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Brief Communication

Enhanced recovery after surgery: Preoperative carbohydrate loading and insulin management in type 2 diabetes

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HIGHLIGHTS

- Administering insulin prior to CHO-L is feasible.
- Insulin prior to CHO-L may attenuate hyperglycemia without risk of hypoglycemia.
- Key points to consider when administering insulin prior to CHO-L are discussed.
- An algorithm designed for non-specialty providers is provided.

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ABSTRACT

We assessed our institutional practice of individualized insulin dosing for patients with type 2 diabetes receiving preoperative carbohydrate loading (CHO-L) within an enhanced recovery after surgery (ERAS®) protocol. Patients enrolled in an ERAS® protocol with concomitant type 2 diabetes received rapid acting insulin (Novolog® [insulin aspart]) prior to 50 g CHO-L on the day of surgery. Following CHO-L and the administration of insulin, no hypoglycemic episodes occurred with preoperative POC glucose values between 6.8 and 12.3 mmol/L (123 and 221 mg/dL). Our experience demonstrates that administering rapid acting insulin prior to CHO-L in patients with type 2 diabetes is feasible and targets the potentially negative influence CHO-L may impose on preoperative glycemia in this population. Important considerations of this approach are highlighted and an insulin dosing algorithm designed for non-specialty providers is suggested.

Introduction

Significant interest regarding the optimal management of the perioperative period has led to the adoption of enhanced recovery after surgery (ERAS®) programs among many institutions. Patient nutritional status is an integral component of an ERAS® program. Experiments have demonstrated that even short periods of caloric deprivation, such as an overnight fast, can instigate an altered stress response [1]. In response to the potentially deleterious physiology of preoperative fasting, ERAS® protocols recommend to minimize fasting time and provide carbohydrate loading (CHO-L) of a clear low-osmolality beverage prior to surgery [2]. Entering surgery in the metabolically fed state has been shown to preserve glycogen reserve, reduce protein catabolism as well as postoperative insulin resistance [3].

A coinciding priority pertaining to the perioperative period is optimal glycemic control. Accordingly, CHO-L has largely been avoided in surgical patients with diabetes for several reasons including concern for instigating hyperglycemia and its barrage of associated complications on recovery [4]. To date, the incorporation of preoperative carbohydrate loading has largely been demonstrated in euglycemic patients [5].

Ultimately, the surgical patient with diabetes creates a unique challenge for two independently beneficial clinical practices, one for optimal perioperative glycemic control and another for providing the

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Table 1
Demographic and clinical characteristics of patients receiving insulin prior to CHO-L.

Variables	N	Median (IQR) or n (%)
Age (year)	100	63.5 (56.5–74)
BMI (kg/m^2)	94	31 (28–35)
Female gender	100	52 (52 %)
Race	99	
White		70 (70.7 %)
Black		13 (13.1 %)
Asian		6 (6.1 %)
Hispanic		8 (8.1 %)
Unknown		2 (2.0 %)
POC BG upon admission (mmol/L)	100	7.7 (6.5–9.0)
POC BG immediately prior to surgery mmol/L (mmol/L)	100	9.2 (6.8–12.3)
POC BG post-operative (mmol/L)	100	9.4 (7.8–10.7)
Dose of insulin prior to CHO-L (units)	100	2 (2–3)
*Correction dose prior to CHO-L (units)	100	0 (0–2)
Total CHO-L insulin dose (units)	100	2.5 (2–4)
$^+$HbA1c (%; mmol/mol)	90	6.9 (6.3–7.9); 52 (45–63)
Takes insulin at home	100	20 (20 %)
Insulin dose consistent with orders	99	99 (100 %)
Type of surgery	100	
Gyn-oncology		16 (16 %)
Colorectal		75 (75 %)
Pancreatic		7 (7 %)
Urologic		2 (2 %)

IQR: interquartile range = 25th–75th percentile.
BMI: body mass index; POC BG: point-of-care blood glucose.
To convert mmol/L to mg/dL multiple by 18.
$^+$Hemoglobin A1c (HbA1c) measurements ranged from 2 weeks preoperative to postoperative day 1.
*Standard correction scale:

POC BG (mmol/L)	POC BG (mg/dL)	Insulin (units)
<8.33	<150	0
8.38–11.10	151–200	2
11.15–13.87	201–250	4
13.93–16.65	251–300	6
16.70–19.42	301–350	8
≥19.48	>351	10

*Sensitive correction scale:

POC BG (mmol/L)	POC BG (mg/dL)	Insulin (units)
<8.33	<150	0
8.38–11.10	151–200	1
11.15–13.87	201–250	2
13.93–16.65	251–300	3
16.70–19.42	301–350	4
≥19.48	>351	5

CHO-L component of an ERAS® program. The objective of this analysis was to describe our institution's approach to CHO-L in a diabetes population while addressing the risk of preoperative hyperglycemia.

Methods

This is an Institutional Review Board approved retrospective chart review of patients with type 2 diabetes who received prandial insulin prior to CHO-L the morning of surgery at NYU Langone Hospital-Long Island.

Description of our clinical approach

Patients enrolled in an ERAS® protocol with concomitant type 2 diabetes were initially identified at preadmission testing. The age, weight, home anti-hyperglycemic medication regimen and renal function (assessed by creatinine values and estimated glomerular filtration rate) of each patient were reviewed with a dedicated endocrinologist. Insulin orders to be administered prior to CHO-L on the day of surgery were recommended to the surgical team and comprised of two components: a prandial dose of rapid acting insulin for CHO-L and a correctional dose of insulin for the existing blood glucose. The correctional scale was further delineated according to either a standard or sensitive scale (Table 1). Novolog® (insulin aspart) was used for both prandial and correctional insulin administration. The prandial and correctional insulin dosages were added together and given as one injection approximately 15 min prior to CHO-L. On the day of surgery, patients were instructed to arrive 3 h prior to surgery start time. Upon arrival, point-of-care glucose was obtained and patients were given the recommended dose of insulin prior to CHO-L which consisted of a 50 g carbohydrate containing ClearFast® beverage (12 oz).

Table 2
Patients with point-of-care blood glucose between 3.8 and 9.9 mmol/L (70–180 mg/dL).

	POC BG N (%)	95 % confidence interval
POC BG upon admission	81 (81 %)	72 %–88 %
POC BG immediately prior to surgery and after CHO-L with insulin	55 (55 %)	45 %–65 %
POC BG postoperative	63 (63 %)	53 %–72 %

POC BG: point-of-care blood glucose.

Description of chart review data analysis

Point-of-care blood glucose (POC BG) upon hospital arrival and prior to CHO-L, prior to surgery and postoperatively were analyzed. Demographic characteristics were summarized for the overall sample and presented using the median (interquartile range) or frequency (percentage) as appropriate based on the type and distribution of specific variables (Table 1). Continuous variables were assessed for normality using the Kolmogorov-Smirnov test, histogram, and Q-Q plot. The proportion of patients with POC BG >70 and POC BG between 70 and 180 was computed along with 95 % exact binomial confidence intervals. SAS® 9.4 software was used to conduct all analyses.

Results

One hundred patients were included in the analysis dating from May of 2015 until September 2019. The median age was 63.5. The majority of patients were white (52 % female) and either overweight (BMI >25 kg/m^2) or obese (BMI >30 kg/m^2). Colorectal surgery was the most represented type of surgery.

The cohort of patients evaluated within this pilot possessed a median HbA1c of 6.9 % (52 mmol/mol) with the majority receiving non-insulin outpatient regimens. The median glucose upon admission was below the threshold required for correctional insulin to be administered and 2.5 units of Novolog® was the median dose administered prior to CHO-L.

The proportion of patients with POC BG > 3.8 mmol/L (>70 mg/dL) and between 3.8 and 9.9 mmol/L (70–180 mg/dL) was computed along with 95 % exact binomial confidence intervals (Table 2). No patients incurred a hypoglycemic episode as a result of insulin that was administered prior to CHO-L.

Discussion

Patients with type 2 diabetes have not been rigorously evaluated and invariably excluded from receiving preoperative CHO-L. The 2018 Enhanced Recovery After Surgery Society Guidelines for perioperative care in elective colorectal surgery acknowledged that the evidence is too

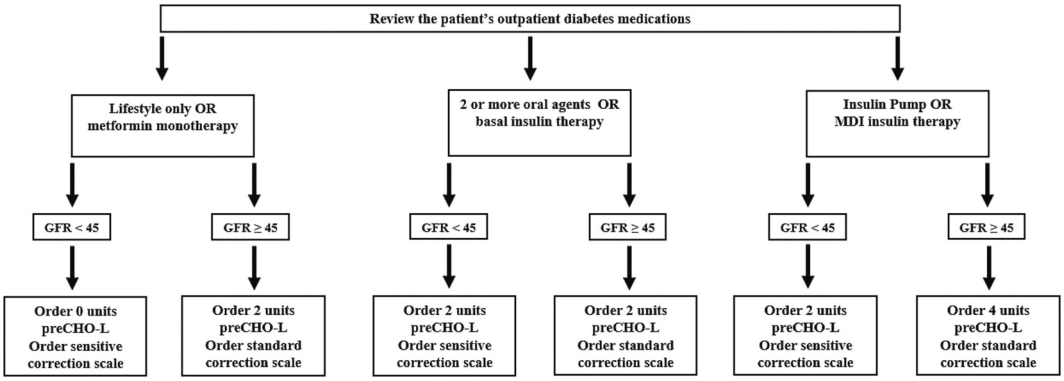

Fig. 1. Algorithm for insulin management prior to carbohydrate loading on the day of surgery.
MDI: multiple daily injection.

weak to allow routine recommendation of CHO-L in patients with diabetes [6]. To date, the Endocrine Society clinical practice guidelines for hospitalized adult patients offer a conditional recommendation against administering carbohydrate containing oral fluids preoperatively in all forms of diabetes [7].

Despite the paucity of high quality data to inform best practices, there is growing interest to clarify the actual risk-benefit analysis of CHO-L in a diabetes population. Several findings evaluating CHO-L and glucose in this population, albeit limited in scope, favor safety and effectiveness [8,9]. Our findings offer additional real-world glucose data for the surgical patient with well controlled type 2 diabetes receiving CHO-L. Several clinical implications were identified and are discussed further.

Risk of hypoglycemia

Insulin prior to CHO-L was rapid acting and administered approximately 180 min prior to scheduled procedure time. Nevertheless, patients with chronic kidney disease were included and were potentially susceptible to hypoglycemia due to delayed clearance of insulin. Given the numerous undesirable hemodynamic and neurologic perturbations associated with hypoglycemia [10], avoidance of hypoglycemia was set at the highest priority. Although all patients had type 2 diabetes, their relative insulin sensitivity varied significantly as evident in outpatient treatment regimens consisting of lifestyle modification to multiple daily insulin injections (MDI). For these reasons, the glucose-lowering effect of CHO-L insulin was difficult to predict. A conservative approach that consistently averted hypoglycemia was chosen.

Risk of hyperglycemia

A significant percentage of patient's (45 %) POC BG results were above our desired target glucose of 9.9 mmol/L (180 mg/dL) immediately prior to surgery despite insulin administration. This is likely a consequence of cautious insulin dosing; however, the glucose measurements were in context postprandial from the CHO-L. Additional data are needed; however, it would be reasonable to expect that an even higher percentage of patients would be exposed to preoperative hyperglycemia without such an intervention [9]. Our process focused on immediate preoperative glycemia in effort to address anticipatory hyperglycemia. This detail oriented and targeted approach was welcomed and subsequently facilitated the adoption of CHO-L in diabetes patients across multiple surgical specialties. Elective cardiac procedures have since been added to the participating surgical disciplines.

Integration of CHO-L insulin dosing algorithm

Our experience with endocrinologic input guided the development of an insulin dosing algorithm (Fig. 1) for use on the day of surgery. The patient's outpatient diabetes medication regimen and renal function were the most highly considered variables when ordering the insulin dose for CHO-L. The algorithm takes into account the intensity of outpatient treatment but did not address and is not intended to medically manage those medications. Following review of this pilot project, the proposed insulin management algorithm was approved by our Pharmacy and Therapeutics Committee and is currently managed autonomously by non-specialty providers at NYU Langone-Long Island. The net utility of this algorithm has not been determined; however, may serve as a clinical template to other institutions considering CHO-L for their patients with type 2 diabetes.

Limitations of findings

This proof of concept pilot project was intended to assess the feasibility of coordinating preoperative insulin orders prior to CHO-L for patients with diabetes throughout our institution. As such, no information surrounding the impact of CHO-L on clinical outcomes is provided. Although the preoperative glucose assessment suggests short term safety, more robust confirmatory data using this approach are needed. No episodes of intraoperative hypoglycemia were reported; however, intraoperative information pertaining to intravenous fluids, surgical time and intraoperative POC BG were not consistently collected for the purposes of this feasibility review. The evaluated cohort of patients had a median HbA1c of 6.9 % suggesting good glycemic control which may have limited the extent our intervention impacted glucose lowering. Our findings also do not address other forms of diabetes, namely type 1 diabetes, an inherently insulin sensitive state with an even higher likelihood for hypoglycemia.

Conclusion

Our experience suggests that administering prandial insulin prior to CHO-L for patients with type 2 diabetes is feasible and provides an insulin dosing template (Fig. 1) for other organizations. Although it is not possible to evaluate the clinical outcomes of this intervention, it is a step forward in addressing the use of CHO-L in this previously underrepresented population. Withholding the physiologic and psychologic benefits of CHO-L may not be necessary in this population. Rather, implementing a strategy that specifically addresses and may mitigate its potential hazards offers the patient with diabetes a tailored adaptation aimed for maximum benefit. Ultimately, randomized, prospective studies are necessary to quantify the impact of CHO-L on hyperglycemia in patients with type 2 diabetes and the potential role of prandial insulin.

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Ethical approval statement

Consent for this research was obtained by the NYU Langone Institutional Review Board (IRB: i20-00557).

CRediT authorship contribution statement

Cindy Bredefeld: Writing – review & editing, Writing – original draft, Data curation, Conceptualization. **Amy Patel:** Writing – review & editing. **Shahidul Islam:** Formal analysis. **Virginia Peragallo-Dittko:** Writing – review & editing, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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