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# Early Enteral Nutrition Prevents Intra-abdominal Hypertension and Reduces the Severity of Severe Acute Pancreatitis Compared with Delayed Enteral Nutrition: A Prospective Pilot Study

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**Abstract**

*Background* To investigate the effects of early enteral nutrition (EEN) on intra-abdominal pressure (IAP) and disease severity in patients with severe acute pancreatitis (SAP).

*Methods* Enteral nutrition (EN) was started within 48 h after admission in the EEN group and from the 8th day in the delayed enteral nutrition (DEN) group. The IAP and intra-abdominal hypertension (IAH) incidence were recorded for 2 weeks. The caloric intake and feeding intolerance (FI) incidence were recorded daily after EN was started. The severity markers and clinical outcome variables were also recorded.

*Results* Sixty patients were enrolled to this study. No difference about IAP was found. The IAH incidence of the EEN group was significantly lower than that of the DEN group from the 9th day (8/30 versus 18/30; $P = 0.009$) after admission. The FI incidence of the EEN group was higher than that of the DEN group during the initial 3 days of feeding (25/30 versus 12/30; $P = 0.001$; 22/30 versus 9/30; $P = 0.001$; 15/30 versus 4/30; $P = 0.002$). Patients with an IAP <15 mmHg had lower FI incidence than those with an IAP ≥15 mmHg on the 1st day (20/22 versus 17/38; $P < 0.001$), the 3rd day (11/13 versus 8/47; $P < 0.001$), and the 7th day (3/5 versus 3/55; $P = 0.005$) of feeding. The severity markers and clinical outcome variables of the EEN group were significantly improved.

*Conclusions* Early enteral nutrition did not increase IAP. In contrast, it might prevent the development of IAH. In addition, EEN might be not appropriate during the initial 3–4 days of SAP onset. Moreover, EN might be of benefit to patients with an IAP <15 mmHg. Early enteral nutrition could improve disease severity and clinical outcome, but did not decrease mortality of SAP.

## Introduction

As an important tool in the management of severe acute pancreatitis (SAP), enteral nutrition (EN), especially early enteral nutrition (EEN), could effectively increase the blood flow of gut mucosa and stimulate the intestinal motility [1, 2]. Early enteral nutrition also maintains the gut integrity, prevents bacterial and endotoxin translocation, and decreases the incidence of infectious complications [1, 3]. Moreover, EEN has been shown to reduce the length of hospital stay and mortality in patients with SAP [1, 3, 4].

However, the role of EEN might be changed in SAP patients who have intra-abdominal hypertension (IAH). Previous studies had shown that gut was the most sensitive splanchnic organ to the increase of intra-abdominal pressure (IAP) [5]. Intra-abdominal hypertension could significantly reduce the blood flow of gut, leading to the development of intestinal ischemia and edema [6, 7], which would consequentially increase the permeability of the intestinal mucosal barrier, and ultimately cause bacterial translocation [5, 8, 9]. Nevertheless, the different effects of specific IAP levels on the tolerance of EEN have not yet been reported.

The study was registered at ClinicalTrials.gov (Identifier: NCT01507766).

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Furthermore, the effects of early enteral feeding on the IAP in SAP also remain unknown. Because of the severe inflammatory response of SAP, EEN may possibly increase the burden of bowel, cause expansion of the intestinal cavity, and thus increase IAP. However, there have been rare reports in the literatures of an association between EEN and IAH in patients with SAP. Cothren and colleagues [10] suggested that early enteral feeding was tolerated well after definitive abdominal closure in patients undergoing decompressive laparotomy for abdominal compartment syndrome. However, the precise role of EN in this syndrome was unclear and their conclusions remained controversial.

The present study aimed to investigate the effects of EEN on IAP, as well as the effects of specific IAP levels on the tolerance of enteral feeding in SAP patients. Moreover, the impacts of EEN on the disease severity and clinical outcome of SAP were also studied.

## Materials and methods

### Study design

This was a single-center prospective pilot clinical trial. Patients were randomly (simple randomization) allocated to receive either EEN or delayed enteral nutrition (DEN) on admission. The study protocol was approved by the Ethics Committee of the hospital, and informed consent was obtained from each patient or his/her first-degree relatives.

### Patients

From September 2010 to September 2011, all adult patients (aged 18–70 years) admitted within 3 days of onset of symptoms to the Surgical Intensive Care Unit (SICU) of the General Surgery Institute, Jinling Hospital, were enrolled into this study. The diagnostic criteria of SAP were accordant with the Atlanta criteria of 1992 [11], defined as acute pancreatitis with one or more local complications (e.g., pseudocyst, necrosis, or abscess) or/and organ failure or/and acute physiology and chronic health evaluation II (APACHE II) score >8. Patients who had received decompressive measures or artificial nutrition (either EN or parenteral nutrition) before admission, patients with chronic organ dysfunction or immunodeficiency or malnutrition, and patients with ileus or pancreatitis in pregnancy were all excluded. Figure 1 is the flow diagram of the participants. All patients received specialized medical therapy for SAP [12–14], such as intensive monitoring, restricted fluid resuscitation, oxygen administration, stopping oral feeding, and exocrine pancreatic suppression (somatostatin analogue). In our center, antibiotic prophylactic was used only for patients with no infection of pancreatic necrosis [15]. When patients developed pancreatic infection, the use of antibiotics would be conformed to the antimicrobial susceptibility testing results of necrotic tissue [15]. Furthermore, percutaneous catheter drainage was also performed initially for patients with pancreatic infection [16], and the surgical necrosectomy was delayed as long as possible [15, 16].

### Nutrition protocols

A nasojejunal feeding tube (size 10 French; Flocare, Nutricia Ltd) was placed beyond the ligament of Treitz endoscopically or radiologically, and the position of the tip was checked by fluoroscopy. In the EEN group, the tube was placed within 24 h after admission, and enteral feeding was established from the next 24 h. Patients in the DEN group were offered EN on the 8th day after admission, and a nasojejunal tube was placed on the 7th day. Peptide-based formula (Peptisorb, Nutricia Ltd) was given in the first 24–48 h, and if the patients tolerated it well, a whole protein formula (Nutrison Fibre, Nutricia Ltd.) was later substituted. The goal caloric needs of EN were determined as 20–25 kcal/kg/day [17, 18], and protein needs were determined as 1.5 g/kg/day [3, 17]. The feeding was advanced continuously toward the goal calorie intake [17] via a pump. The rate was initiated at 15–20 mL/h and increased gradually by 15–20 mL every 6–8 h to the goal rate, depending on the patient's tolerance [3]. The feeding protocols of ventilated patients were consistent with the other SAP patients because no consensus had been reached on the nutritional strategy of patients needing mechanical ventilation [19, 20]. The most common problem of enteral feeding in ventilated patients might be that they cannot eat normally by mouth, and in this study, all patients enrolled were fed through a nasojejunal tube. Feeding intolerance (FI) was diagnosed when the enteral feeding appeared to be discontinued because of high gastric residual volume (>200 mL), repeated nausea, vomiting, abdominal pain or distension, diarrhea, or aspiration [21, 22].

Total parenteral nutrition was administered during the 1st week after admission in the DEN group. The caloric need was calculated as 20–25 kcal/kg/day and the calorie:nitrogen ratio was determined to be 120–150:1 [23]. Fifty to seventy percent of the total energy need was provided by glucose, and the use of lipids was based on serum triglyceride levels [23]. Moreover, appropriate amounts of vitamins, trace elements, electrolytes, and insulin were also added into the intravenous solution.

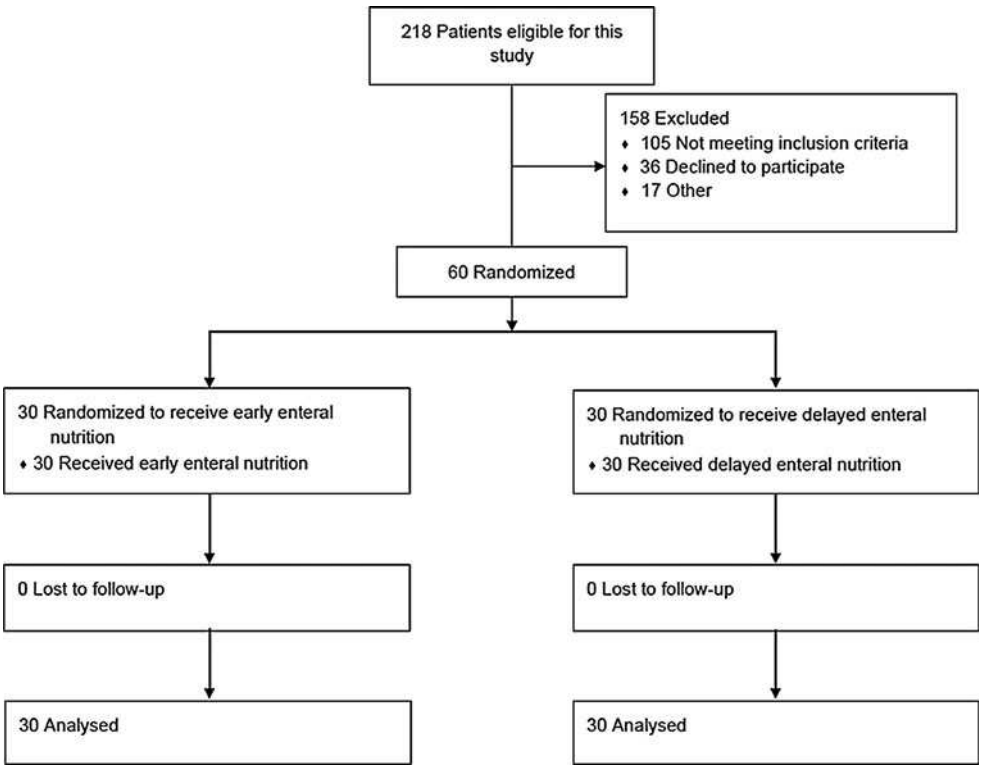


**Fig. 1** Enrollment, randomization, and follow-up of participants

### Measurement of IAP

The IAP monitoring was performed in accordance with the bladder technique recommended by the World Society of Abdominal Compartment Syndrome in 2006 [24]: The patient was placed in the supine position, 25 mL of saline was instilled into the bladder and the vesical pressure was measured at end-expiration with a pressure transducer zeroed at the level of the mid-axillary line. The IAP was determined every 6 h and continued for 2 weeks after admission. Intra-abdominal hypertension was defined by a sustained or repeated pathological elevation in IAP $\geq$12 mmHg [25]. To avoid local infection of the urinary tract, each patient included was given a percutaneous minimally invasive vesicostomy after informed consent was obtained.

### Data collection

On admission, the baseline characteristics, including age, sex, body mass index (BMI), and etiology were recorded. Contrast-enhancement computed tomography (CECT) was also performed on admission. The APACHE II score, sequential organ failure assessment (SOFA) score, and C-reactive protein (CRP) level were assessed on the 1st and 3rd days after admission. All parameters were repeated on the 7th and 14th days. The number of patients with FI symptoms, as well as caloric intake, was recorded on a daily basis after enteral feeding was started. The levels of IAP were recorded as a daily average. The incidence of IAH was also noted daily during the 2 weeks after admission. The clinical outcome variables, including hospital mortality, duration of ICU stay, and development of multiple organ dysfunction syndrome (MODS) and pancreatic infection were also recorded.

### Statistical analysis

All the data were presented as medians (interquartile ranges), if not stated otherwise. Categorical variables were expressed as absolute numbers or in percentages, and were analyzed with the $\chi^2$ test. Continuous variables were compared by the Mann–Whitney *U*-test or the Wilcoxon Signed Ranks Test, as appropriate. Statistical Package for the Social Sciences (SPSS, version 17.0, Chicago, IL) software was used for statistical analysis. A level of $P < 0.05$ was considered statistically significant.

## Results

As shown in Fig. 1, 218 SAP patients were enrolled to accrue to 60 study participants during the study period. The demographic data and clinical parameters of the patients on admission were presented in Table 1. The principal etiological factors of SAP were biliary (60 %, 36/60) and

hyperlipidemia (23 %, 14/60). The triglyceride levels of the 14 hyperlipidemia patients were 6.6 (5.7–8.8) mmol/L on admission.

Fifty-two patients had pancreatic necrosis on CECT scan on admission, whereas 38 and 27 patients were noted to have the disease on day 7 and day 14, respectively. Thirteen patients developed pancreatic infection during their hospital stay; nevertheless, only 6 patients (4 in the DEN group and 2 in the EEN group) eventually underwent operation. Seven patients had organ failure at the time of admission, whereas 25 patients (42 %, 25/60) developed organ failure during their hospital stay. Of those 25 patients, 18 (30 %, 18/60) developed MODS, and 3 (5 %, 3/60) died of MODS or septic shock.

## Intra-abdominal pressure and intra-abdominal hypertension

As shown in Fig. 2, no difference in IAP between the two groups was found during the two weeks after admission. This phenomenon revealed that EEN did not increase IAP during the early stage of SAP.

Thirty-nine patients (65 %, 39/60) developed IAH on admission, whereas 7 (12 %, 7/60) developed it on the 14th day after admission. Figure 3 exhibits the difference in IAH incidence between the two groups. The incidence of the EEN group was significantly lower than that of DEN group from the 9th day after admission (8/30 versus 18/30; $P = 0.009$). Although no significant difference was found at the 14th day after admission (1/30 versus 6/30; $P = 0.103$), the IAH incidence in the EEN group was still numerically lower than that of the DEN group. Therefore, it can be inferred that EEN might be able to prevent the development of IAH in SAP patients.

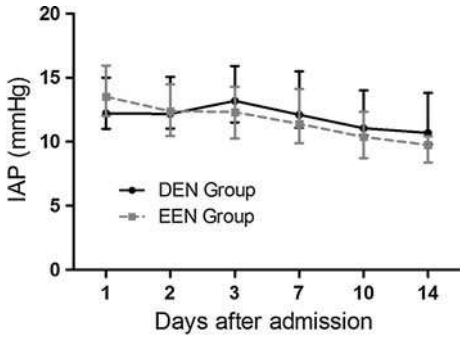


**Fig. 2** Fluctuation tendency of intra-abdominal pressure (IAP) between the early enteral nutrition (EEN) group and the delayed enteral nutrition (DEN) group

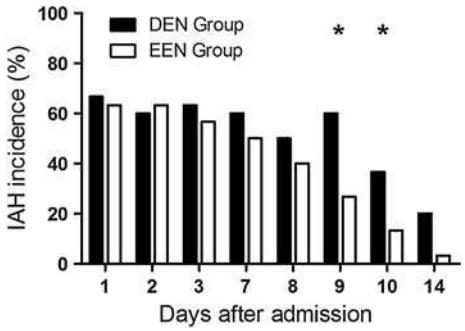


**Fig. 3** Comparison of intra-abdominal hypertension (IAH) incidence between the EEN group and the DEN group $*P < 0.05$

## Enteral nutrition

During the first 3 days of feeding, abdominal distension was the most common intolerance symptoms (day 1:60 %, 36/60; day 2:48 %, 29/60; day 3:32 %, 19/60). As shown in Fig. 4a, the FI incidence in the EEN group was higher than that in the

**Table 1** Demographic data and clinical parameters on admission

| | DEN group ($n = 30$) | EEN group ($n = 30$) | $P$ value |
|---|---|---|---|
| Age, years | 43 (34.5–51) | 45 (35–52) | 0.594 |
| Sex (male:female) | 18:12 | 20:10 | 0.287 |
| Etiology, *n* (%) | | | |
| Biliary origin | 17 (57) | 19 (63) | 0.278 |
| Hyperlipidemia | 8 (27) | 6 (20) | 0.373 |
| Alcohol abuse | 3 (10) | 4 (13) | 1.000 |
| Idiopathic | 2 (7) | 1 (3) | 1.000 |
| BMI | 24.6 (23.5–26.8) | 25.8 (23.9–28.8) | 0.158 |
| APACHE II score | 9.5 (8.5–11) | 10 (8–11.5) | 0.994 |
| SOFA score | 4.5 (3.5–5.5) | 4 (3–5) | 0.880 |
| CRP, mg/L | 203.5 (188–253) | 195 (161–247.5) | 0.214 |
| Duration after disease onset, days | 2 (1.5–2.5) | 1.5 (1–2.75) | 0.783 |

*DEN* delayed enteral nutrition; *EEN* early enteral nutrition; *BMI* body mass index; *APACHE II* acute physiology and chronic health evaluation II; *SOFA* sequential organ failure assessment; *CRP* C-reactive protein

DEN group during the initial 3 days of feeding (25/30 versus 12/30; $P = 0.001$; 22/30 versus 9/30; $P = 0.001$; 15/30 versus 4/30; $P = 0.002$). However, no difference was found from the 4th day of feeding (12/30 versus 6/30; $P = 0.091$), which indicated that too early EN might increase the FI incidence during the early stage of feeding.

Figure 4b displays the difference in daily caloric intake (Kcal) between the two groups. The caloric intake in the EEN group was significantly lower than that in DEN group during the first 3 days of feeding [350 kcal (300–500) versus 600 kcal (300–900); $P = 0.016$; 500 kcal (400–700) versus 1,000 kcal (800–1,350); $P = 0.004$; 950 kcal (875–1,300) versus 1,350 kcal (1,000–1,525); $P = 0.012$)]. In other words, the actual caloric intake in EEN group was insufficient during the initial 3 days of feeding.

Table 2 demonstrates the differences in FI incidence among different IAP groups. We divided patients into four groups according to the levels of IAP. Patients with an IAP >20 mmHg were assigned into group A, $15 \leq$ IAP $\leq 20$ mmHg into group B, $12 \leq$ IAP $< 15$ mmHg into group C, and IAP <12 mmHg into group D. The FI incidence between group A and B as well as group C and D was not different during the 1st week of feeding. The FI incidence of group D was different from that of both group A and B ($P < 0.05$) during the same days, whereas the FI incidence in group C was lower than that of groups A and B from day 3 of feeding ($P < 0.05$).

We also compared the difference in FI incidence between group (A + B) and group (C + D). The results manifested that the FI incidence of group (A + B) (IAP ≥15 mmHg) was significantly higher than that of group (C + D) (IAP <15 mmHg) during the first 7 days of feeding (20/22 versus 17/38; $P < 0.001$; 11/13 versus 8/47; $P < 0.001$; 3/5 versus 3/55; $P = 0.005$). Therefore, we concluded that EN might be performed well in patients with an IAP <15 mmHg.

Severity markers and clinical outcome variables

As shown in Table 3, the APACHE II scores, SOFA scores, and CRP levels of the EEN group were significantly different from those of the DEN group from the 7th day after admission.

**Table 2** The number of patients with FI in different groups of intra-abdominal pressure (IAP)

| IAP (mmHg) | Day 1 of feeding | | Day 3 of feeding | | Day 7 of feeding | |
|---|---|---|---|---|---|---|
| | $n_1$ | $n_2$ | $n_1$ | $n_2$ | $n_1$ | $n_2$ |
| IAP >20 | 5 | 5 | 5 | 5 | 1 | 1 |
| 15 ≤ IAP ≤ 20 | 15 | 17 | 6 | 8 | 2 | 4 |
| 12 ≤ IAP < 15 | 7 | 12 | 3 | 15 | 2 | 16 |
| IAP <12 | 10 | 26 | 5 | 32 | 1 | 39 |
| *P* value | 0.003 | | <0.001 | | <0.001 | |

*FI* feeding intolerance; *IAP* intra-abdominal pressure; $n_1$ the number of patients with feeding intolerance; $n_2$, the number of patients in different intra-abdominal pressure groups

Table 4 shows that the incidences of MODS and pancreatic infection, as well as the duration of ICU stay of the EEN group were all significantly lower than those of the DEN group. Nevertheless, no difference in hospital mortality between the two groups was found.

## Discussion

This prospective pilot clinical trial investigated the effects of EEN on IAP and disease severity in patients with SAP. We found that EEN did not increase IAP; in contrast, it might prevent the development of IAH. However, EEN might also increase the FI incidence during the first 3 days of feeding. In addition, our study concluded that different levels of IAP had various effects on the incidence of FI. Enteral nutrition might be of benefit in patients with an IAP <15 mmHg. Compared with DEN, EEN could ameliorate disease severity and clinical outcome, but not decrease the mortality of SAP patients.

In the present study, the 23 % incidence of hyperlipidemia as the cause for SAP was relatively high. It may reflect the increase in risk factors for hyperlipidemia (e.g.,

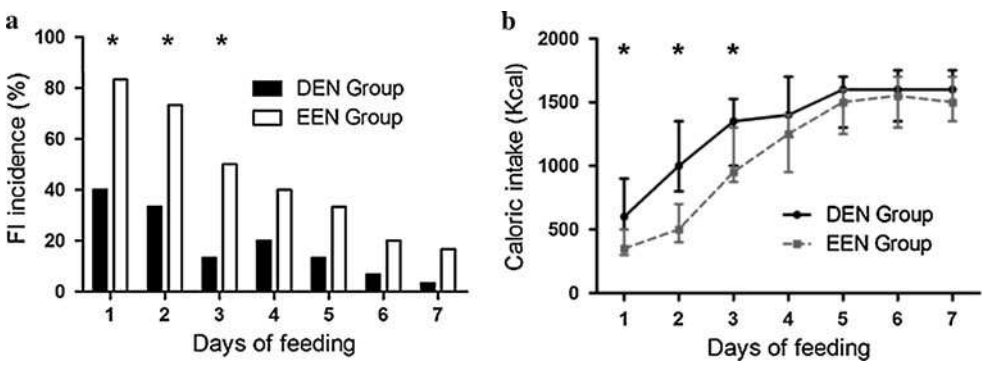


**Fig. 4** Comparison of feeding intolerance (FI) incidence (**a**) and daily caloric intake (**b**) between the EEN group and the DEN group *$P < 0.05$

**Table 3** Clinical markers of severity

| | | DEN group ($n = 30$) | EEN group ($n = 30$) | $P$ value |
|---|---|---|---|---|
| APACHE II score | Day 1 | 10 (8.8–11.5) | 10.5 (9–12) | 0.991 |
| | Day 3 | 9.5 (8.5–11) | 10 (8.5–11) | 0.837 |
| | Day 7 | 8.5 (8–9.5) | 6.25 (6–8.5) | 0.031 |
| | Day 14 | 6.5 (5–8) | 4.5 (3.5–6.5) | 0.028 |
| SOFA score | Day 1 | 5 (3.5–6.5) | 5.5 (4.5–6.5) | 0.885 |
| | Day 3 | 4.5 (4–5.5) | 4 (3–5) | 0.631 |
| | Day 7 | 3.5 (3–4.5) | 1.5 (1–2.5) | 0.021 |
| | Day 14 | 2.75 (1.5–3) | 1 (0.5–1.5) | 0.012 |
| CRP level, mg/L | Day 1 | 197.5 (168–261) | 201.5 (121–268.3) | 0.182 |
| | Day 3 | 206 (156–254) | 162 (120.8–220) | 0.154 |
| | Day 7 | 150.5 (64.5–218.5) | 60 (32.3–143.3) | 0.023 |
| | Day 14 | 44 (17.3–96.8) | 11 (4–33.3) | 0.001 |

**Table 4** Clinical outcome variables

| | DEN group | EEN group | $P$ value |
|---|---|---|---|
| Hospital mortality, $n$ (%) | 3 (1/30) | 7 (2/30) | 1.000 |
| ICU stay, days | 12 (8–21) | 9 (5–14) | 0.033 |
| MODS, $n$ (%) | 43 (13/30) | 17 (5/30) | 0.024 |
| Pancreatic infection, $n$ (%) | 33 (10/30) | 10 (3/30) | 0.028 |

*ICU* intensive care unit; *MODS* multiple organ dysfunction syndrome

obesity, hypertension, or abnormalities of glucose metabolism) throughout China. As one of the possible manifestations of this increasing risk of hyperlipidemia, the BMI of 60 patients in this study was 25.0 (23.7–27.5) (relatively high in the Chinese population) on admission.

The mechanisms underlying the increased IAP in patients with SAP have been described in previous articles. In those reports, retroperitoneal or peripancreatic fluid collections, bowel and visceral edema, and swollen pancreas were the most common causes of the development of IAH [8, 9, 26, 27]. Moreover, aggressive fluid resuscitation, ileus, hypoalbuminemia, and other factors may contribute to the development of IAH [8, 9, 26, 27]. The IAH incidence of 65 % in the present study is consistent with the incidence reported in previous studies, which in patients with SAP ranged from 60 to 80 % [8, 26]. Although the managements of IAH in patients with SAP have been improving [9, 26, 28, 29], the clinical effects remain uncertain, and the mortality associated with this complicated disease is still extremely high [8, 9, 26, 30].

For most patients, nonsurgical interventions should be applied as initial treatment to decrease the IAP in the early stage of SAP [8, 9, 28]. As an essential part of nonsurgical treatments for SAP, EN has become widely accepted in clinical practice. Enteral nutrition, especially EEN, is superior to parenteral nutrition in reducing the incidence of infectious complications, the length of hospital stay, and the mortality in patients with SAP [1, 3, 4]. In accordance with previous studies, our results showed that EEN could probably prevent the development of IAH, although the exact mechanisms underlying this phenomenon remained unknown. Early enteral nutrition increases antioxidant activity and modulates the inflammatory and sepsis response [1, 19, 31, 32], thus reducing the incidence of systemic inflammatory response syndrome and subsequent MODS. Therefore, in the acute phase of SAP, which is characterized by "hyperinflammatory" mechanisms [1], EEN might improve the inflammatory-associated peripancreatic exudation and edema of the intestinal wall. Early enteral nutrition also improves intestinal blood flow and facilitates intestinal motility [1, 2], and this may stimulate bowel peristalsis and thereby decrease the incidence of paralytic ileus. Moreover, EEN maintains gut integrity and prevents bacterial and endotoxin translocation [1, 3], which is considered the main cause of the gut-derived infectious complications of SAP [33]. Accordingly, EEN had the ability to prevent the development of sepsis, which had also proved to be an important risk factor for IAH [24, 25]. However, further studies are required to reveal the precise pathophysiological effects of EEN on IAH.

Feeding intolerance is a common complication of enteral feeding. McClave et al. [34] suggested that intolerance of EN might be related to the peak inflammation of severe pancreatitis within the initial 4–5 days. In contrast, Grau et al. [35] asserted that EEN did not increase the incidence of gastrointestinal complications. Data from this trial showed that EEN might increase the FI incidence during the first 3 days of feeding. Moreover, the caloric intake in the EEN group was also lower than that in the DEN group during the first 3 days of feeding. These consequences suggested that EEN might be not appropriate during the initial 3–4 days after onset of the disease, which actually was not far from McClave's conclusion.

Gudmundsson et al. [6] reported that an IAP of 20 mmHg did not change the gastrointestinal blood flow of pigs, whereas an IAP of 30 mmHg reduced tissue flow of abdominal organs. Diebel et al. [7] revealed that the intestinal mucosal blood flow decreased significantly at an IAP of 20 mmHg and became worse at an IAP of 40 mmHg in pigs. As a serious complication of SAP, IAH led to ischemia and hypoxia of the intestinal tract [5, 8, 9], which might cause the dysfunction of EN absorption. However, the specific effects of different IAP levels on feeding tolerance were still not clear. The findings of current research demonstrated that different levels of IAP had various effects on the incidence of FI. The FI incidence in patients with an IAP $\geq$15 mmHg was significantly higher than that in patients with an IAP <15 mmHg. Our results in human beings indicated that enteral feeding might be accomplished well in patients with an IAP <15 mmHg, which was inconsistent with the previous studies.

Several studies had reported that early initiation of jejunal feeding improved the severity and clinical outcome of SAP [1, 3]. Our study found that the disease severity markers as well as the clinical outcome variables of the EEN group were significantly improved. However, no differences in hospital mortality were found, likely because the study, which had a small sample size, was not powered to find a difference in mortality. In addition, this study found that EEN could prevent the development of IAH in the early phase of SAP. As a common and severe complication of SAP, IAH was also related to high mortality, a high rate of organ failure, and prolonged ICU stay [8, 9, 24–26, 30, 36, 37]. Therefore, the improved outcome of patients in the EEN group might be attributable to both early enteral feeding and reduced occurrence rate of IAH.

Several limitations in this study should be discussed. Because of the small sample size and the single-center design, our results might be uncertain, and their accuracy should be tested by further large-scale studies. Moreover, because this study was not based on a pathophysiological model, the precise mechanisms of EEN in SAP should be verified by more basic experiments. In addition, because our parameters were only recorded for two weeks, the effects of EEN in the later stages of SAP should be confirmed by future studies.

In conclusion, EEN did not increase IAP; in contrast, it might prevent the development of IAH. Early enteral nutrition might be not appropriate during the initial 3–4 days after SAP onset. Moreover, EN might be performed well in patients with an IAP <15 mmHg. Furthermore, EEN had the ability to improve disease severity and clinical outcome, but did not decrease the mortality associated with SAP. Nevertheless, the precise mechanisms of EEN are still not clear, and further studies are required to verify our conclusions.

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**Conflict of interest** The authors declare no conflict of interest

## References

1. Oláh A, Romics L Jr (2008) Early enteral nutrition in acute pancreatitis: benefits and limitations. Langenbecks Arch Surg 393:261–269
2. Bakker OJ, van Santvoort HC, van Brunschot S et al (2011) Pancreatitis, very early compared with normal start of enteral feeding (PYTHON trial): design and rationale of a randomised controlled multicenter trial. Trials 12:73
3. Hegazi R, Raina A, Graham T et al (2011) Early jejunal feeding initiation and clinical outcomes in patients with severe acute pancreatitis. J Parenter Enteral Nutr 35:91–96
4. Kumar A, Singh N, Prakash S et al (2006) Early enteral nutrition in severe acute pancreatitis: a prospective randomized controlled trial comparing nasojejunal and nasogastric routes. J Clin Gastroenterol 40:431–434
5. Deenichin GP (2008) Abdominal compartment syndrome. Surg Today 38:5–19
6. Gudmundsson FF, Gislason HG, Dicko A et al (2001) Effects of prolonged increased intra-abdominal pressure on gastrointestinal blood flow in pigs. Surg Endosc 15:854–860
7. Diebel LN, Dulchavsky SA, Wilson RF (1992) Effect of increased intra-abdominal pressure on mesenteric arterial and intestinal mucosal blood flow. J Trauma 33:45–48
8. De Waele JJ, Leppäniemi AK (2009) Intra-abdominal hypertension in acute pancreatitis. World J Surg 33:1128–1133. doi: 10.1007/s00268-009-9994-5
9. Chen H, Li F, Sun JB et al (2008) Abdominal compartment syndrome in patients with severe acute pancreatitis in early stage. World J Gastroenterol 14:3541–3548
10. Cothren CC, Moore EE, Ciesla DJ et al (2004) Postinjury abdominal compartment syndrome does not preclude early enteral feeding after definitive closure. Am J Surg 188:653–658
11. Bradley EL 3rd (1993) A clinically based classification system for acute pancreatitis. Summary of the international symposium on acute pancreatitis, Atlanta, Ga, September 11–13, 1992. Arch Surg 128:586–590
12. Tao HQ, Zhang JX, Zou SC (2004) Clinical characteristics and management of patients with early acute severe pancreatitis: experience from a medical center in China. World J Gastroenterol 10:919–921
13. De Campos T, Braga CF, Kuryura L et al (2008) Changes in the management of patients with severe acute pancreatitis. Arq Gastroenterol 45:181–185
14. Mao EQ, Tang YQ, Fei J et al (2009) Fluid therapy for severe acute pancreatitis in acute response stage. Chin Med J (Engl) 122:169–173
15. Brisinda G, Vanella S, Crocco A et al (2011) Severe acute pancreatitis: advances and insights in assessment of severity and management. Eur J Gastroenterol Hepatol 23:541–551
16. Van Baal MC, van Santvoort HC, Bollen TL et al (2011) Systematic review of percutaneous catheter drainage as primary treatment for necrotizing pancreatitis. Br J Surg 98:18–27
17. McClave SA, Martindale RG, Vanek VW et al (2009) Guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient: society of critical care medicine

(SCCM) and American society for parenteral and enteral nutrition (A.S.P.E.N.). J Parenter Enteral Nutr 33:277–316
18. Kreymann KG, Berger MM, Deutz NE et al (2006) ESPEN guidelines on enteral nutrition: intensive care. Clin Nutr 25:210–223
19. Rice TW, Swope T, Bozeman S et al (2005) Variation in enteral nutrition delivery in mechanically ventilated patients. Nutrition 21:786–792
20. Rice TW, Mogan S, Hays MA et al (2011) Randomized trial of initial trophic versus full-energy enteral nutrition in mechanically ventilated patients with acute respiratory failure. Crit Care Med 39:967–974
21. Spanier BW, Bruno MJ, Mathus-Vliegen EM (2011) Enteral nutrition and acute pancreatitis: a review. Gastroenterol Res Pract. doi:10.1155/2011/857949
22. Reintam A, Parm P, Redlich U et al (2006) Gastrointestinal failure in intensive care: a retrospective clinical study in three different intensive care units in Germany and Estonia. BMC Gastroenterol 6:19
23. Gianotti L, Meier R, Lobo DN et al (2009) ESPEN guidelines on parenteral nutrition: pancreas. Clin Nutr 28:428–435
24. Cheatham ML, Malbrain ML, Kirkpatrick A et al (2007) Results from the international conference of experts on intra-abdominal hypertension and abdominal compartment syndromeII. Recommendations. Intensive Care Med 33:951–962
25. Malbrain ML, Cheatham ML, Kirkpatrick A et al (2006) Results from the international conference of experts on intra-abdominal hypertension and abdominal compartment syndrome. I. Definitions. Intensive Care Med 32:1722–1732
26. De Waele JJ, Hoste E, Blot SI et al (2005) Intra-abdominal hypertension in patients with severe acute pancreatitis. Crit Care 9:R452–R457
27. Dambrauskas Z, Parseliunas A, Gulbinas A et al (2009) Early recognition of abdominal compartment syndrome in patients with acute pancreatitis. World J Gastroenterol 15:717–721
28. Oda S, Hirasawa H, Shiga H et al (2005) Management of intra-abdominal hypertension in patients with severe acute pancreatitis with continuous hemodiafiltration using a polymethyl methacrylate membrane hemofilter. Ther Apher Dial 9:355–361
29. De Waele JJ, Hoste EA, Malbrain ML (2006) Decompressive laparotomy for abdominal compartment syndrome: a critical analysis. Crit Care 10:R51
30. Ke L, Ni HB, Sun JK et al (2012) Risk factors and outcome of intra-abdominal hypertension in patients with severe acute pancreatitis. World J Surg 36:171–178. doi:10.1007/s00268-011-1295-0
31. Windsor AC, Kanwar S, Li AG et al (1998) Compared with parenteral nutrition, enteral feeding attenuates the acute phase response and improves disease severity in acute pancreatitis. Gut 42:431–435
32. Meier R, Ockenga J, Pertkiewicz M et al (2006) ESPEN guidelines on enteral nutrition: pancreas. Clin Nutr 25:275–284
33. Ammori BJ (2003) Role of the gut in the course of severe acute pancreatitis. Pancreas 26:122–129
34. McClave SA, Dryden GW (2002) Issues of nutritional support for the patient with acute pancreatitis. Semin Gastrointest Dis 13:154–160
35. Grau T, Bonet A, Grupo de Trabajo de Metabolismo y Nutrición de la Sociedad Española et al (2005) Multicenter study on incidence of total parenteral nutrition complications in the critically-ill patient ICOMEP study. Part II. Nutr Hosp 20:278–285
36. Al-Bahrani AZ, Abid GH, Holt A et al (2008) Clinical relevance of intra-abdominal hypertension in patients with severe acute pancreatitis. Pancreas 36:39–43
37. Ke L, Tong ZH, Ni HB et al (2012) The effect of intra-abdominal hypertension incorporating severe acute pancreatitis in a porcine model. PLoS One 7:e33125