Original Article

Effectiveness of the improved B-ultrasound method for measuring the antral section to guide enteral nutrition in patients with sepsis in a randomized controlled trial

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Background and Objectives: This study aimed to evaluate the application of the improved B-ultrasound method (hereafter referred to as B method) for measuring the antral section to evaluate gastric motility in guiding EN for patients with sepsis. **Methods and Study Design:** In this single-center, non-blinded, randomized controlled trial, 64 patients with sepsis were randomly enrolled from January 2018 to December 2019. The improved B method (study group) and physicians' clinical experience (control group) were used to guide EN. The two groups patients were separated randomly both. **Results:** Compared with the control group, the study group had a significantly shorter EN start time, faster initial rate of EN, lower incidence of EN interruption, and shorter Tmax (p<0.05,95% confidence intervals.) and exhibited lower incidences of adverse reactions (p<0.05). Kaplan–Meier survival analysis demonstrated that the study group exhibited significantly fewer adverse EN complications (p=0.029), shorter MV duration, and decreased ICU stay and in-hospital mortality (p<0.05). **Conclusions:** The improved B method could perform real-time monitoring of gastric function. Additionally, compared with the physician's personal clinical experience, the improved B method exhibits a better effect in guiding EN for patients with sepsis.

Key Words: improved B method, enteral nutrition (EN), sepsis, clinical, control group

INTRODUCTION

Sepsis is a major challenge in critical care medicine and is currently referred to as organ dysfunction caused by a dysregulated host response to infection that could endanger life.[1] The percentage of patients who develop sepsis and the mortality rate of patients with sepsis in intensive care units (ICUs) are 7%–19% and 20%–70%, respectively.[2-6]

Enteral nutrition (EN) has become the optimal nutritional support for patients with sepsis,[7] and timely enteral nutrition can dramatically improve the prognosis of severe patients.8 However, patients with sepsis normally develop gastrointestinal dysfunction at varying degrees. Hence, personalized EN should be developed for such critically ill patients.[8,9]

The accurate measurement of gastrointestinal function is very important for EN. Most physicians develop an EN plan for patients with sepsis using conventional gastrointestinal motility monitoring parameters such as auscultation for bowel sounds, observation of nausea, vomiting, abdominal distension, diarrhea and other EN intolerance, and the measurement of gastric residual amount by gastric tube extraction. However, these above approaches are traditional, imprecise, and rely on the personal experience of physicians. With the development of ultrasound and intensive care technology, some medical institutions use the improved B-ultrasound method (hereafter referred to as B method) to guide EN for critically ill patients.[10] However, ever, at present, there have been no reports on the value of the improved B method for measuring the antral section in EN for patients with sepsis.

This study aimed to confirm if measurement of the antral section by the improved B method provides individualized EN plans and improves the prognosis of patient with sepsis compared with the clinical experience of physicians.

METHODS

Study design and ethics

This was a single-center, non-blinded, randomized controlled trial. The study was approved by the institutional review board of the First Affiliated Hospital of Xi'an Jiaotong University, and all patients provided informed consent. The study was conducted according to the tenets

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Manuscript received 22 December 2020. Initial review and accepted 08 January 2021.
doi:

of the Declaration of Helsinki and Good Clinical Practice guidelines.

Patient selection and group design

Patients who were admitted to the Department of Critical Care Medicine in our tertiary-care university-affiliated hospital from January 2018 to December 2019 were assessed for possible enrollment according to the inclusion and exclusion criteria. The inclusion criteria were as follows: (1) patients with sepsis (Sepsis-3 definition) and (2) patients planned for EN through nasogastric tube. The exclusion criteria were as follows: (1) age <18 years; (2) hemodynamic instability; (3) patients who underwent gastrectomy; (4) patients who could undergo gastrointestinal perfusion; and (5) patients with flatulence who could not be observed via ultrasonography.

Patients were divided into the study and control groups using the random number table method. In total, 64 patients were qualified for inclusion, with 31 and 33 patients in the study and control groups, respectively (Figure 1).

Intervention

The patients in the study group were treated with the improved B method for measuring the antral section to determine gastric residual volume (GRV) and gastric antral movement index (MI). The Siemens portable B-ultrasound machine (Acuson Cypress, Germany) was

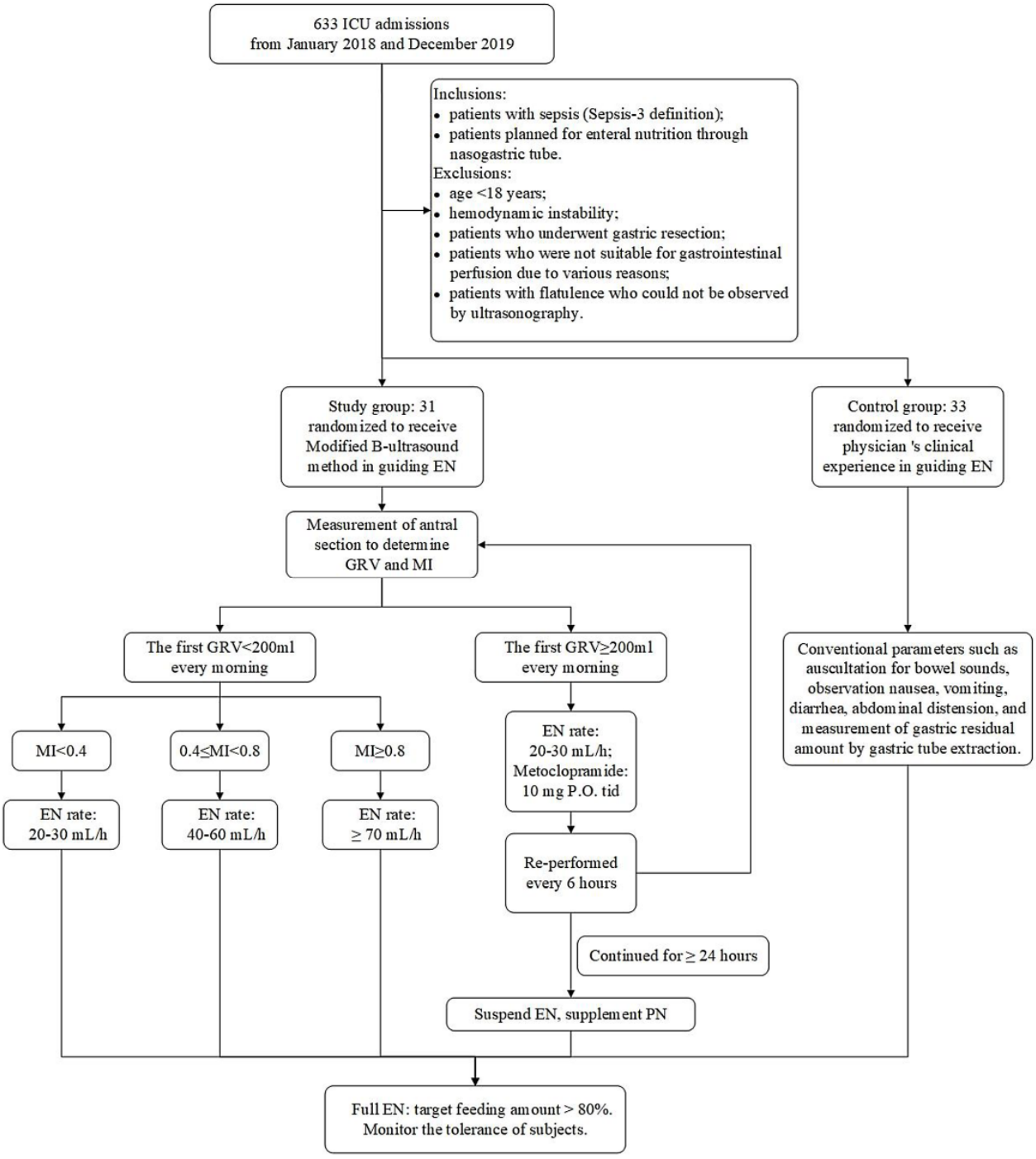

Figure 1. Flow diagram depicting patient selection and nutrition feeding protocols. EN: enteral nutrition; GRV: gastric residual volume; MI: gastric antral movement index; PN: parenteral nutrition.

applied to evaluate gastric function in 31 study subjects.

Indexes assessed by the improved B method involved fasting antrum area (AA), antrum contraction frequency (ACF), and three consecutive maximum antrum relaxation areas and minimum antrum contraction areas (Srel and Scon). On the basis of these data, the following formulas can be calculated:[10,11] GRV = 27.0 + 14.6 × Right-latCSA − 1.28 × age (Right-latCSA, fasting AA in the right lateral position [cm2], age (years]); antrum contraction frequency (ACF) = antrum contraction times within 6 min following gastric filling/3; ΔS = Srel − Scon; antrum contraction amplitude (ACA) = ΔS/Srel; and antrum motility index (MI) = ACF × ACA.

Examination method: Patients were fasted for 8 h and gastric function was evaluated through the improved B method. Patients were injected with 0.3 L of warm water at 37 °C–42 °C within 2 min through the gastric tube in the right lateral position. Gastric indexes were determined afterward.

Nutrition Plan: As per the Parenteral and Enteral Nutrition guidelines of American Society,[12] EN was conducted as follows: the objective feeding amount was 25~30 kcal/(kg•d); EN rate depended on patient's GRV and MI; and gastric function was examined every morning. If the first GRV <200 mL every morning during the study,[13] when MI <0.4, EN rate was limited to 25±5 mL/h; when 0.4 ≤ MI＜0.8, EN rate was 50±10 mL/h; and when MI ≥0.8, EN rate was ≥70 mL/h. If the first GRV ≥200 ml every morning during the study, EN rate was limited to 25±5 mL/h and the patient was given metoclopramide 10 mg three times a day. Then, the improved B-ultrasound method was performed every 6 hours; if GRV was still >200 ml after 24 hours, EN was suspended and parenteral nutrition (PN) would begin. Further, when the objective feeding amount was >80%, full EN could be realized. In the course of EN, the patients' tolerance was accurately detected.

EN for the control group was developed according to the clinical experience of the physician.

Data collection

Demographic and clinical data including age; gender; body mass index (BMI); Acute Physiology and Chronic Health Evaluation (APACHE) II score; Sequential Organ Failure Assessment (SOFA) score; infection site; prevalence of diabetes and blood glucose level; use of vasoactive drugs, analgesics, and sedatives; and use of mechanical ventilation (MV) were collected. The APACHE II and SOFA scores were determined using the worst values measured within the initial 24 hours after ICU admission. Infection sites were categorized as respiratory, intra-abdominal, urinary tract, other, and multiple.[14] Biochemical variables, including white blood cell and platelet counts and levels of hematocrit, alanine transaminase, albumin, and lactate, were measured at initial presentation. Moreover, the following clinical endpoints were collected: implementation of EN including EN start time, initial rate of EN, interruption of EN, Tmax, and EN-relevant adverse complications. Prognostic indexes including MV duration, ICU stay length, in-hospital mortality, and 30-day mortality were also collected. In addition, mortality data were acquired from medical records and/or telephone conversations with the patient or his/her relatives.

Statistics

Statistical analyses were performed using SPSS 25.0. $p<0.05$ indicated statistical significance, and all tests were two sided. Continuous variables were expressed as average ± standard deviation (SD), skewed data were expressed as median and IQR and categorical variables were presented as n (%). The study and control groups were compared in terms of normally distributed continuous variables using independent sample t-tests, abnormally distributed continuous variables using rank sum test, and categorical variables using Chi-squared test. Kaplan–Meier survival curves were plotted, and log-rank test was used to analyze intergroup differences among EN complications.

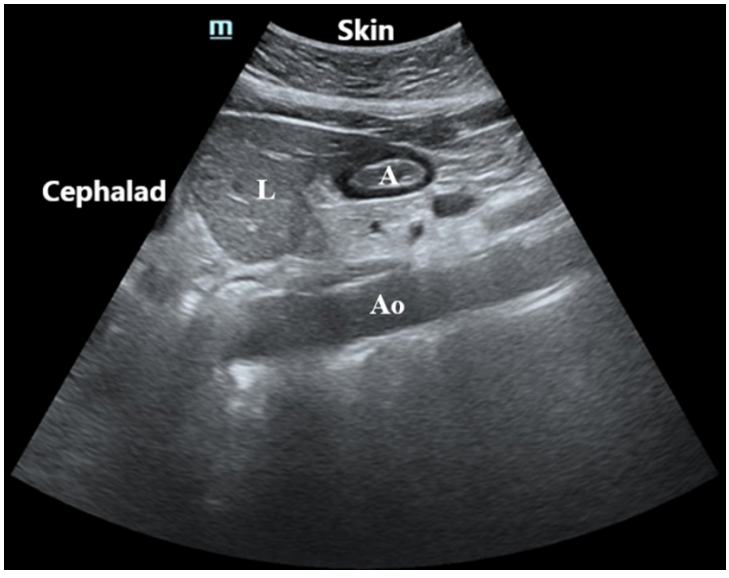

Figure 2. Ultrasound measurement of the antral section. A = gastric antrum; L = liver; Ao = aorta.

RESULTS

In total, 64 patients were included in the study, with 31 and 33 in the study and control groups, respectively (Figure 1). The antral section was measured after ultrasound imaging displayed the left lobe of the liver, superior mesenteric vein, and abdominal aorta (Figure 2).

Differences in demographic, clinical, and biochemical data between the groups

The demographic, clinical, and biochemical data of patients in each group are presented in Table 1. Mean patient age was 55.34±14.17 years, and 57.8% of patients were male. The average BMI was 22.81±4.21 kg/m^2. The average SOFA and APACHE II scores were 8.36±2.63 and 16.14±3.79, respectively. Infection sites were categorized as multiple, respiratory, and intra-abdominal in 45.3%, 25.0%, and 10.9% of patients, respectively. The prevalence of diabetes mellitus was 29.7%. The mean blood glucose level was 8.53±81.36 mmol/L. In total, 60.9%, 43.8%, and 43.8% of patients received vasoactive drugs, analgesics, and sedatives, respectively. The utilization of MV was 42.2%. As shown in Table 1, the two groups did not significantly differ in terms of demographic, clinical, or biochemical data.

Table 1. Differences in demographic, clinical, biochemical and nutritional data between the study and control groups[†]

	Total (n=64)	Study group (n=31)	Control group (n=33)	*p* value[‡]
Demographic and clinical data				
Age (y)	55.3±14.2	54.3±16.7	56.3±11.5	0.59
Male (%)	37 (57.8%)	17 (54.8%)	20 (60.6%)	0.64
BMI (kg/m^2)	22.8±4.21	23.5±4.02	22.2±4.36	0.24
APACHE II score	16.1±3.79	15.9±3.51	16.4±4.07	0.63
SOFA score	8.36±2.63	8.05±2.01	8.66±3.11	0.35
Infection site				0.49
Respiratory	16 (25.0%)	6 (19.4%)	10 (30.3%)	
Intra-abdominal	7 (10.9%)	4 (12.9%)	3 (9.1%)	
Urinary tract	5 (7.8%)	2 (6.5%)	3 (9.1%)	
Other	7 (10.9%)	2 (6.5%)	5 (15.2%)	
Multiple	29 (45.3%)	17 (54.8%)	12 (36.4%)	
Prevalence of DM	19 (29.7%)	11 (35.5%)	8 (24.2%)	0.33
Blood glucose level (mmol/L)	8.53±1.36	8.72±1.27	8.36±1.44	0.29
Drugs that affect gastrointestinal function (%)				
Vasoactive drugs	39 (60.9%)	20 (64.5%)	19 (57.6%)	0.57
Analgesics	28 (43.8%)	12 (38.7%)	16 (48.5%)	0.43
Sedatives	28 (43.8%)	11 (35.5%)	17 (51.5%)	0.20
Use of MV	27 (42.2%)	14 (45.2%)	13 (39.4%)	0.64
Biochemical data				
WBCs (10^9/L)	14.2±9.93	13.8±8.85	14.6±11.0	0.74
Platelets (10^9/L)	124±114	119±97.4	130±129	0.70
Hematocrit (%)	28.4±7.87	29.3±7.57	27.5±8.16	0.36
ALT (U/L)	132±178	145±155	118±198	0.54
Albumin (g/L)	26.4±5.55	25.8±5.89	26.9±5.23	0.40
Lactate (mmol/L)	2.80±1.86	2.57±2.05	3.01±1.67	0.35
Nutritional data				
NUTRIC score	4.93±2.05	4.72±2.21	5.13±1.89	0.43
Hemoglobin (g/L)	105±27.9	109±24.1	100±30.9	0.22
Albumin (g/L)	26.4±5.55	25.8±5.89	26.9±5.23	0.40
Prealbumin (mg/L)	145±72.4	138±68.9	152±76.1	0.46

BMI: body mass index; APACHE: Acute Physiology and Chronic Health Evaluation; SOFA: Sequential Organ Failure Assessment; RRT: renal replacement therapy; DM: diabetes mellitus; MV: mechanical ventilation; WBC: white blood cell; ALT: alanine transaminase; NUTRIC: NUTrition Risk in the Critically ill.

[†]Results were presented as average ± standard deviation or n (%).

[‡]*p* values were obtained by comparing the two groups using independent sample t-tests, rank sum test, or Chi-squared test.

Table 2. Enteral nutrition implementation in the study and control groups[†]

	Study group (n=31)	Control group (n=33)	*p*[‡]
EN start time (hours)	28.5±21.8	41.5±27.7	0.041
Initial rate of EN (mL/h)	39.8±14.2	31.2±11.6	0.011
Interruption of EN	1 (3.2%)	7 (21.2%)	0.030
Time required to reach the maximum feeding rate (days)	3.3±1.5	4.3±1.9	0.022

EN: enteral nutrition. Interruption of EN was indicated as long as EN infusion was interrupted: and it was recorded as one case: irrespective of the number or duration of interruptions that occurred in each patient.

[†]Results were presented as average ± standard deviation or n (%).

[‡]*p* values were obtained by comparing the two groups using independent sample t-tests, rank sum test, or Chi-squared test.

Table 3. Comparison of EN-related adverse reactions between the two groups†

	Study group (n=31)	Control group (n=33)	p‡
Reflux	1 (3.2%)	8 (24.2%)	0.016
New-onset pneumonia	1 (3.2%)	7 (21.2%)	0.030
Vomiting	2 (6.5%)	5 (15.2%)	0.265
Diarrhea	2 (6.5%)	9 (27.3%)	0.027
Abdominal distension	3 (9.7%)	10 (30.3%)	0.040

EN: enteral nutrition.
†Results were presented as n (%).
‡p values were obtained by comparing the two groups using Chi-squared test.

Table 4. Comparison of prognosis between the two groups†

	Study group (n=31)	Control group (n=33)	p‡
Duration of MV (hours)	39.3±60.7	79.8±89.9	0.038
Length of ICU stay (days)	6.01±4.77	9.26±6.69	0.029
In-hospital mortality	3 (9.7%)	10 (30.3%)	0.040
30-day mortality	5 (16.1%)	11(33.3%)	0.112

MV: mechanical ventilation; ICU: intensive care unit.
†Results were presented as average ± standard deviation or n (%).
‡p values were obtained by comparing the two groups using independent sample t-tests, rank sum test, or Chi-squared test.

Difference in EN implementation between study and control groups

The study and control groups were compared in terms of EN start time, initial rate of EN, interruption of EN, and Tmax. As shown in Table 2, the study group had a significantly shorter EN start time, faster initial rate of EN, lower incidence of EN interruption, and shorter time to reach the maximum feeding rate (p<0.05 for all).

Difference in EN-related adverse reactions between the two groups

Table 3 shows the adverse reactions occurring during EN. Compared with the control group, the study group had lower incidences of new-onset pneumonia, reflux, diarrhea, and abdominal distension (p<0.05). However, the two groups did not significantly differ in terms of vomiting. Kaplan–Meier survival curves demonstrate that the improved B method dramatically reduced adverse reactions during EN (p=0.029) (Figure 3).

Difference in EN-related adverse reactions prognoses between the study and control groups

In Table 4, the MV duration in the study and control groups was 39.3±60.7 and 79.8±89.9 hours, respectively. Independent sample t-test analysis demonstrated that compared with the control group, the study group had a significantly shorter MV duration (p<0.05). The length of ICU stay in the study and control groups was 6.01±4.77 and 9.26±6.69 days, respectively, and it was significantly shorter in the study group (p<0.05). In-hospital mortality in the study and control groups was 9.7% and 30.3%, respectively, and it significantly differed between the groups (p<0.05). In addition, 30-day mortality in the study and control groups was 16.1% and 33.3%, respectively, but the two groups exhibited no significant differences in 30-day mortality.

DISCUSSION

In critically ill patients, including patients with sepsis who cannot resume oral food intake, artificial nutrition has become a primary intervention method. It is exten-

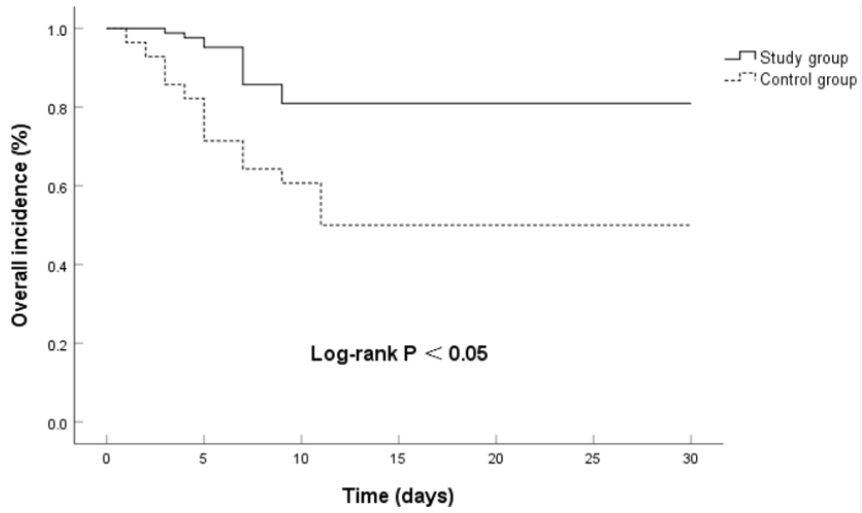

Figure 3. Difference in EN complications between the study and control groups. Groups were compared using log-rank test (p< 0.05). EN: enteral nutrition.

sively agreed upon by international nutrition guidance that early EN should be the first choice of intervention after ICU admission for patients without absolute EN contraindications.[12,15] A multicenter survey including 26 European hospitals found that patients who underwent optimal nutritional support exhibited better physical conditions.[16,17] However, the success of EN to positively change clinical results depends on GI tract function. Therefore, to develop a personalized EN scheme for patient recovery, real-time monitoring of gastric function is warranted.

In the present study, the study group exhibited a significantly shorter EN start time, faster initial rate of EN, lower incidence of EN interruption, and shorter Tmax. These results are likely because the improved B method is capable of evaluating the GI function of a patient with sepsis and is beneficial for the precise control of EN rate by clinicians. Consequently, the incidences of some adverse EN complications were significantly lower, and Kaplan–Meier survival curves indicated that the EN complications in patients with sepsis were significantly less. Patients in the study group exhibited a significantly better recovery, shorter MV durations and ICU stays, and lower in-hospital mortality. Personalized EN therapy stratifies patients according to GI function throughout the course of sepsis, and the improved B method is a good process to detect GI function.

The conventional gastrointestinal motility monitoring used in the ICU includes auscultation of the abdomen to assess bowel sounds; observation of intestinal nutritional intolerance such as nausea, vomiting, abdominal distension and diarrhea; and the measurement of gastric residual amount by gastric tube extraction. However, the use of these methods to evaluate patients' gastric motility and inform the EN plan is subjective and imprecise.

Moreover, there are many influencing factors for the measurement of gastric residue via gastric tube extraction such as the depth, position, diameter, number of openings of the gastric tube and whether the gastric tube is obstructed or not.[18] If the gastric tube is introduced too shallowly and the determined remaining gastric volume is too small, an excessively high EN rate can result and lead to a series of adverse reactions. Conversely, if the gastric tube is inserted too deeply, the gastric mucosa would be damaged. The 2016 guidelines of the American College of Critical Care Medicine and the American Society for Enteral and Parenteral Nutrition do not recommend the traditional gastric tube reflux method for determining gastric residue as an indicator to determine the tolerance of EN.[12] Therefore, a more effective method of gastrointestinal motility monitoring is urgently needed by ICU physicians.

B-ultrasound devices are miniature and portable, and several medical institutions take advantage of B-ultrasound to measure the antral section.[19,20] However, the conventional method needs patients to stay in a standing position while drinking 0.5 L liquid, which is difficult in case of critically ill patients.[21,22] Therefore, in this work, the improved B method was applied,[10] wherein patients had to stay in the right lateral position to fill the gastric cavity with 0.3 L fluid; real-time monitoring of gastrointestinal motility was performed, with the aim to provide personalized EN to patients with sepsis.

Study limitations

The limitations of this study are as follows. First, all ultrasonographic measurements were performed by a single operator, which can create measurement bias. Second, the differences in physicians' personal clinical experience are prone to subjective bias in guiding EN. Third, this study was limited to a relatively short-term clinical outcome, and further studies are required to assess the effect of the improved B method as an EN guiding method for long-term (3-month, 6-month, or 1-year) clinical events in sepsis. Fourth, this study was prone to selection and information bias owing to its single-center design and relatively small sample size. Therefore, multicenter studies are required to confirm the value of the improved B method for measuring the antral section during EN in patients with sepsis.

Our study showed that compared with the physician's personal clinical experience, the improved B method can effectively inform EN implementation for patients with sepsis, reduce the incidence of EN complications, and improve prognosis of patients with sepsis according to the objective indicators of gastrointestinal function provided by ultrasound. These findings may reflect that the improved B method is efficient for informing the EN plans of patients with sepsis. In conclusion, the improved B method for measuring the antral section shows a good effect in guiding EN for patients with sepsis.

CONFLICT OF INTEREST AND FUNDING DISCLOSURES

The authors declare that there is no conflict of interest.

This study was supported by the general new medical and new technology award of the first affiliated hospital of Xi'an Jiaotong university in 2020 (XJYFY-2020N28), the National Nature Science Foundation of China (Grant No. 82070549), the Dr. Li Jieshou (Academician of CAS) Research Fund for Intestinal Barrier (LJS-201801), and the clinical research award of the first affiliated hospital of Xi'an Jiaotong university (No. XJTU1AF-CRF-2019-016).

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