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*Original Article*

# Application of point-of-care ultrasound in monitoring gastric residual volume in neurosurgical critical patients with enteral nutrition support

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**Abstract:** Objective: The aim of the current study was to explore the feasibility and value of point-of-care ultrasound (POCUS) in monitoring gastric residual volume (GRV) in neurosurgical critical patients with enteral nutrition (EN) support. Methods: A total of 72 neurosurgical critical patients, newly admitted to the Intensive Care Unit (ICU) and requiring EN support treatment, were collected and randomly divided into two groups, according to random number table. Groups included the POCUS monitoring GRV group (study group) and gastric juice withdrawal monitoring GRV group (control group), with 36 cases each. Nasogastric tubes were indwelled in patients of the two groups. Fresubin nutrition fluid was injected with a nutrient pump for 18 hours per day, according to the target feeding quantity, and adjusted by the detected GRV. After 7 consecutive days of observation, tolerance to EN, feeding interruption rates, the number of TEN total enteral nutrition (TEN), and average daily EN fluid volumes, prealbumin, and albumin levels, as well as prognosis, were compared. Results: During the observation period, incidence of reflux and aspiration in the study group was significantly lower than that in the control group, with values of (8.3% vs. 27.8%, $P$=0.032) and (2.8% vs. 16.7%, $P$=0.047). There were no significant differences in incidence of diarrhea and feeding interruption between the two groups ($P$>0.05). The number of TEN and average daily EN liquid volumes in the study group were significantly higher than those in the control group, with values of (88.9% vs. 69.4%, $P$=0.042) and (946.4±290.2 (mL/d) vs. 806.8±233.1 (mL/d), $P$=0.028). Levels of albumin and prealbumin in the study group were significantly higher than those in the control group, with values of (31.7±4.6 (g/L) vs. 28.8±4.2 (g/L), $P$ = 0.032) and (205.7±29.9 (mg/L) vs. 190.1±27.1 (mg/L), $P$=0.017). There were no significant differences in incidence of ventilator-associated pneumonia (VAP), ICU stays, and in-hospital mortality rates between the two groups ($P$>0.05). Conclusion: Monitoring gastric residual volume (GRV) with point-of-care ultrasound (POCUS), guiding enteral nutrition (EN) support, can effectively reduce occurrence of reflux and aspiration and increase intake of EN. Therefore, this method is worthy of promotion.

**Keywords:** Enteral nutrition, gastric residual volume, point-of-care ultrasound, neurosurgical critical disease

## Introduction

Enteral nutrition (EN) has been widely used in clinic because of its safety, efficiency, and physiology. Early EN can decrease incidence of infections, shorten ICU stays, and lower medical costs and mortality rates of critically ill patients [1, 2]. Neurosurgical critical patients often have different degrees of gastrointestinal dysfunction. They are prone to gastric retention, which can increase occurrence of gastrointestinal intolerance, including regurgitation, aspiration, diarrhea. It can affect the efficacy of EN therapy [3]. Therefore, dynamic monitoring of gastric residual volume (GRV) is particularly important in critically ill patients with EN support [4]. At present, the method of gastric juice withdrawal is widely used in clinical practice to monitor GRV, adjusting the implementation of EN. However, it has a complicated operation, affects the accuracy of GRV, and causes abdominal distension, excessive GRV, increased incidence of reflux, and other complications [5]. A simple, convenient, and noninvasive method, point-of-care ultrasound (POCUS) has been used in the localization of nasal-gastrointestinal

**Table 1.** Comparison of basic data between the two groups

| Clinical data | Study group (n=36) | Control group (n=36) | *P* value |
|---|---|---|---|
| Gender case (%) | | | 0.458 |
| Male | 25 (69.4) | 22 (61.1) | |
| Female | 11 (30.6) | 14 (38.9) | |
| Age (year) | 54.4±11.5 | 55.1±12.3 | 0.552 |
| APACHE II score (score) | 21.0 (18.5, 23.0) | 21.5 (19.0, 24.0) | 0.281 |
| GCS score (score) | 9.5±1.9 | 9.1±1.7 | 0.534 |
| BMI (kg/m$^2$) | 21.3±2.4 | 22.2±2.8 | 0.881 |
| Prealbumin (mg/L) | 198.5±28.8 | 194.1±27.9 | 0.661 |
| Serum albumin (g/L) | 30.2±5.3 | 30.8±5.5 | 0.762 |
| Vasoactive agents case (%) | | | 0.345 |
| Use | 21 (58.3) | 19 (52.8) | |
| Non-use | 15 (41.7) | 17 (47.2) | |
| Mechanical ventilation case (%) | | | 0.465 |
| Use | 24 (66.7) | 21 (58.3) | |
| Non-use | 12 (33.3) | 15 (41.7) | |
| Incidence causes case (%) | | | 0.914 |
| Traumatic brain injury | 19 (52.8) | 21 (58.3) | |
| Spontaneous intracerebral hemorrhage | 8 (22.2) | 5 (13.9) | |
| Spontaneous subarachnoid hemorrhage | 5 (13.8) | 4 (11.1) | |
| Intracranial tumor | 2 (5.6) | 4 (11.1) | |
| Intracranial aneurysm | 2 (5.6) | 2 (5.6) | |

tubes and the determination of antral motility indexes during the implementation of EN in ICU patients [6-8]. The purpose of this study was to investigate the feasibility and value of POCUS in monitoring GRV, guiding the implementation of EN in neural critically ill patients.

## Materials and methods

### *General data*

A total of 72 neurosurgical critical patients, newly admitted to the ICU of Taizhou Integrated Chinese and Western Medicine Hospital and requiring EN support treatment, were collected and randomly divided into two groups, according to a random number table. Groups included the POCUS monitoring GRV group (study group) and gastric juice withdrawal monitoring GRV group (control group), with 36 cases each. There were 40 cases of traumatic brain injury (TBI), 13 cases of spontaneous intracerebral hemorrhages (SICH), 9 cases of spontaneous subarachnoid hemorrhage (SAH), 6 cases of intracranial tumors (ICT), and 4 cases of intracranial aneurysms in patients enrolled. There were no significant differences between the two groups concerning general data, including gender, age, acute physiology and chronic health evaluation (APACHE II) scores, Glasgow coma scale (GCS) scores, body mass index (BMI), prealbumin, serum albumin, outcomes of the use of mechanical ventilation, and vasoactive agents (P>0.05) (**Table 1**).

Inclusion criteria: Critically ill patients diagnosed with nervous system diseases; Patients that could not eat and required indwelling nasogastric tubes for EN [9].

Exclusion criteria: Patients with restricted ultrasound observations of single-section of gastric sinuses due to various causes (obesity, flatulence, abdominal radiotherapy); Patients with a previous history of gastrointestinal surgery, gastrointestinal neoplasms, peptic ulcers, and other gastrointestinal diseases; Patients under the age of 18; Patients with contraindications to EN that could not implement EN in 3 days [10]; Patients with families refusing to participate.

The current study was approved by the Ethical Review Committee. Informed consent was obtained from all patients and guardians.

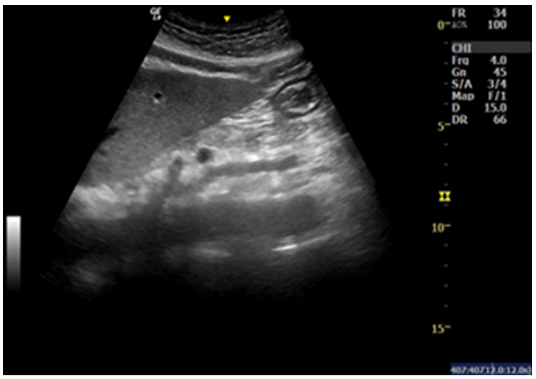

**Figure 1.** Gastric sinus development.

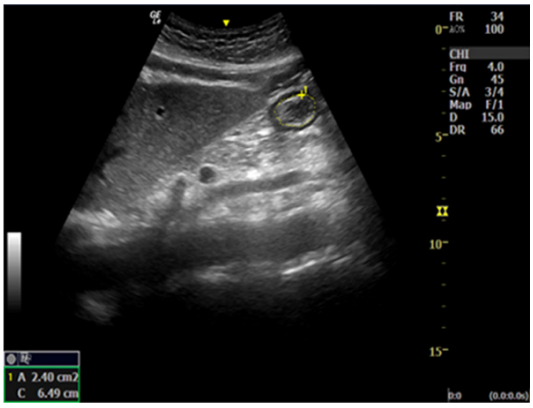

**Figure 2.** Gastric sinus area (GSA) measurement.

*Methods*

EN was performed in new ICU patients, without EN support contraindications and with stable hemodynamics, within 24 to 48 hours. Patients in both groups were treated with manual blind insertion of disposable gastric catheters (Flocare, NUTRICIA Company). The position of nutrition tubes in the stomach was determined by bedside X-rays. The same EN fluid (Fresubin, Huarui Pharmaceutical Co, Ltd.) was pumped with a nutrition pump (Flocare, NUTRICIA Company), according to the target feeding quantity, 18 hours per day, for a total of 7 days. The control group used the syringe withdrawing method every 8 hours to monitor GRV, as well as every 4 hours after implementation of EN. When GRV ≤ 200 mL, the original speed was maintained. If GRV > 200 mL, the EN pump was suspended [10]. The control group used POCUS to monitor GRV with the patients in a supine position during measurement. A GE LogiQ e portable ultrasonic diagnostic instrument with the probe frequency of 3.5 MHz was used to observe the single-section of gastric sinus. The ultrasound probe was placed at the inferior xiphoid and the size of the gastric sinus was developed by ultrasound at a vertical abdomen angle (Gastric sinus development is shown in **Figure 1**. Gastric sinus area (GSA) measurements are shown in **Figure 2**) [11]. GSA was calculated by anterior and posterior gastric sinus (AP) and cephalosacral (CC) diameters measured by ultrasound, GSA = (AP * CC * π/4). Next, the GRV was calculated according to GSA, GRV (mL) = 27.0 + 14.6 * CSA ($mm^2$) * 1.28 * age [11]. GRV was monitored every 4 hours after implementation of EN. When GRV ≤ 200 mL, the original speed was maintained. If GRV > 200 mL, the EN pump was suspended. All ultrasonic operators received Critical Care Ultrasound On-the-Job Training certification in Zhejiang Province.

According to guidelines of American Society for Parenteral and Enteral Nutrition (ASPEN) 2016, the target heat calorie within one week was calculated by a simplified prediction formula (25-30 kcal/kg/d). EN support target energy of obese patients (BMI > 30) was calculated by (11-14 kcal/kg/d) [9]. According to the digestive function of the patients, 1/3 target heat calories were given on the first day, 1/2 target heat calories were given on the second day, and full volume was given on the third day, achieving total enteral nutrition (TEN). If EN intolerance occurred, the infusion speed of EN was slowed down. Patients with reflux and aspiration were intramuscularly injected with 10 mg of metoclopramide. Feeding was interrupted if the GRV was larger than 200 mL or intolerance still occurred when infusion speed was less than 10 mL/h. The observation period was 7 days after admission to ICU for EN. Patients with EN treatments less than 7 days or those in which the standard section could not be observed by ultrasounds were excluded. Cases in the same group were supplemented to 36, according to the random number table.

*Outcome measures*

Incidence of various kinds of feeding intolerance, feeding interruption rates, the number of TEN, average daily EN liquid volumes, serum albumin levels, prealbumin levels, hospital stays, and discharge statuses were observed in the two groups.

Definition of excessive GRV: More than 200 mL of fluid was extracted from gastrointestinal cavity every 4 hours during EN [10].

**Table 2.** Comparison of EN tolerance and feeding interruption between the two groups

| Groups | Diarrhea (n, %) | Reflux (n, %) | Aspiration (n, %) | Feeding interruption (n, %) |
|---|---|---|---|---|
| Study group (n=36) | 6 (16.7) | 3 (8.3) | 1 (2.8) | 9 (25.0) |
| Control group (n=36) | 3 (8.3) | 10 (27.8) | 6 (16.7) | 7 (19.4) |
| *P* value | 0.285 | 0.032 | 0.047 | 0.571 |

**Table 3.** Comparison of TEN and albumin levels on the 7th day between the two groups

| Groups | EN volume (mL/d) | TEN (case %) | Serum albumin (g/L) | Prealbumin (mg/L) |
|---|---|---|---|---|
| Study group (n=36) | 946.4±290.2 | 32 (88.9) | 31.7±4.6 | 205.7±29.9 |
| Control group (n=36) | 806.8±233.1 | 25 (69.4) | 28.8±4.2 | 190.1±27.1 |
| *P* value | 0.028 | 0.042 | 0.032 | 0.017 |

Definition of diarrhea: Defecation frequency ≥ 3 times per day; Defecation amount ≥ 200 g/day or 250 mL/day; Shaped in paste or water form (Reference to the Bristol Stool Scale, category 5-7) [12].

Definition of reflux: Stomach content refluxed from the digestive tract into the esophagus, pharynx, or mouth [13].

Definition of aspiration: Inhaled material entered the airway below glottis [13].

Definition of feeding interruption: Suspension of EN due to feeding intolerance (diarrhea, reflux, aspiration) or GRV more than 200 mL.

Definition of ventilator-associated pneumonia (VAP): Pneumonia that occurs from 48 hours after mechanical ventilation to 48 hours after extubation belongs to VAP. Diagnostic criteria for VAP: 1) Newly occurring or progressive infiltrating shadows are seen on chest X-ray images; 2) Meet at least two of the following at the same time: (1) Body temperature > 38°C or < 36°C; (2) Peripheral blood leukocyte count > 10 * $10^9$/L or < 4 * $10^9$/L; (3) Purulent secretion appeared in tracheal bronchus. Exclusion of pulmonary edema, ARDS, tuberculosis, and pulmonary embolisms [14].

*Statistical methods*

Data was detected by normality testing first. Measurement data with normal distribution are expressed as mean ± standard deviation. They were analyzed using t-tests. Data with nonomal distribution and uneven variances are expressed by medians (interquartile). Comparisons between groups were conducted with rank sum tests. Count data are expressed by rate/percentage/constituent ratios. $\chi^2$ tests were used among the groups. Test level was set at $\alpha$=0.05. P<0.05 indicates that differences are statistically significant. SPSS19.0 software was used for all statistical processing and mapping (SPSS Inc, Chicago, IL).

## Results

*Comparison of tolerance to EN and feeding interruption between the two groups*

In this study, there were 9 patients in the study group and 7 in the control group experiencing feeding interruptions. In the study group, there were 2, 4, and 3 patients experiencing interruptions due to intestinal obstructions, aspiration pneumonia, and gastric retention. In the control group, there were 4, 2, and 1 patient experiencing interruptions due to gastric retention, active gastrointestinal bleeding, and severe intestinal infections. Because EN treatment was less than 7 days, newly eligible patients were included and supplemented to 36, according to the random number table. There were statistically significant differences between the two groups concerning incidence of reflux and aspiration (P<0.05). The number of patients with reflux and aspiration in the study group was less than that in the control group. There were no statistically significant differences concerning incidence of diarrhea and feeding interruptions (P>0.05) (**Table 2**).

*Comparison of TEN, prealbumin, and serum albumin between the two groups*

There were statistically significant differences in the number of TEN after 7 days and daily EN volumes between the two groups (*P*<0.05). Values of the study group were higher than those in the control group. There were statistically significant differences in serum albumin and prealbumin between the two groups after 7 days (*P*<0.05). Values in the study group were

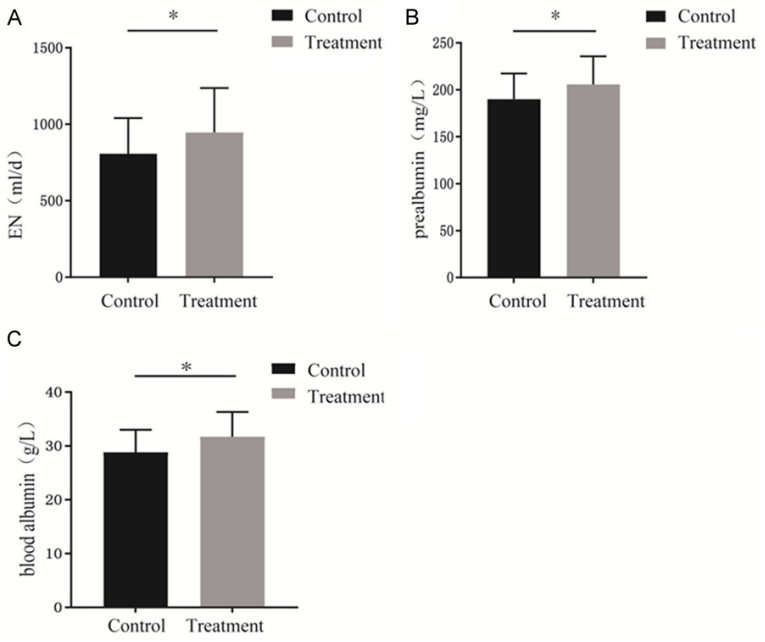


**Figure 3.** Comparison of EN, prealbumin, and serum albumin between the two groups. A: EN volume; B: Prealbumin; C: Serum albumin. *P<0.05.

**Table 4.** Comparison of VAP incidence and related prognostic indicators between the two groups

| Groups | VAP (n, %) | Duration of ICU stay (d) | In-hospital mortality rate (n, %) |
|---|---|---|---|
| Study group (n=36) | 3 (8.3) | 11.0 (9.5, 12.0) | 4 (11.1) |
| Control group (n=36) | 5 (13.9) | 12.0 (10.0, 12.5) | 6 (16.7) |
| *P* value | 0.453 | 0.351 | 0.496 |

higher than those in the control group (**Table 3**, **Figure 3**).

*Comparison of incidence and prognosis of VAP*

There were no significant differences in incidence of VAP, ICU stays, and in-hospital mortality rates between the two groups (P>0.05) (**Table 4**).

## Discussion

EN can protect the physiological function of the gastrointestinal tract and prevent atrophy of intestinal villi. These features are more beneficial in maintaining the balance of intestinal microecology and protecting the barrier function of gastrointestinal mucosa, compared with parenteral nutrition support therapy. Rational EN provides nutrients for the body, maintaining metabolism and providing vital regulatory effects on the metabolism [15] Neuro surgical critical patients often have consciousness disorders, accompanied by masticatory and dysphagia disorders, hiccups, nausea, vomiting, stress-related gastrointestinal hemorrhages, and disorders of intestinal flora. Therefore, it is recommended that neurosurgical critical patients that cannot be fed orally be given priority for EN treatment [16]. However, various feeding intolerances can occur in the course of EN, including abdominal distension, excessive GRV, vomiting, reflux, diarrhea, and astriction. Excessive GRV is most common, with an incidence of up to 39% [17]. At present, CT and routine gastric juice withdrawal are often used to measure GRV. Although CT has a high accuracy, it cannot be widely used in clinic because of the lack of real-time dynamic observation. This increases the risk of unstable transport of hemodynamics in patients. Gastric juice withdrawal is easily affected by the position of the patient and the nutrition tube, resulting in inaccurate GRV measurements. Therefore, an objective, accurate, and dynamic GRV measurement method is needed to guide implementation of EN.

With the development of medical equipment and wide application of clinical ultrasound, POCUS has been more widely used in clinic because of its fast, convenient, non-invasive, and repeated image acquisition. In the early stages, 90 patients under mechanical ventilation in the ICU were treated with gastric sinus singlesection to measure GSA. GRV was quickly obtained and timely adjusted to the nutritional supply strategy. Results showed that monitoring GRV by POCUS increased the intake of protein and shortened operating times of nurses [18]. This study found no differences between POCUS and gastric juice withdrawal concerning incidence of diarrhea and feeding interruption. However, monitoring GRV by POCUS reduced

incidence of reflux and aspiration in patients. At the same time, it also increased the number of TEN, average daily EN fluid volumes, and serum albumin and prealbumin levels. Results were consistent with a previous study on patients with mechanical ventilation in the ICU [18]. Gastric juice withdrawal may lead to inadequate aspiration because of the position of the patient, the position of the feeding tube (tube break, adherent), and other factors. This can easily lead to less GRV measured. In clinic, fluid after aspiration is often injected back into the stomach. This is equivalent to passively increasing the amount and speed of EN in a short time, increasing occurrence of reflux and aspiration. These factors affect implementation of EN and reduce the intake of calories and protein. Repeated injections of retracted gastric content into the stomach by stomach tubes may cause secondary pollution, resulting in increased incidence of diarrhea [5].

A previous investigation showed that only 72.1% of the nursing staff monitored GRV according to standard practice. Reasons could be related to the busy work in the ICU, complicated operations of repeated withdrawal of the gastric juice, and the peculiar smell of gastric juice [19]. Results of the current study showed that POCUS not only reduced incidence of feeding intolerance, but also did not increase incidence of adverse clinical outcomes in patients with critical neural diseases. This method was easily accepted by the patients and their families because of its non-invasiveness. Moreover, it was unnecessary for nursing staffs to retract the gastric juice and then inject back into the stomach repeatedly. This reduced the workload and improved work efficiency.

However, monitoring GRV by POCUS still has some limitations [20]. Measurement of GSA using the gastric sinus single-section method, gastrointestinal gas can easily interfere. Thus, the data of some patients may not be accurately obtained. In addition, the accuracy of POCUS in measuring GSA is related to operator experience. Although operators receive Critical Care Ultrasound On-the-Job Training in Zhejiang Province, results of GRV assessment vary, to some extent, between different operators. Moreover, this was a single-center, prospective, and observational study, with a small sample size. Therefore, expansion of sample sizes, along with multicenter randomized controlled trials, in the future will assist in verifying the clinical application of POCUS for monitoring GRV.

In conclusion, monitoring GRV by POCUS to guide EN reduces occurrence of reflux and aspiration, while and increasing the number of TEN and intake of protein. It shows no effects on incidence of VAP, ICU stays, and in-hospital mortality rates. Therefore, the gastric sinus single-section method can be used as an effective index for monitoring GRV in neurosurgical critical patients. It may guide the safe implementation of EN more objectively, safely, effectively, and dynamically. Moreover, POCUS achieves fast, convenient, non-invasive, and repeated image acquisition. Thus, it is worthy of promotion in clinic.

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## Disclosure of conflict of interest

None.

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