Bedside gastrointestinal ultrasound combined with acute gastrointestinal injury score to guide enteral nutrition therapy in critically patients

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Research Article

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Abstract

BACKGROUND—To use gastric ultrasound to evaluate function and to determine the start time of enteral nutrition (EN) in patients with acute gastrointestinal injury (AGI).

METHODS—We reviewed records from 105 patients who suffered AGI levels two (AGI II). We recorded several data points, including ultrasonographic transverse area of gastric antrum (CSA), left descending colonic or right ascending colonic diameter (D), colonic peristatic frequency (F), EN start time, EN dose, prealbumin (PA), and EN complications. The recovery of intestinal function after EN treatment was judged as success. If there was EN treatment complication, this was judged as failure. We analyzed the changes in gastrointestinal function after EN treatment, to determine feeding time.

RESULTS—There were 69 patients in the successful group, and 36 in the failure group. There were no significant differences between the two groups in age, intraperitoneal pressure (IAP), APACHE II, PA and disease composition ($p > 0.05$).There were significant differences in terms of EN startup time, CSA, D, F, and PA, between the EN success and failure groups. Receiver operating curve analysis showed that combined CSA , D,F evaluation determined the best time to start EN.

CONCLUSIONS—Monitoring gastric antrum transversal area, colonic diameter, colonic peristatic frequency using ultrasound can guide the timing of initiation of enteral nutrition treatment.

Introduction

When the body suffers serious damage, it is easy to cause spasmodic contraction of the gastric and mesenteric arteries, and then lead to gastrointestinal mucosal ischemia necrosis. This in turn leads to acute gastrointestinal injury (AGI)[1], manifesting as gastrointestinal peristalsis, absorptive dysfunction, gastrointestinal bleeding, intestinal dilatation, and other complications.

When diseases are controlled, early nourishing feeding is recommended, followed by transition to targeted feeding. Enteral nutrition therapy for severely ill patients can promote the recovery of gastrointestinal function, maintain mucosal integrity, and correct intestinal flora imbalance[2]. Currently, it is recommended to start EN within 24 to 48 hours after the patient is stabilized, and to continue feeding for 24 hours[3]. The AGI score is based on subjective assessment (the only objective indicator is IAP).Severely ill patients are often unable to cooperate to the point of generating the score properly, either because of invasive mechanical ventilation, need for analgesia and sedation, or many other reasons. Therefore, more objective evidence is needed to monitor intestinal function.

Gastrointestinal ultrasound objectively measures the transverse area of the gastric antrum, the colon diameter and the frequency of peristalsis, so as to observe the gastrointestinal function. In this study, intra-abdominal pressure, gastric antrum ultrasonic cross-sectional area, left descending colonic/right descending colonic diameter, colonic peristatic frequency, EN start time, EN dose, prealbumin (PA), and EN complications were recorded. We dynamically monitored the process of enteral nutrition therapy, nourishing feeding, and targeted feeding; we recorded the start time of enteral nutrition.

Materials And Methods

Patients

This observational study was approved by the ethics committee of Zhangzhou Affiliated Hospital of Fujian Medical University (20180212D). Written informed consent to participate in the study was obtained from each patient.

The inclusion criteria for the research groups were as follows:> age of 18 years; AGI II; and hospitalization time greater than 120 hours. The exclusion criteria were as follows: open abdominal trauma; abdominal tumor; large amount of peritoneal effusion; acute gastrointestinal function injury ≥ III magnitude; pregnancy.

We reviewed records of 105 patients admitted to the intensive care unit of Zhangzhou Hospital affiliated to Fujian Medical University from December 2018 to February 2020 who suffered acute gastrointestinal injury (AGI II) with NRS2002 score ≥ 3 points. After their circulatory status had been stabilized for at least 4 hours, enteral nutritional suspension (short peptides, 1 kcal/ml) was administered. Nourishing feeding at 20 ml/H was given within 24 to 48 hours after EN initiation. If there was no enteral nutritional intolerance, 40 ml/H of targeted feeding was given. We recorded 420 data points, including IAP, CSA, D, F, EN start time, EN dose, PA, and EN complications. The recovery of intestinal function after EN treatment was judged as success. If there was a large amount of gastric retention, vomiting, aspiration pneumonia, intestinal dilatation, or other complications, this was judged as failure.

Ultrasound Examination

The subjects were examined using bedside antrum ultrasound and colonic ultrasound by skilled researchers with severe ultrasonic training certificates. During and after the examinations, we took care to avoid wound contamination and to disinfect the probes.

Antrum ultrasonography

The Sonosite M-Tube to was used for monitoring, with the 2–5 MHz convex array probe. The patient lies on the right side (supine position for patients who cannot lie on the right side due to critical condition). The head of the bed is raised 30–45 degrees, and the direction of the probe is parallel to the longitudinal axis of the body, under the xiphoid process. Clear gastric antrum ultrasound was obtained at the right side of the median sagittal line (Fig. 1A/B) [4].

Section of gastric antrum was taken by ultrasound, and then use Simpson 's integral method, trace along the edge of the gastric antrum, then utilizing ultrasonic data packet to scan and calculate the area of gastric antrum [5], to evaluate gastric volume (Fig. 2).

Colonic ultrasonography

We placed the 2–5 MHz convex array probe on the abdomen along the left descending colon or right descending colon, and scanned vertically from top to bottom. If necessary, the probe was rotated 90° to

increase horizontal sliding scanning (Fig. 3A/B) [6].

Statistical analysis

Data were analyzed using SPSS version 20.0 software (IBM Corporation, Armonk, NY). All numeric data were expressed as mean ± standard deviation. Continuous variables between groups were compared using the independent samples t-test. We used MedCalc to draw receiver operating characteristic (ROC) curves. $P < 0.05$ was considered statistically significant.

Results

A total of 105 patients were studied, and 420 data points were collected. There were 65 male patients and 40 female patients. The EN success group included 69 patients, and the failure group included 36 patients. The clinical characteristics of the study groups are shown in Table 1.

Table 1
Clinical characteristics of the two groups of patients

Characteristic	Successful (n = 69)	Failure (n = 36)	T	P
Age, y	71.84 ± 9.15	70.5 ± 5.9	-0.446	0.657
APACHE	26.98 ± 1.43	27 ± 1.58	-0.048	0.962
IAP st, mmHg	17.78 ± 1.49	17.45 ± 1.96	0.958	0.34
Pa st, mg/L	69.39 ± 15.06	63.89 ± 15.03	1.793	0.076
Diseases, n (%)				
Pneumonia	11(15.9)	2(5.6)		
Heart failure	23(33.3)	12(33.3)		
Septic shock	19(27.5)	10(27.7)		
Celiac inflammation	8(11.6)	5(13.9)		
Pancreatitis	6(8.7)	2(5.6)		
MODS	2(3.0)	5(13.9)		
T-test was used for measurement data, and the χ^2 test was used for counting data. $P < 0.05$ was considered statistically significant.				
A total of 105 patients were studied, and 420 data points were collected. There were 65 male patients and 40 female patients. The EN success group included 69 patients, and the failure group included 36 patients. The clinical characteristics of the study groups are shown in Table 1.				

Single-factor comparison of EN initiation between the two groups. Analysis between the two groups showed that there were significant differences in terms of time of enteral nutrition initiation. When EN was started

between the two groups, there were significant differences in CSA, D, PAand F, but no differences in IAP (Table 2).

Table 2
Single-factor comparison of EN initiation between the two groups

	EN		T	P
	Successful	Failure		
EN St	14.69 ± 8.98	19.51 ± 13.35	-2.21	0.029*
IAP	17.78 ± 1.46	17.46 ± 1.96	0.958	0.34
CSA	9.10 ± 1.32	10.75 ± 1.94	-5.18	< 0.001*
D	2.83 ± 0.31	3.37 ± 0.48	-7.1	< 0.001*
F	2.87 ± 0.98	2.29 ± 0.97	2.87	0.005*

Group 1 is the EN success group; Group 2 is the EN failure group. EN St, time to start enteral nutrition; IAP, intraperitoneal pressure, mmHg; CSA, the transverse antrum area of cm; D, diameter of left descending colonic or right ascending colonic, cm; F, colonic peristalsis frequency, BPM; PA, prealbumin, mg/L.P < 0.05: have statistically significant.

ROC curve of IAP, CSA, D ,F and the joint evaluation of CSA, D ,F: IAP has the lowest AUC area;CSA, D, F all have higher predicted values than IAP when compared with IAP.When CSA, D and F were combined to evaluate the success of EN, the positive predictive value was higher than that of single indicator.When CSA + D + F combined evaluation, the area under the AUC curve was the largest and the positive predictive value was the highest.When D + F was used to evaluate the success of EN, there was no statistical difference with other indicators, the possible reason being that these two indicators could only represent colon function, not the recovery of the whole gastrointestinal function (Table 3a/3b, Fig. 4).

Table 3a
IAP, CSA, D ,F and PRE were used to evaluate gastrointestinal function recovery

	cut–off	Youden index	Sensitivity 95% CI	Specificity 95% CI	AUC 95% CI	PPV 95% CI	NPV 95% CI
IAP	≤ 16	0.07	54.93 (48.9–60.8)	52.03 (43.7–60.3)	0.502 (0.454–0.550)	68.7 (62.3–74.7)	37.6 (30.9–44.6)
CSA	≤ 9	0.65	83.45 (78.6–87.6)	81.08 (73.8–87)	0.896 (0.86–0.92)	89.4 (85.1–92.9)	71.9(64.4–78)
D	≤ 2.9	0.6642	91.2 (87.3–94.2)	75.0 (67.2–81.7)	0.92(0.889–0.94)	87.5 (83.2–91.0)	81.6(74.1–87.7)
F	> 3	0.566	70.77(65.1–76)	85.81(79.1–91)	0.845(0.808–0.878)	90.5(85.9–94)	60.5(53.5–67.1)
PRE (CSA + D + F)	> 0.68	0.77	88.73 (84.5–92.2)	88.51 (82.2–93.2)	0.95(0.925–0.97)	93.7 (90.1–96.3)	80.4 (73.4–86.2)
PRE (CSA + D)	> 0.58	0.74	88.03 (83.7–91.6)	85.81 (79.1–91.0)	0.946(0.92–0.96)	92.3 (88.4–95.1)	78.9 (71.8–84.9)
PRE (CSA + F)	> 0.55	0.72	87.32 (82.9–91.0)	84.46 (77.6–89.9)	0.925 (0.89–0.95)	91.5 (87.5–94.5)	77.6 (70.4–83.8)
PRE (D + F)	> 0.65	0.65	77.11 (71.8–81.9)	87.84 (81.5–92.6)	0.914 (0.88–0.94)	92.4 (88.3–95.4)	66.7 (59.6–73.2)

Table 3b
Pairwise comparison of IAP, CSA, D,F and PRE

	AUC difference	Standard error	95% CI	Z	P
IAP-CSA	0.393	0.0297	0.335–0.452	13.252	< 0.001*
IAP-PRE(CSA,D,F)	0.448	0.289	0.391–0.504	15.523	< 0.001*
IAP-PRE(CSA,D)	0.444	0.029	0.387–0.501	15.286	< 0.001*
IAP-PRE(CSA,F)	0.423	0.0289	0.366–0.479	14.613	< 0.001*
IAP-PRE(D,F)	0.411	0.0301	0.352–0.470	13.679	< 0.001*
CSA-PRE(CSA,D,F)	0.0544	0.0113	0.032–0.076	4.832	< 0.001*
CSA-PRE(CSA,D)	0.0505	0.0108	0.0293–0.0718	4.658	< 0.001*
CSA-PRE(CSA,F)	0.0293	0.007	0.014–0.044	3.801	0.001*
CSA-PRE(D,F)	0.0179	0.017	-0.015-0.05	1.058	0.29
PRE(CSA,D,F)- PRE(CSA,D)	0.0038	0.002	-0.0004-0.008	1.742	0.08
PRE(CSA,D,F)- PRE(CSA,F)	0.025	0.006	0.0128–0.037	4.027	0.001*
PRE(CSA,D,F)- PRE(D,F)	0.036	0.008	0.018–0.054	4.07	< 0.001*
PRE(CSA,D)- PRE(CSA,F)	0.02	0.007	0.007–0.035	3.009	0.002*
PRE(CSA,D)- PRE(D,F)	0.03	0.01	0.0125–0.053	3.175	0.001*
PRE(CSA,F)- PRE(D,F)	0.011	0.011	-0.011-0.034	0.982	0.326

IAP, intra-abdominal pressure,mmHg; CSA, transverse area of gastric antrum,cm^2; D, diameter of left descending colonic or right ascending colonic,cm; F, colonic peristalsis frequency; PRE, the joint evaluation of transverse area of gastric antrum and colonic diameter, colonic peristalsis frequency.

ROC curve of IAP, CSA, D ,F and PRE

6a:ROC curve of IAP, CSA, D,F and the joint evaluation of CSA, D,F: The sensitivity and specificity of different parameters were compared with the enteral nutrition success group: IAP ≤ 16mmHg, AUC 0.502;CSA ≤ 9cm2, AUC 0.896□D ≤ 2.9cm, AUC 0.92□F > 3bpm, AUC0.845□CSA + D + F, AUC 0.95.

6b: IAP, CSA, D,F and PRE, pairwise comparison showed statistical difference.

Discussion

The structure of the gastrointestinal tract is complex, with many physiological functions. When the balance of Systemic Inflammatory Response Syndrome and Compensatory Anti-inflammatory Response Syndrome (SIRS/CARS) was broken, gastrointestinal function is often impaired[7]. In a study of 242 patients who underwent mechanical ventilation for longer than 48 hours, the incidence of gastrointestinal bleeding was 46.7%, most of which occurred within 48 hours postoperatively[8]. Proper mechanical ventilation Settings can protect gastrointestinal function[9, 10].The use of high pressure ventilator, renal failure, decreased platelet count

were important risk factors for gastrointestinal bleeding, while enteral nutrition was an independent protective factor[11].

Successful enteral nutrition therapy for severely ill patients can promote the repair of gastrointestinal mucosa, promote the recovery of gastrointestinal function, and reduce the rate of endogenous infections[12]. Nevertheless, some patients are feeding-intolerant, characterized by gastric retention, vomiting, diarrhea, and abdominal distention[13].Therefore, it is extremely important to effectively and comprehensively assess the status of gastrointestinal function[14], and then to guide the timing of initiation of enteral nutrition treatment [15, 16] .

In previous studies of our team [17], it was found that intra-abdominal pressure could not reflect the absorption function state of intestinal function;Successful enteral nutrition treatment can promote the improvement of gastrointestinal function indicators such as gastric antrum cross-sectional area, colon diameter and peristalsis frequency [18, 19]. In IAP similar states, although circulation is stable, some patients do not have synchronous recovery of intestinal function[20].This phenomenon is not reflected by abdominal examination and IAP[21]. It indicates that gastrointestinal ultrasound can better evaluate the damage state of gastrointestinal function, and enteral nutrition therapy can be carried out earlier[22].

Continuous feeding of short peptide nutritional preparations can achieve the target calorie[23].There were fewer feeding complications. When enteral nutrition is absorbed, it promotes intestinal mucosal repair and contributes to the recovery of humoral and cellular immune function in the early post-traumatic period[24] .

Comparison of the gastrointestinal assessment results of the successful and failed groups at the initiation of enteral nutrition showed no significant difference in IAP at the initiation of EN.There were statistical differences in the start time of EN, CSA, D and F, suggesting that the successful group may have a better basis of gastrointestinal function and less gastrointestinal function injury, which means we can start enteral nutrition therapy earlier.

We found that IAP ≤ 16mmHg, AUC 0.502, IAP does not reflect gastrointestinal function;CSA ≤ 9cm2, AUC 0.896;D ≤ 2.9cm, AUC 0.92;F > 3 BPM, AUC0.845;The results indicated that the three indexes could reflect the recovery of gastrointestinal function.When CSA, D and F were combined, the positive predictive value and AUC of CSA, D and F were higher than those of single index, the difference was statistically significant ($P < 0.001$), except for D + F combination ($P > 0.05$).When the patients met the combination of the above three indicators, namely CSA ≤ 9cm2, D ≤ 2.9cm, F > 3bpm, and AUC 0.95, enteral nutrition therapy was initiated, with a successful measurement value of 93.7%, suggesting a more complete assessment of gastrointestinal function.

The disadvantage of this study is that the single-center study has a small number of cases, which needs to be confirmed by more studies.

Conclusions

Monitoring gastric antrum transversal area and colonic diameter using ultrasound can guide the timing of initiation of enteral nutrition treatment.

Abbreviations

AGI：Acute gastrointestinal injury; APACHE II：Acute Physiology and Chronic Health Evaluation II; CARS：Compensatory Anti-inflammatory Response Syndrome; CSA：transverse area of gastric antrum; D：left descending colonic or right ascending colonic diameter; EN：enteral nutrition; F：colonic peristatic frequency; IAP：intra-abdominal pressure; SIRS：Systemic Inflammatory Response Syndrome; PA：prealbumin; JE：The joint evaluation of transverse area of gastric antrum and colonic diameter.

Declarations

Ethical approval and consent to participate

This observational study was approved by the ethics committee of Zhangzhou Affiliated Hospital of Fujian Medical University (20180212D). Written informed consent to participate in the study was obtained from each patient.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent for publication

Not applicable

Availability of data and materials

All data generated or analysed during this study are included in this published article [and its supplementary information files].

Competing interest

All the authors declare that they have no conflict of interest.

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The funder had no role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

Authors' contribution

Conception and design: Qingjiang Zheng; Drafting the manuscript: Jiawei Lai, Linli Chen; Prepared all figures and tables: Daofeng Huang; Data collection and analysis: Shuhong Chen, Jinzhan Lin. All authors have read, edited, and approved the manuscript.

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Figures

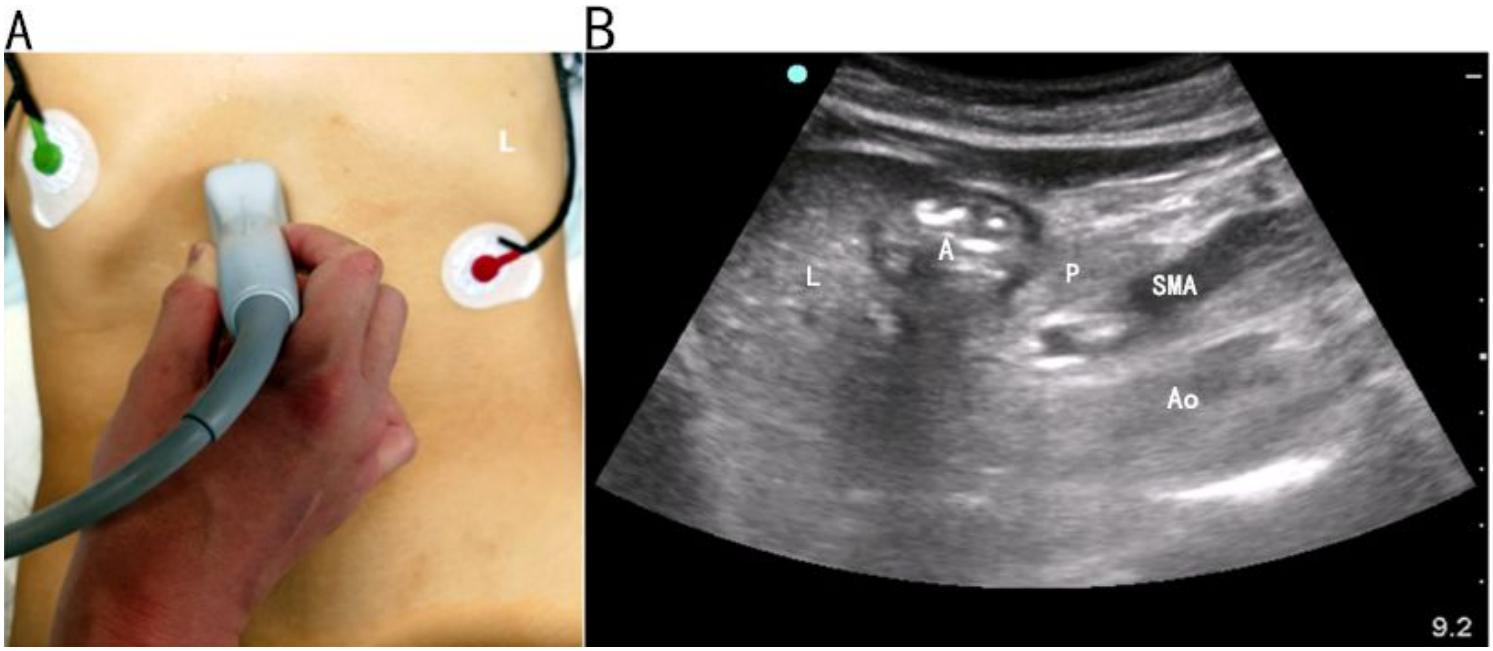

Figure 1

Ultrasonic examination of the gastric antrum

A:The Sonosite M-Tube to was used for monitoring, with the 2–5 MHz convex array probe. The patient lies on the right side (supine position for patients who cannot lie on the right side due to critical condition). The head of the bed is raised 30–45 degrees, and the direction of the probe is parallel to the longitudinal axis of the body, under the xiphoid process. Clear gastric antrum ultrasound was obtained at the right side of the median sagittal line.

B: Schematic diagram of standard section:L: liver. A: antrum of stomach. P: pancreas. SMA:superior mesenteric artery. Ao: aortaventralis.

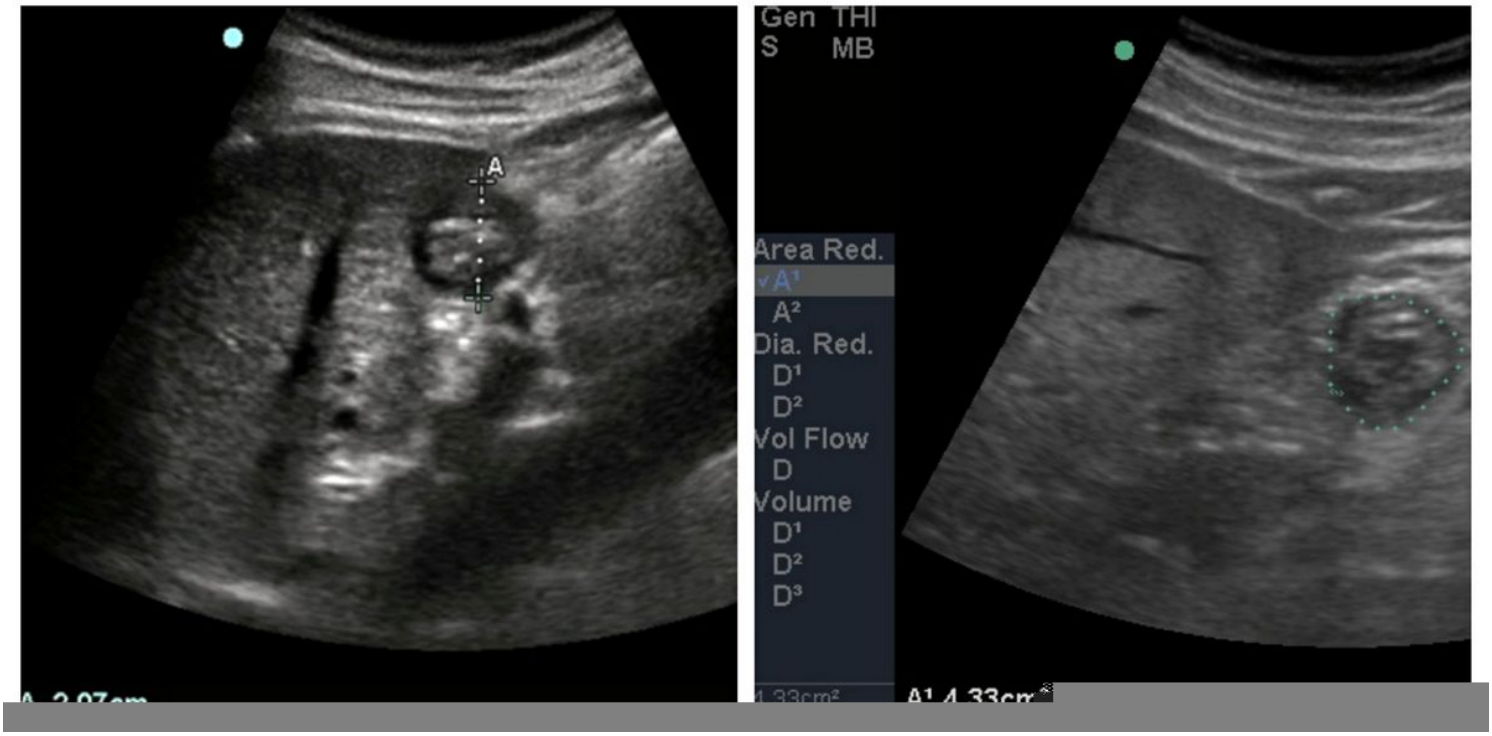

Figure 2

Scan and calculate the area of gastric antrum

Section of gastric antrum was taken by ultrasound, and then use Simpson 's integral method, trace along the edge of the gastric antrum, then utilizing ultrasonic data packet to scan and calculate the area of gastric antrum, we applied the following formula(5): GV (ml) = 27.0 + 14.6 × right-lateral CSA − 1.28 × age, to evaluate gastric volume.

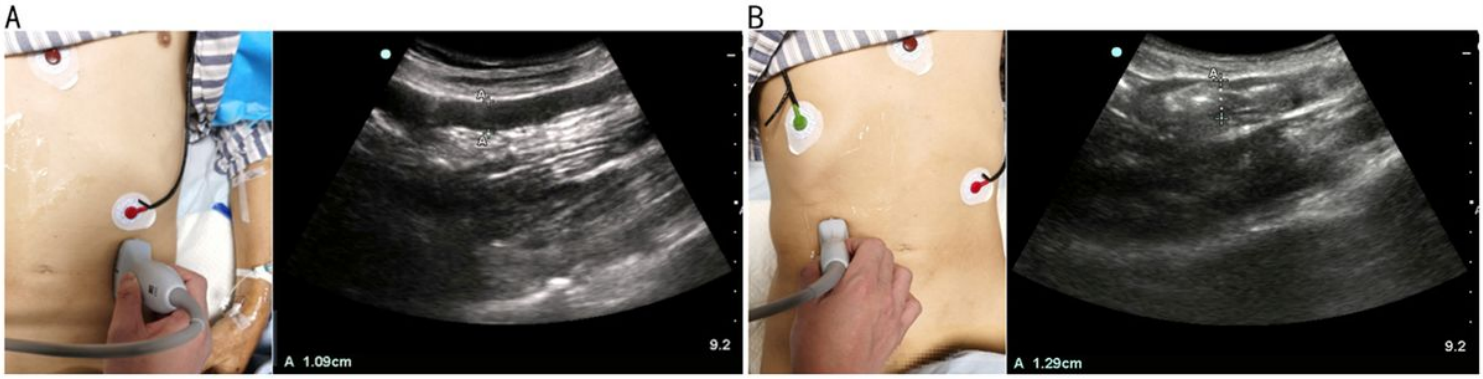

Figure 3

Left semicolon ultrasound and Right colonic ultrasound

A: The Sonosite M-Tube to was used for monitoring, with the 2–5 MHz convex array probe. The ultrasound probe was placed in the front line of the left axilla, and the direction of the probe was parallel to the longitudinal axis of the body, then obtained a clear image of the descending colon on the left. Then we measured the left descending colon diameter.

B: The Sonosite M-Tube to was used for monitoring, with the 2–5 MHz convex array probe. The ultrasound probe was placed in the front line of the right axilla, and the direction of the probe was parallel to the longitudinal axis of the body, then obtained a clear image of the right ascending colon. Then we measured the inner diameter of the right ascending colon.

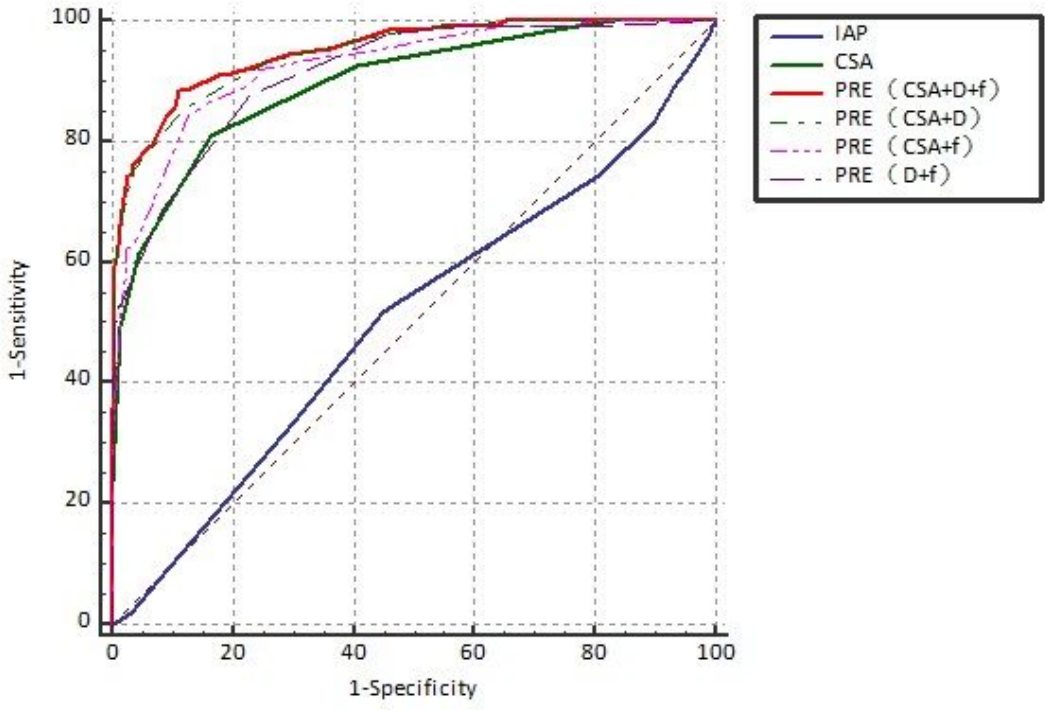

Figure 4

ROC curve of IAP, CSA, D , F,PRE

ROC curve of IAP, CSA, D ,F and the joint evaluation of CSA, D ,F: IAP has the lowest AUC area;CSA, D, F all have higher predicted values than IAP when compared with IAP.When CSA, D and F were combined to evaluate the success of EN, the positive predictive value was higher than that of single indicator.When CSA+D+ F combined evaluation, the area under the AUC curve was the largest and the positive predictive value was the highest.When D+ F was used to evaluate the success of EN, there was no statistical difference with other indicators, the possible reason being that these two indicators could only represent colon function, not the recovery of the whole gastrointestinal function

IAP, intra-abdominal pressure; CSA, transverse area of gastric antrum; D, left descending colonic or right ascending colonic diameter ; pre, the joint evaluation of transverse area of gastric antrum, colonic peristatic frequency and colonic diameter.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- researchdata.xlsx