diameters were measured in the supine and right lateral decubitus positions (Figure 1). The antral cross-sectional area (CSA) and total gastric fluid volume were calculated using the following standard formulas: CSA = (AP × CC × π)/4 and gastric volume (mL) = 27.0 + 14.6 × right-lateral CSA − 1.28 × age [22]. If the total gastric volume (mL) was >1.5 × the body weight (kg), aspiration risk was considered high [22].

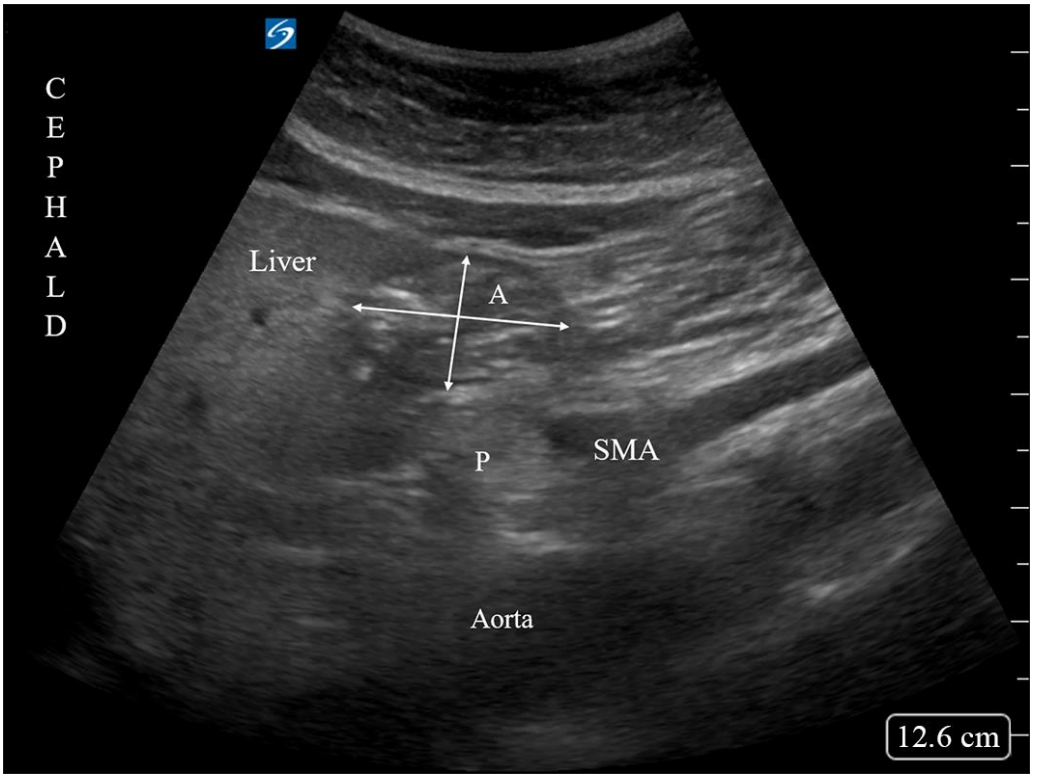

Figure 1. Ultrasonographic measurement of the gastric antrum (A, antrum; P, pancreas, SMA, superior mesenteric artery)

Statistical analyses

We calculated the sample size required to detect a difference in glucose variability >4% between the control and CHO groups [23]. Accordingly, 22 subjects were required in each group to achieve a statistical power of 90% at $P<0.05$. Ultimately, we enrolled 25 patients in each group to account for a 10% dropout rate. Intergroup comparisons were conducted using the *t*-test, Mann–Whitney *U* test, Fisher's exact test, or χ^2 test, as appropriate. The Bonferroni correction was applied to adjust for multiple comparisons of blood glucose levels. Continuous variables are presented as mean±SD or median (interquartile range); categorical variables are presented as numbers (percentages). Statistical analyses were performed using R version 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria), SPSS version 23.0 (IBM Corp., Armonk, NY), or MedCalc Statistical Software version 18.11.3 (MedCalc Software Ltd., Ostend, Belgium). A *P* value <0.05 was considered statistically significant.

III. RESULTS

Among the 53 patients screened for eligibility between August 20, 2019, and October 7, 2020, 50 were enrolled in this study and assigned to a group. Among these patients, two experienced hypoglycemic episodes (one in each group), and two experienced hyperglycemia at T1 (>250 mg/dL, both in the CHO group) during the study period. They were treated with glucose or intravenous insulin and excluded from the final analysis of the metabolic response to the carbohydrate drink. Forty-six patients completed this study (Figure 2).

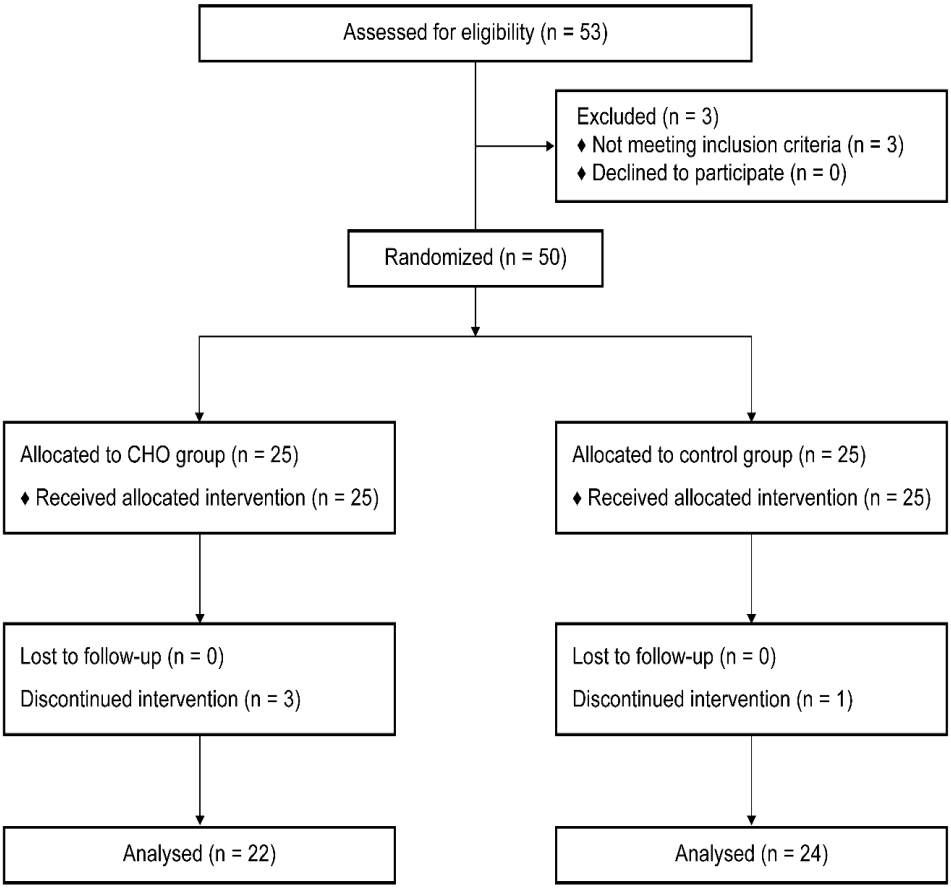

Figure 2. Patient selection flowchart

Patient baseline characteristics, American Society of Anesthesiologists physical status classification, HbA1c levels, and diabetes medication usage were similar between both groups (Table 1). Patients in the CHO group had larger gastric volumes than those in the control group, yet this difference was not significant (61.3 vs. 15.2 mL, P=0.082). Although two patients in the CHO group and one patient in the control group were considered to be at high risk of aspiration, there was no significant difference in aspiration risk between groups. Moreover, intraoperative variables, such as operation time, fluid output, blood

pressure, and vasopressor use, were not significantly different between groups (Table 2).

Table 1 Patient characteristics.

	Control group (N=24)	CHO group (N=22)	P
Age (yr)	70.5 ± 6.0	70.3 ± 6.8	0.905
Female/Male	16/8	16/6	0.900
Body mass index (kg/m^2)	25.4 (24.2−27.6)	26.3 (24.6−28.6)	0.389
ASA class (II/III)	21/3	19/3	>0.999
Hypertension	16 (64)	17 (77)	0.638
HbA1c (mmol/mol)	46 (42−49)	48 (43−54)	0.218
Creatinine (mg/dl)	0.83 ± 0.18	0.80 ± 0.20	0.538
CSV in supine (cm^2)	4.9 (3.8−6.3)	7.1 (5.8−8.1)	0.057
CSV in RLD (cm^2)	5.9 (5.0−8.9)	8.1 (7.5−8.9)	0.093
Gastric volume (ml) in RLD	15.2 (4.6−68.8)	61.3 (36.4−78.3)	0.082
Gastric volume/kg (ml/kg)	0.3 (0.1−1.1)	0.8 (0.7−1.0)	0.106
Patients with >1.5ml/kg	1 (4)	2 (9)	0.938
Diabetes medication			
DPP-IV inhibitors	13 (54)	9 (41)	0.546
Metformin	20 (83)	19 (86)	>0.999
Pioglitazone	4 (16)	2 (9)	0.743
Sulfonylurea	4 (17)	9 (41)	0.135

SGLT-2 inhibitors	6 (24)	4 (18)	0.840
Details of oral medication			>0.999
1 oral medication	13 (54)	11 (50)	
2+ oral medication	11 (46)	11 (50)	

Values are presented as median (interquartile range), mean ± standard deviation, or number of patients (%). ASA, American Society of Anesthesiologist; CSA, cross-sectional area; RLD, right latera decubitus; DDP, dipeptidyl peptidase; SGLT, sodium-glucose cotransporter.

Table 2 Intraoperative variables.

	Control group (N=24)	CHO group (N=22)	P
Anesthesia time (min)	123 (110−165)	123 (100−150)	0.280
Operation time (min)	89 (73−120)	84 (63−104)	0.226
The kind of operation			>0.999
Total knee arthroplasty	19 (79)	18 (82)	
Total hip arthroplasty	5 (21)	4 (18)	
Fluid input (ml)	600 (425−800)	475 (400−650)	0.471
Urine output (ml)	250 (105−475)	250 (125−525)	0.541
Intraoperative bleeding (ml)	50 (50−100)	50 (50−100)	0.416
The lowest mean blood pressure (mmHg)	68.0 ± 14.6	69.4 ± 12.3	0.734
Vasopressor use	11 (46)	10 (46)	>0.999

Values are presented as median (interquartile range), mean ± standard deviation, or number of patients (%).

Participant blood glucose levels at the five time points were not significantly different between groups (Figure 3). The measured time intervals of baseline–T1, T1–T2, T2–T3, and T3–T4 were approximately 2.5, 0.5, 1.5, and 1 h, respectively. Using the variation coefficient, we observed that patients in the CHO group experienced significantly greater glucose variability than those in the control group (16.5% vs. 10.1 %, P =0.008, Table 3). Insulin levels (22.8 vs. 8.4 μU/mL, P<0.001) and HOMA-IR (8.5 vs. 2.7, P<0.001) were also higher in the CHO group than in the control group. Glucagon and activated GLP-1 levels were similar between both groups. Moreover, FFA levels were not significantly different between both groups.

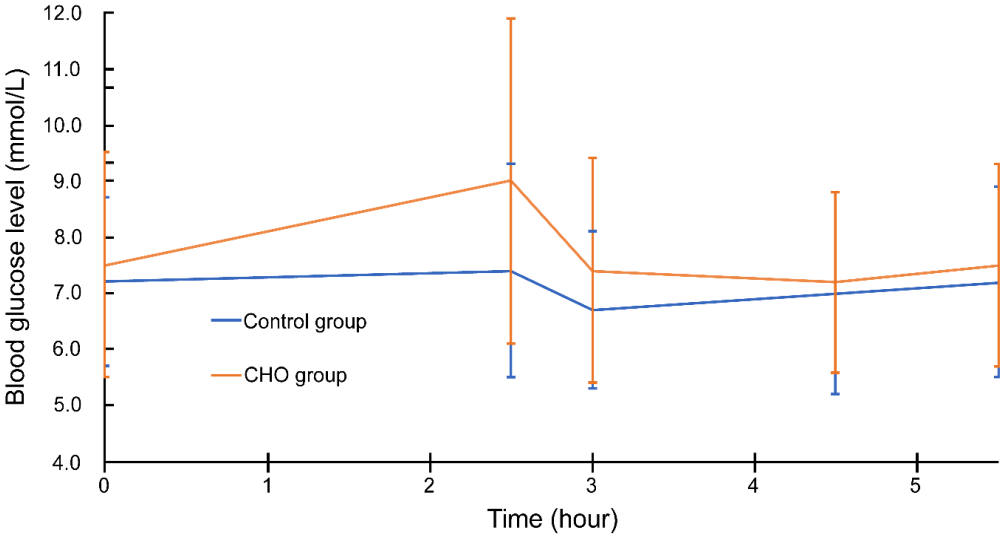

Figure 3. Changes in blood glucose levels after carbohydrate (CHO) drink intake

Table 3 Intraoperative glucose and hormone levels.

	Control group (N=24)	CHO group (N=22)	P
Glucose variability			
Coefficient of variation	10.9 (7.6−14.8)	16.5 (10.4−24.1)	0.008
J index	18.9 (15.9−25.2)	25.2 (17.9−39.6)	0.046
Insulin (μU/ml)	8.4 (7.8−13.4)	22.8 (14.4−35.7)	<0.001
C-peptide (ng/ml)	2.5 (2.0−3.3)	4.1 (2.9−5.5)	0.005
Insulin resistance	2.7 (2.2−4.8)	8.5 (5.6−19.2)	<0.001
Active GLP-1 (pM)	2.0 (2.0−3.8)	2.0 (2.0−5.2)	0.813
Glucagon (pg/ml)	133.0 (76.5−192.5)	130.0 (87.0−167.0)	0.974
Free fatty acid (μEq/L)	503.4 ± 235.9	362.9 ± 257.4	0.058
Free fatty acid >600 μEq/L	9 (38)	4 (18)	0.260

Values are presented as median (interquartile range), mean ± standard deviation, or number of patients (%). Coefficient of variation, standard deviation [SD] ÷ mean × 100%; J index, 0.324 × [mean + SD]^2; insulin resistance, fasting glucose (mmol/L) × fasting insulin (μU/ml); GLP, glucagon-like peptide.

Regarding postoperative outcomes, nausea and vomiting occurred more frequently in the CHO group than in the control group, although this difference was not significant (Table 4). Delirium was higher in the CHO group than in the control group (17% vs. 0%, *P*=0.046). Patients in the CHO group had higher postoperative WBC counts than those in the control group (9,640 vs. 7,545 /μL, *P*=0.026).

Table 4 Postoperative outcome.

	Control group (N=24)	CHO group (N=22)	P
Postoperative hospital day	3 (3–3)	3 (3–3)	0.516
Nausea	7 (29)	10 (46)	0.402
Vomiting	2 (8)	7 (32)	0.066
Dizziness	4 (17)	2 (9)	0.667
Hypotension	3 (13)	1 (5)	0.609
Delirium	0	4 (18)	0.045
Wound dehiscence	2 (8)	2 (9)	>0.999
White blood cell (cells/μL)			
Postoperative	7545 [6240–10085]	9640 [8620–11560]	0.026
Postoperative 1 day	8085 [7035–9370]	9085 [8010–11250]	0.082
Neutrophil/lymphocyte ratio			
Postoperative	4.2 (2.8–5.0)	4.5 (2.7–6.1)	0.884
Postoperative 1 day	6.3 (4.9–9.8)	6.6 (5.0–10.6)	0.598
Pain scores at rest			
Postoperative 6h	2 (0–5)	2 (0–5)	0.725
Postoperative 24h	4 (0–5)	4 (2–6)	0.440
Postoperative 48h	2 (0–3)	2 (1–3)	0.918

Values are presented as median (interquartile range), mean ± standard deviation, or number of patients (%).

IV. DISCUSSION

To the best of our knowledge, this was the first randomized trial to investigate the effect of preoperative carbohydrate therapy on glucose variability in diabetic patients. The preoperative administration of an oral carbohydrate drink increased glucose variability and insulin resistance in patients with

non-insulin-dependent type 2 diabetes mellitus undergoing elective total hip or knee arthroplasty.

Paradoxically, insulin resistance, which causes hyperglycemia, can be reduced by preoperative carbohydrate therapy; however, the same carbohydrate drink administered in preoperative carbohydrate therapy also elevates blood glucose levels [2]. Glucose variability is represented by fluctuations in glucose levels and deleterious cellular processes caused by hyperglycemic spikes or hypoglycemic troughs [24]; repeated glycemic fluctuations generate inflammatory cytokines and cause endothelial dysfunction [25].

We hypothesized that preoperative carbohydrate loading may influence glucose variability and insulin resistance in diabetic patients. A previous study showed that diabetic patients exhibited peak glucose levels 60 min after consuming a carbohydrate drink, an interval twice as high as that in healthy subjects ($P<0.01$) [14]. Although the aforementioned study reported that this peak returned to baseline levels within 180 min, the corresponding results suggested that carbohydrate loading may increase glycemic variability in diabetic patients, similar to our findings. In our study, the administration of a preoperative carbohydrate drink to diabetic patients increased glucose levels preoperatively and did not prevent perioperative hypoglycemia. Glycemic variability also induces oxidative stress and neuroinflammation, resulting in dysfunctions in the central nervous system, endothelial cells, and blood–brain barrier, ultimately leading to neurovascular and cognitive dysfunctions [26]. Interestingly, in our study, delirium incidence was higher in the CHO group than in the control group. Delirium is a cognitive disturbance associated with neuroinflammation causing acute and intermittent impairment in attention and awareness [27]. Thus, increased glycemic variability may have influenced delirium incidence in the CHO group.

Several studies have reported that administrating a carbohydrate drink preoperatively reduces insulin resistance, whereas a prolonged fasting period

increases insulin resistance [7, 9, 28-30]. However, in our study, we observed that insulin resistance was higher in the CHO group than in the control group. Diabetic patients are presumed to have increased insulin resistance; thus, carbohydrate drink intake increases blood glucose levels and glycemic variability without lowering insulin resistance. FFAs are closely associated with insulin resistance and type 2 diabetes mellitus [31]. Although FFAs are important energy sources, particularly during fasting, abnormalities in FFA metabolism may contribute to the pathogenesis of atherosclerosis and cardiovascular diseases in patients with type 2 diabetes [31, 32]. In our study, the CHO group usually had lower FFA levels than the control group, but the proportion of patients with FFA levels above the normal upper limit was similar between both groups. Despite enrolling patients with well-managed diabetes (mean HbA1c, 6.6%), those who received a preoperative carbohydrate drink experienced little benefits compared with patients who fasted in terms of glucose variability and metabolic responses.

A previous study that included non-diabetic patients reported that preoperative carbohydrate drink consumption reduces the incidence of postoperative nausea and vomiting [33]. However, in our study, we observed no statistical difference in the incidence of postoperative nausea and vomiting between the two groups. Delayed gastric motility associated with diabetic autonomic neuropathy (gastroparesis), whose clinical symptoms include nausea and vomiting [34], may be correlated with this result. A study evaluating gastric emptying using ultrasonography in non-diabetic patients undergoing surgery determined that the gastric volume 2 h after consuming a 200-mL carbohydrate beverage was similar to that after consuming mineral water [35]. In our study, which only included diabetic patients, we observed a greater difference in gastric volume between both groups compared with that reported previously [14, 35]. This may be explained by the difference between the CHO group and control group in that the former drank 400 mL of a carbohydrate beverage,

while the latter fasted overnight. Interestingly, two patients from the CHO group who were excluded because of hyperglycemia had significantly large gastric volumes (>2.5 mL/kg) and high aspiration risks. The gastric emptying rate following a meal is a critical factor for maintaining adequate postprandial glucose levels [34]. Ingested food stimulates GLP-1 release, which slows gastric emptying. [34]. Among the two patients with large gastric volumes, one had elevated GLP-1 levels (8.19 pM). After excluding these patients, the final analysis demonstrated that the proportion of patients considered to be at a high risk of aspiration was similar between both groups. Therefore, although carbohydrate drink intake did not statistically increase aspiration risk, its use in diabetic patients still requires caution.

This study has some limitations. First, this study was conducted in a real perioperative condition. More than study volunteers, our participants were actual patients hospitalized for scheduled surgical procedures. Therefore, the 2–3-h interval between carbohydrate drink intake and gastric volume measurement was not uniform in all patients. Furthermore, patients often experience anxiety and agitation preoperatively. This emotional stress may have influenced gastric emptying and metabolic response processes [36]. Nonetheless, we could observe how carbohydrate drinks affected diabetic patients in actual clinical practice. Second, glucose levels were not measured simultaneously in all patients because of actual practice circumstances. Surgery is expected to greatly influence changes in glucose levels and metabolic response; thus, we set time points for measuring blood glucose levels according to surgery stages (start and end of surgery), similar to a previous study [37]. Considering that the maximum change in blood glucose levels after ingesting a carbohydrate drink occurred within 180 min [14], we deemed that changes in blood glucose levels were sufficiently observed in our study.

V. CONCLUSION

In conclusion, preoperative oral carbohydrate therapy increases glucose variability and insulin resistance in diabetic patients. Oral carbohydrate treatment should be administered cautiously to diabetic patients considering metabolic and safety aspects.

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ABSTRACT (IN KOREAN)

당뇨 환자에서 수술 전 탄수화물 음료 섭취가 혈당 변화에 미치는 영향

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서 성 민

Background: 수술 전 탄수화물 치료는 인슐린 저항성을 완화시키고 동화 상태로 대사를 변화시킨다. 이러한 수술 전 탄수화물 치료의 이점에도 불구하고, 수술 받는 당뇨 환자에 있어서는 혈당 조절의 손상과 위운동장애에 의한 흡인의 위험으로 탄수화물의 치료에 있어 우려가 있었다. 이 연구는 예정된 고관절, 무릎 관절성형술을 받는 당뇨환자를 대상으로 탄수화물 치료가 주술기 혈당 변동성과 대사 반응에 어떤 영향을 주는지 조사하는데 그 목표가 있다.

Methods: 2019년 8월부터 2020년 10월 사이에 50명의 당뇨환자들을 무작위로 대조군과 CHO 군에 배정하였다. CHO 군의 환자들은 마취 2~3시간 전 400 mL의 탄수화물 음료를 마셨다. 대조군 환자들은 수술 전 자정부터 경구 섭취가 제한되었다. 다섯 개의 시점에서 혈당을 측정하였다: 탄수화물 음료의 섭취 전, 척수 마취 전, 수술 시작 전, 수술 끝난 직후, 수술 1시간 경과 후. 인슐린과 유리 지방산 수치는 척수 마취

전 측정하였다.

Results: 혈당 변동성은 CHO군에서 대조군 보다 통계학적으로 유의하게 높았다(16.5% vs. 10.9%, p=0.008). 추가적으로 인슐린 저항성 또한 CHO군에서 대조군 보다 높았다(8.5 vs 2.7, p<0.001). 유리 지방산의 수치는 두 군 사이에 통계학적으로 유의한 차이는 보이지 않았다. (대조군 vs CHO군; 503 uEq/L vs 363 uEq/L, p=0.058).

Conclusion: 주술기 경구 탄수화물 음료 섭취는 당뇨환자에서 혈당 변동성과 인슐린 저항성을 증가시켰다. 당뇨환자에서 대사와 안전성을 고려하여 탄수화물 음료 섭취에 주의를 기울여야 한다.

핵심되는 말: 탄수화물, 당뇨, 혈당, 인슐린 저항성