Research Article

Gradual sucrose gastric loading test: A method for the prediction of nonsuccess gastric enteral feeding in critically ill surgical patients

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Abstract

Background and Aims: Intolerance of gastric enteral feeding (GEN) commonly occurs in surgical Intensive Care Unit (SICU). A liquid containing sugar could prolong gastric emptying time. This study was to propose a method for prediction of nonsuccess GEN using gastric volume after loading (GVAL) following gradual sucrose gastric loading. **Materials and Methods:** Mechanical ventilator supported and hemodynamically stable patients in SICU were enrolled. About 180–240 min before the GEN starting, a sucrose solution (12.5%; 450 mosmole/kg, 800 mL) was administered via gastric feeding tube over 30 min with 45° head upright position. GVAL was measured at 30, 60, 90, and 120 min after loading. GEN success status using clinical criteria was assessed at 72 h after the starting GEN protocol. The receiving operating characteristic (ROC) and c statistic were used for discrimination at each time point of GVAL. **Results:** A total of 32 patients were enrolled and completed the protocol. 14 patients (43.7%) were nonsuccessful GEN. The nonsuccess group was found to have significantly more GVAL than the other group at all-time points during the test ($P < 0.05$). The most discriminating point of GVAL for the prediction of nonsuccess was 150 mL at 120 min after loading with a sensitivity of 92.3%, specificity of 88.9%, positive predictive value of 85.7%, negative predictive value of 94.1%, and ROC area 0.97 (95% confidence interval 0.91–1.00). **Conclusion:** A high GVAL following sucrose gastric loading test might be a method to predict nonsuccess GEN in critically ill surgical patients.

Keywords: Critical illness, enteral nutrition, predictions, stomach contents, sucrose

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Introduction

Critically ill patients need an appropriate energy supply particularly in patients who were previously malnourished or elderly patients who had lower body reserves.[1] Postoperative patients are at a high risk of caloric deficit. Energy deficit during a period of critical illness could lead to worse outcomes and also increase infective complications. In addition, later energy provision does not alleviate these effects.[2] Although gastric enteral feeding (GEN) is a preferred option in Intensive Care Units (ICU), many mechanisms could potentially result in gastric dysmotility.[3] There are many proposed accurate methods for measurement of gastric emptying time including the scintigraphy, paracetamol absorption test, breath tests, refractometry, ultrasound, and gastric impedance monitoring.[4] However, because of method difficulties, one of the most popular and inexpensive test "poor man's test" for gastric emptying is the measurement of gastric residual volume (GRV).[5] In critically ill patients, a high GRV level is also related to disease severity and worse outcomes.[6]

In addition to the essential energy provision of carbohydrates, the osmolarity and fructose-containing carbohydrates could increase gastric emptying time.[7]

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In a high-risk situation of gastric contents aspiration, although intubation is required during anesthetic induction, preoperative drinking of 400 mL of oral carbohydrate treatment 150 min before the estimated time of surgery is safe.[8] In addition, the gastric retention could be estimated by a saline gastric load test in surgical practice.[9,10] A positive result was defined as gastric volume after loading (GVAL) >400 mL of saline 30 min after rapid administration of 750–800 mL.[9,10] Therefore, use of carbohydrate loading in critically ill patients might be a method allowing gastric emptying time estimation and prediction of GEN success as well as being a relatively harmless procedure.

To achieve the energy target particularly in malnourished patients and decrease the energy deficit, the European Society of Parenteral and Enteral Nutrition suggested that parenteral nutrition should be considered within 24–48 h in all patients who are not expected to be on normal nutrition within 3 days or if enteral feeding is contraindicated or intolerance.[11] On the other hand, routine regular GRV checking during enteral feeding is currently a controversial issue.[12] The prediction of nonsuccess GEN method might be a triage parameter for selection the patient who needs close monitoring. However, the prediction of common GEN nonsuccess is not well-estimated in clinical practices. Therefore, the objective of this study was to propose a method of GEN nonsuccess predictor at 72 h after GEN initiation using GVAL measurements after 12.5% sucrose gastric loading.

Materials and Methods

Study design and population

The study design was a delayed – cross-sectional diagnostic study in the surgical Intensive Care Units (SICU) at a university-based hospital in Thailand. Patients enrolled were those who needed enteral feeding via nasogastric (NG) or orogastric (OG) tube and required mechanical ventilator support for > 3 days between January 2011 and November 2012. An OG was inserted only if an NG tube was contra-indicated as in skull-based fracture and rhinorrhea. Patients excluded from the study were those who had unstable vital signs, needed inotropic or vasopressor drugs or had a prior gastrectomy. As there was no prior similar study, 33 patients were initially enrolled for a pilot study (one was excluded). The study flow was demonstrated in Figure 1. The Institute Ethics Committee approved this study (Study code SUR110701A13X).

Study protocol

This test was a prefeeding procedure. After informed patient consent had been secured, the patient's head was raised to 45° upright. An NG or OG (14 French) was inserted, and the position was checked by listening for an air blowing sound in the stomach. All remaining gastric contents were withdrawn. SICU nurses gradually fed 800 mL of 12.5% sucrose (12.5 g of sucrose per 100 mL; 450 mosmol/L) over 30 min via NG or OG (14 French) by feeding pump. For safety issues during the test, it was ensured that the head was elevated during the procedure. Abdominal symptoms including abdominal tenderness, distention, nausea, vomiting, patient discomfort, and aspiration were observed during the administration period. If these signs and symptoms occurred, the test was discontinued, and all gastric contents were withdrawn. A total GVAL was measured at 30, 60, 90, and 120 min, respectively. All viscous contents of the GVAL were returned after each time point. The test was performed by the same trained physician. All patients were fed on hospital prepared formula (1 calorie/mL concentration; Protein: Fat: Carbohydrate = 55:30:15%, respectively, nonprotein calories to gram nitrogen ratio = 133:1). Feeding was started between 180 and 240 min after loading test. This time period was the duration of enteral feeding preparation and transfer from hospital dietetic unit to the ICU. Blood glucose, blood urea nitrogen (BUN), creatinine (Cr), sodium and potassium levels were tested before and after loading.

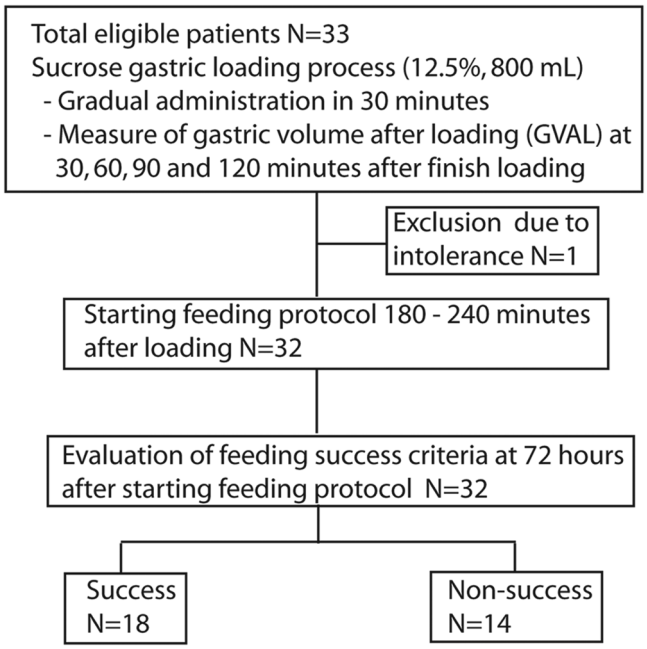


Figure 1: Study flow

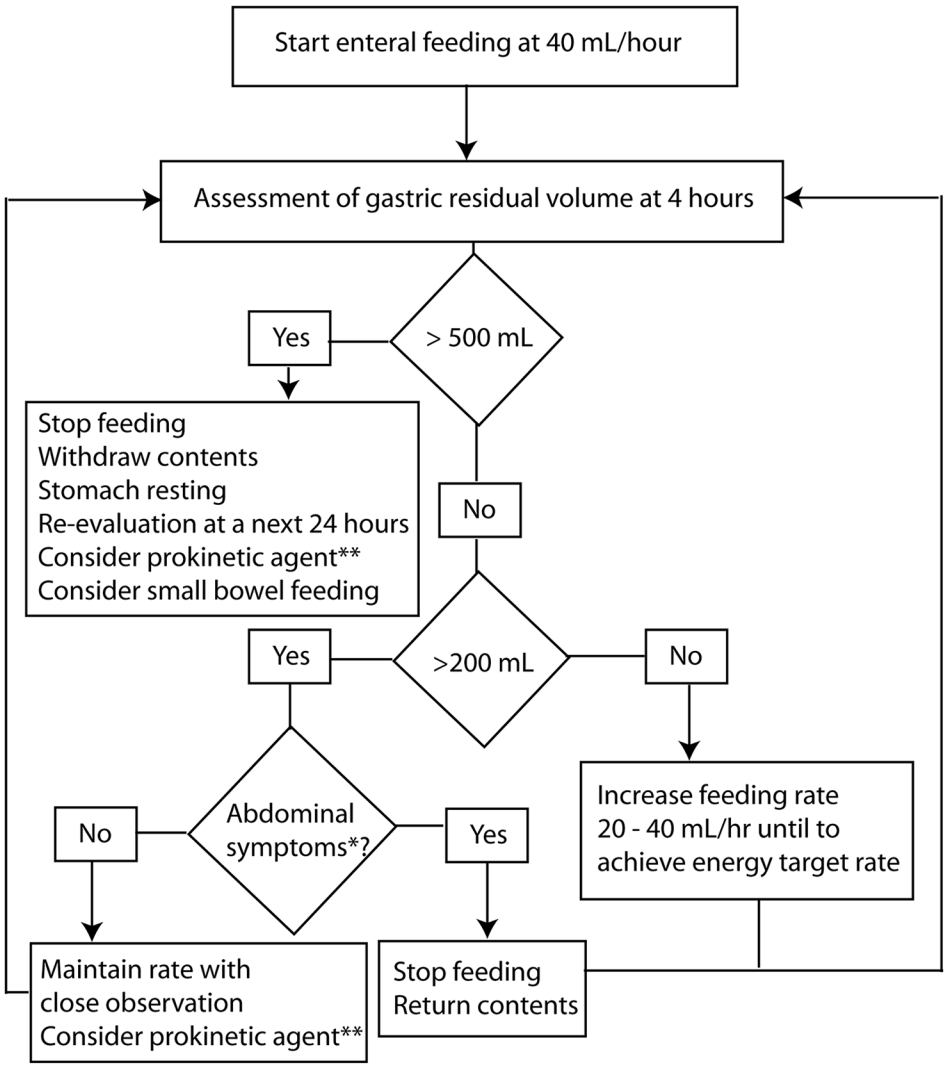
Feeding method and outcome measurement

All patients received the same standard hospital enteral formula and enteral feeding protocol. Prokinetic drugs were prohibited during the study period for

confounding factor prevention. The enteral feeding target was set by energy expenditure estimation recommendation (25–30 kcal/kg/day).[13] This estimation depended on patient status, the severity of disease, and attending intensivist's decision. Initially, the feeding rate was started at 40 mL/h continuously and increased progressively by 20–40 mL every 4 h if there were no signs and symptoms of feeding intolerance. Although the starting rate was slightly higher than the traditional feeding protocol in algorithms for critical-care enteral and parenteral therapy study at 25 mL/h, the recent of daily volume based PEP-up protocol in critically ill patient allowed the maximum rate up to 150 mL/h.[14,15] The feeding rate increased until the energy target was achieved. The detailing of feeding protocol and decision guideline in this study was demonstrated in Figure 2. The hospital enteral formula was changed to peptide-based formula or fiber-containing formula if patient developed diarrhea.[16] Feeding success at 72 h after starting GEN was defined as patients who could receive energy of ≥80% of the estimate required calories or target rate via the stomach route without abdominal symptoms.[11,14]

Data collection and statistical analysis

The demographic data, ICU admission details, acute physiologic and chronic health assessment evaluation II score (APACHE II), number of starving day before feeding, GVAL after the sucrose loading test at different times, calories per day that patients received at 72 h after starting feeding were collected. The data were analyzed by STATA software (version 11.0, STATA Inc., College Station, TX). Continuous variable data differences were tested using the Student's *t*-test for normal



*Abdominal symptoms including abdominal tenderness, distention, nausea, vomiting, or abdominal discomfort
**Prokinetic agent was prohibited during the study period

Figure 2: Gastric enteral feeding protocol and decision guideline

distribution data and reported as mean ± standard deviation or median (25–75 inter-quartile range [IQR]) for nonparametric distribution and tested with a Mann–Whitney U-test. For categorical variables, Pearson's Chi-square and Fisher's exact test were used. Differences between before and after laboratory testing values were tested using a paired *t*-test or Wilcoxon's sign rank based on their distribution. The authors considered receiver-operating characteristic (ROC) plots and ROC area or a c statistic for assessing test's discriminate ability to determine the optimal cut-off point of the independent variable (GVAL) for the prediction of GEN success. Hosmer – Lemeshow goodness of fit was tested for calibration between observation and the model at each time point. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) as well as the likelihood ratio were reported. The statistical significance of the differences was considered at $P < 0.05$.

Results

Thirty-three SICU patients were enrolled to initiate gastric loading. 1 patient vomited during the loading test and was excluded. The before testing median day (IQR) was performed in day 3 (2–4) after ICU admission. The remainder did not develop adverse events during the test, and all protocol measurements were completed, except 1 patient felt mild abdominal discomfort. Pulmonary complications including ventilator-associated pneumonia after the procedure did not occur in all enrolled patients. No alterations of hemodynamic parameters were observed during testing. Regarding patient demographic data and admission details in Table 1, 14 patients (43.7%) were unsuccessful with GEN according to the study definitions. 3 patients developed diarrhea, and the enteral formula was modified. There were no statistically significant differences ($P > 0.05$) between the nonsuccessful and successful groups regarding patient characteristics, including age, gender, body weight, height, body mass index, site of surgery, underlying diseases, SICU admission causes, nil by mouth reasons, energy requirement, and APACHE II score on the day of testing. Regarding the basic laboratory testing in Table 2, there was no difference in blood glucose level ($P = 0.73$), BUN ($P = 0.40$), creatinine ($P = 0.57$), sodium ($P = 0.70$), and potassium ($P = 0.27$) before and after sucrose loading. The median amounts of GVAL were statistically significantly different between the successful and nonsuccessful group [Table 3]. The predicted model of nonsuccess was fitted to every time point when they were tested by Hosmer – Lemeshow goodness of fit. ROC area increased over time, and the highest value was the

Table 1: Patient data before sucrose loading test

	All (*n*=32)	Success (*n*=18)	Nonsuccess (*n*=14)	*P*
Male (%)	24 (75.0)	14 (77.8)	10 (71.4)	0.68
Median age in years (IQR)	44.5 (32-52)	45 (27-48)	44 (36-53)	0.82
Mean body weight in kg (SD)	63.8 (9.2)	64.3 (9.0)	63.1 (9.8)	0.72
Mean height in cm (SD)	172 (6.6)	173 (6.1)	170 (6.8)	0.22
Mean BMI (SD)	21.6 (2.2)	21.5 (2.1)	21.8 (2.4)	0.69
APACHE II score (SD)	10.1 (2.8)	10.2 (2.8)	9.9 (2.9)	0.74
Trauma (%)	22 (68.8)	14 (77.8)	8 (57.1)	0.21
Underlying disease (%)				
Hypertension	7 (21.9)	4 (22.2)	3 (21.4)	0.96
Coronary artery disease	3 (9.4)	2 (11.1)	1 (7.1)	0.70
Chronic heart failure	1 (3.1)	0 (0)	1 (7.1)	0.25
Chronic lung disease	4 (12.5)	1 (5.6)	3 (21.4)	0.18
Diabetics	2 (6.3)	1 (5.6)	1 (7.1)	0.85
Malignancy	5 (15.6)	3 (16.7)	2 (14.3)	0.85
No underlying diseases	17 (53.1)	10 (55.6)	7 (50.0)	0.75
Site of surgery (%)				
Neurosurgery	7 (21.9)	6 (33.3)	1 (7.1)	0.10
Head and neck	3 (9.4)	2 (11.1)	1 (7.1)	
Thorax	5 (15.6)	3 (16.7)	2 (14.3)	
Abdomen	10 (31.3)	2 (11.1)	8 (57.1)	
Orthopedics	5 (6.3)	1 (5.6)	1 (7.1)	
None	5 (15.6)	4 (22.2)	1 (7.1)	
Cause of admission (%)				
Postoperation	18 (56.3)	11 (57.9)	7 (53.9)	0.37
Infections	8 (25.0)	3 (15.8)	5 (38.5)	
Respiratory failure	5 (15.6)	4 (21.1)	1 (7.7)	
Others	1 (3.1)	1 (5.3)	0 (0)	
Reason for NBM (%)				
Severe sepsis	3 (9.4)	0 (0)	3 (21.4)	0.17
Unstable HD	5 (15.6)	3 (15.8)	2 (14.3)	
Major operations	19 (59.4)	12 (63.2)	8 (57.1)	
Respiratory failure	5 (15.6)	4 (21.1)	1 (7.1)	
Mean energy requirement in kcal (SD)	1913 (275)	1930 (269)	1893 (293)	0.72

BMI: Body mass index; HD: Hemodynamic; IQR: Interquartile range; NBM: Nil by mouth; SD: Standard deviation; APACHE II score: Acute physiologic and chronic health assessment evaluation II score

Table 2: Serum laboratory results before and after sucrose loading test

Mean (SD)	Before	After	*P*
Glucose†	155.5 (44.2)	161.2 (49.7)	0.73
Urea nitrogen†	17.3 (8.8)	19.0 (13.9)	0.40
Creatinine‡	1.0 (0.5)	1.0 (0.6)	0.57
Sodium§	140.4 (4.5)	140.6 (3.9)	0.70
Potassium§	3.8 (0.6)	3.7 (0.5)	0.27

†mg/dL; ‡g/L; §mEq/L. SD: Standard deviation

Table 3: Median amount of GVAL and ROC area in each time point

Time point (min)	Gastric residual volume after sucrose gastric loading test (mL) (IQR)			*P*	ROC area (95% CI)
	All	Success	Nonsuccess		
At 30	317 (175-480)	235 (100-320)	480 (380-550)	<0.01	0.83 (0.68-0.98)
At 60	250 (80-370)	135 (50-250)	370 (300-440)	<0.01	0.88 (0.76-1.00)
At 90	195 (50-288)	80 (30-130)	288 (225-350)	<0.01	0.91 (0.80-1.00)
At 120	110 (20-200)	30 (10-60)	220 (170-355)	<0.01	0.97 (0.91-1.00)

CI: Confidence interval; GRV: Gastric residual volume after glucose gastric loading test; IQR: Inter-quartile range; ROC: Receiving operating characteristic; GVAL: Gastric volume after loading

measurement at 120 min after the sucrose gastric loading test (ROC area 0.98). These meant that the most accurate time of nonsuccessful GEN prediction using GVAL was measurement at 120 min [Figure 3].

Regarding the discrimination on considering ROC [Table 4 and Figure 1], the most appropriate cut-off point for nonsuccessful GVAL after sucrose loading at 30, 60, 90, and 120 min were 400, 300, 200, and 150 mL, respectively. Although, the median GVAL between groups was significant difference at all time points, at 120 min after sucrose loading with a cut-off point at least 150 mL yielded the highest likelihood ratio (9.5), sensitivity (92.3%), specificity (88.9%), PPV (85.7%), and NPV (94.1%). On hospital discharge, 1 patient died 3 weeks after an emergency aortic abdominal aneurysm repair and this condition was not associated with the study protocol.

Discussion

This study proposed a novel method for GEN nonsuccess prediction in critically ill patients. Although feeding via the jejunal route (percutaneous jejunostomy or nasojejunal tube) might increase the success rate for early enteral feeding due to jejunal peristalsis starting earlier than gastric peristalsis and could decrease septic complications after injury, these methods are not widely available especially in limited resource ICUs and also need skilled intervention in nonabdominal surgical patients.[17] Regarding testing method, although there were no previous methods using carbohydrate loading as detailed in this setting, there were some discussion points on the detail of loading the fluid. The concentration of the testing substance in this study was 12.5% sucrose solution (450 mosmol/kg). This was selected for following reasons. (1) This concentration was recommended for preoperative oral carbohydrate loading in abdominal surgery for enhanced patient recovery and (2) high osmolarity and disaccharide containing fructose-hexose solution could increase gastric emptying time.[7,18,19] For testing volume, the authors selected 800 mL of fluid because routine surgical gastric retention diagnostic testing with rapid saline load test utilized 750–800 mL, with the measurement of GVAL performed 30 min later.[9,10] However, rapid administration of saline load test might cause harm in a critically ill patient. Therefore, gradual feeding might alleviate complications. A slow load over 30 min was established in our protocol. Although this protocol was followed, 1 patient vomited during test. For this reason, the authors recommended that all patients should be closely observed during the test especially in patients who were heavily sedated or those who were paralyzed as well as who has defected on airway protective mechanism.

Table 4: Sensitivity, specificity, PPV, NPV, and LR of GVAL after sucrose loading in the most appropriate cut point of each aspirated time for prediction of nonsuccess feeding at 72 h

Cut point	Sensitivity	Specificity	PPV	NPV	LR+	LR−
At 30 min						
≥400 mL	71.4	83.3	76.9	78.9	4.28	0.34
At 60 min						
≥300 mL	76.9	83.3	76.9	83.3	4.61	0.28
At 90 min						
≥200 mL	84.6	77.8	73.3	87.5	3.81	0.20
At 120 min						
≥150 mL	92.3	88.9	85.7	94.1	8.31	0.09

LR+: Positive likelihood ratio; LR−: Negative likelihood ratio; PPV: Positive predictive value; NPV: Negative predictive value; GVAL: Gastric volume after loading

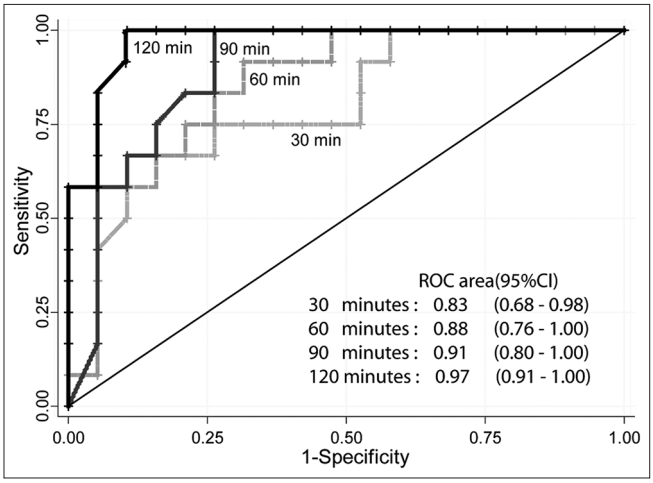


Figure 3: Receiver operating characteristic plots of gastric residual volume measurement at each time point for nonsuccessful enteral feeding at 72 h after sucrose gastric loading test

This study defined nonsuccessful GEN based on the attending intensivist's decision which depended on a combination of abdominal symptoms and receiving energy compared with targeted energy following the feeding protocol.[14,15]

The routine measurement of GRV is controversial, and this regular checking did not provide occurrence differences in pulmonary complications of critically ill patients.[12,21] However, disregarding GRV checking in intolerant patients particular in an ICU setting might lead to patient discomfort and suffering especially in

The prevalence of nonsuccessful GEN was 43.7% which was slightly lower than in the previous study which found 56% in trauma ICU patients.[20] The standard clinical criteria for nonsuccessful enteral feeding were inconsistent. Although the objective measurement of myoelectric activity of the bowel wall might be a better parameter for feeding success, it was unavailable and difficult to perform in a clinical study. Therefore, this

surgical ICU setting. In addition, increased GRV correlated with disease severity and patient outcomes.[6] Sucrose loading might be an alternative method for screening and triage patients who need close monitoring if GEN is initiated. The cut-off point of 150 mL at 120 min after sucrose loading showed the most appropriate sensitivity and specificity in this study. In addition, supplemental parenteral nutrition might be started early particularly in previously malnourished patients or small bowel feeding might be considered early if there is a high possibility of unsuccessful GEN. This strategy might decrease the energy deficit in these patients and result in decreased complications.[2]

The strength of this study was a new proposed method for screening of feeding nonsuccess in critically ill patients. However, there were some inevitable limitations. First, despite slightly higher levels of blood glucose at the postloading period, the blood sugar levels before and after sucrose loading did not show statistically significant differences. In addition, this phenomenon might have occurred from poor absorption of sucrose in nonsuccessful GEN patients. However, extrapolation of these results might be completed cautiously particularly in patients with underlying diabetic mellitus (DM) because only 6% of all enrolled patients had the previous history of DM. Second, all participating patients were surgical patients and hemodynamically stable patients. Using this method in medical ICU patients as well as patients needing high vasopressor requires further validation. Third, although there were no vital signs alterations in all tested patient including elderly patients, gastric distention might induce hypotension via vagal response. Therefore, this method should be used with caution and the testing volume might need to be reduced in frail patients. Forth, although there was no statistical significant difference on site of surgery, the distribution of nonsuccess GEN was not equally in all surgical types. The further validation in each subgroup should be performed in the future study. Finally, clinical outcomes especially nutritional statuses were not included in this study and the sample size on this pilot study was small. In addition, the strict criteria included in this study might not involve all spectrums of critically ill patients. Further pragmatic study using this test with a larger sample size for guiding GEN feeding should be performed. However, this pretest feeding might be a benefit on considering the appropriated nutritional treatment options and triage patients who need close monitoring during GEN.

Conclusion

The sucrose loading test might be a method to predict GEN success particularly using assessment of GVAL at 120 min with a cut-off point >150 mL.

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