Original Article

Enteral nutrition preference in critical care: fibre-enriched or fibre-free?

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Background and Objectives: This study's main aim was to observe the effects of a fibre-enriched nutrition solution on requisite feeding volume, which is directly proportional to energy intake in mechanically ventilated patients with enteral nutrition. **Methods and Study Design:** Some 120 patients who required mechanical ventilation and enteral nutrition with a nasogastric tube were studied. Upon ICU admission, the patient's age, gender, weight, height, comorbidities, diagnosis and APACHE II score were recorded. We assigned two diets to the patients randomly. The control group received the fibre-free nutrition solution. The study group, received the fibre-enriched nutrition solution. Prescribed feeding volume and administered feeding volume, gastric residual volume (GRV), volume ratio (VR), diarrhoea score and gastrointestinal complications (GIC) were recorded, along with daily biochemistry. **Results:** The two groups did not differ with respect to age, sex, weight, BMI, APACHE II score, target caloric intake or GRV ($p>0.05$). On days four and five, the study group had higher VR values ($p<0.05$). Seventy-one (59%) patients had at least one gastrointestinal complication; 44 (73%) of them were controls and 27 (45%) of them study patients. The most commonly observed GIC was diarrhoea. Thirty-eight patients had diarrhoea in control group, and twenty-two patients had diarrhoea in study group, and this difference was statistically significant ($p<0.001$). There were no significant differences between the groups about vomiting and regurgitation. **Conclusions:** We suggest that ICU staff initiate enteral nutrition with fibre-enriched formulas rather than fibre-free formulas to avoid frequent feeding interruptions that cause protein energy malnutrition in ICU patients.

Key Words: fibre-enriched nutrition, volume ratio, diarrhoea, enteral nutrition, gastric residual volume

INTRODUCTION

Studies have shown that enteral nutrition is essential for the feeding of intensive care unit (ICU) patients with healthy gastrointestinal systems.[1] Inefficient nutrition volume administrations cause low daily caloric intake, which is correlated with destructive complications, such as immunosuppression, increased risk of infections and high mortality.[2-5] Thus, uninterrupted, efficient nutrition is crucial in ICU patients. However, conflicting information exists in the literature regarding the preference of enteral feeding solutions. Research on osmolality, fat content, caloric intensity and fibre content of the formulas is ongoing, and a notable amount of studies have focused on fibre content. In regards to fibres that exist in nutrition solutions, oligofructose or fructo-oligosaccharide (FOS) is a short-chain fructan that naturally exists in plants, and it is a soluble, highly fermentable, prebiotic fibre. Inulin is another fructan that is soluble and fermentable and has prebiotic effects. Acacia fibre, which has the same chemical structure as arabic gum, is a soluble and fermentable fibre. Soy polysaccharide is an insoluble fermentable fibre, and resistant starch and alpha cellulose are insoluble and non-fermentable fibres.

The main aim of this study was to observe the effects of a fibre-enriched nutrition solution on requisite feeding volume, which is directly proportional to caloric intake in mechanically ventilated patients with enteral nutrition. Administering the necessary feeding volume depends on gastrointestinal system function; thus, the secondary goal of this study was to investigate the incidence of gastrointestinal complications. Biochemical parameters were evaluated as a prediction of nutrition insufficiency.

METHODS

This study was conducted in a 25-bed adult medical ICU in an education and research hospital. The study was approved by the Institutional Review Board of the hospital. Written informed consent was obtained from the patients' next of kin before beginning the study.

This study included 120 participants who were between 35-90 years of age and were of both genders. All patients were chosen from individuals admitted to our ICU with

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acute cerebrovascular disease (e.g. ischemia, haemorrhage) who required mechanical ventilation and enteral nutrition with a nasogastric tube. Upon ICU admission, the patient's age, gender, weight, height, comorbidities, diagnosis and APACHE II (Acute Physiology and Chronic Health Evaluation) score were recorded. Patients who were fed within 48 h after ICU admission were included in the study. The exclusion criteria were the following: unstable haemodynamic values, sepsis, contraindications for enteral feeding (gastrointestinal tract obstruction, haemorrhage and ileus), pancreatitis, gastrointestinal diseases (ulcerative colitis, Chron's disease and ischaemic or infectious colitis), obese patients (body mass index (BMI) >35 kg/m^2), malnutrition syndromes, immunosuppressed patients and severe biochemical results on admission day. Additionally, patients who were given broad-spectrum antibiotics for a severe infection, whether gastrointestinal or not, were excluded from study.

After ICU admission, a nasogastric tube (12 or 14 Fr, Compat Soft Y; Nestle Nutrition; Germany) was inserted in all patients who were mechanically ventilated and could not be fed orally. Every day, the positioning of the tube was checked radiologically. All patients were managed in the semi-recumbent position (30-45°) to decrease pneumonia incidence**.** Mechanical ventilation settings were adjusted according to the patients' artery blood gas results.

Sealed, numbered envelopes were used for randomization. The medical staff who performed the GI measurements and assessed GI complications were blind to the study. We assigned two diets to the patients randomly. The control group, Group FF, received the fibre free nutrition solution Nutrison (500 mL, Nutricia Advanced Medical Nutrition; Netherlands). The study group, Group FE, received the fibre-enriched nutrition solution Nutrison multifibre (500 mL, Nutricia Advanced Medical Nutrition; Netherlands). The characteristics of 500 mL of Nutrison/Nutrison multifibre are as follows: energy 500 kcal/515 kcal, protein 20 g/20 g, carbohydrate 61.5 g/61.5 g, fat 19.5/19.5 g and osmolarity 255 mOsmL-1/300 mOsmL-1. Nutrison multifibre contains both soluble and insoluble fibres in approximately a 1:1 ratio, 0.7 g and 0.8 g per 100 mL, respectively. The content of the six fibres in the solution are 32% soy polysaccharides, 24% arabic gum, 12.5% inulin, 12% alpha-cellulose, 10.5% oligofructose and 9% resistant starch. All patients were given the nutrition solution using an enteral feeding pump (Kangaroo Enteral Feeding Pump; Covidien; USA). None of the patients received any broad-spectrum antibiotics or antidiarrhoeal or laxative agents such as lactulose, sorbitol or glycerin suppositories. Metoclopramide was administered twice a day to all patients as a prokinetic agent.

Energy administration was aimed at 25-35 kcal/kg/day and was given from 18-24 h every day at a constant rate. On the first day, 50% of the required energy intake was administered, followed by 75% on the second day and 100% on the third day. Enteral nutrition was started at a rate of 20 mL/h and increased at six hour intervals to 40 mL/h, 80 mL/h, 100 mL/h and, if needed, to 120 mL/h. If the patient did not tolerate the nutrition feeds according to the gastric residual volume (GRV) values mentioned below at any time of the day, nutrition rate was decreased to the previous rate. Tolerance to nutrition was assessed daily as the GRV. During the first day of enteral nutrition, GRV was measured every 6 h. On the second day, GRV was measured every 8 h, and for the patients who tolerated the enteral nutrition well, GRV was measured once a day after the third day. GRV was measured by connecting a drainage bag to the nasogastric tube and waiting 15 mins for gravity drainage. The patients were considered to have tolerated the enteral nutrition well when the GRV was <500 mL daily, and those who consumed at least 750 mL of enteral nutrition with <500 mL GRV a day, were included in the study protocol.

The efficiency of the enteral nutrition was measured daily by volume ratio (%).

VR (%) = (administered volume of nutrition / prescribe volume of nutrition) x 100.

During the study, prescribed feeding volume and administered feeding volume, GRV, RV, diarrhoea scores and gastrointestinal complications (GIC) (distension, vomiting, regurgitation and constipation) were recorded. The definitions and managements of the gastrointestinal complications were as follows:

1. Abdominal distention was defined as the presence of excessive amounts of gases in the stomach or intestine. It was diagnosed with tympany or the absence of bowel sounds during physical examination. After ruling out intraabdominal pathologies, nutrition was decreased to half the normal rate when distention was detected. In the following 12 h, if the distension disappeared, nutrition was increased to the original rate, and if it persisted, nutrition was ruled out as its cause.
2. Regurgitation was defined as the observation of enteral formula in the oral cavity. If regurgitation was detected, intraabdominal pathologies were searched for by radiological examination. If a pathology was found, such as ileus or tract obstruction, nutrition was withdrawn, and if GI functioning was normal, nutrition was continued.
3. Vomiting was defined as ejection of the enteral formula through the mouth. The management of the vomiting was same as that for regurgitation.
4. Constipation was defined as the absence of defecation for more than three days. If constipation was observed, the nutrition infusion route was not changed, but a laxative or enema was administered.
5. Diarrhoea was assessed according to a score defined by Hart and Dobb[6] (Table 1). Each stool of the patient was scored according to its estimated volume and consistency. The sum of the scores in 24 h was the diarrhoea score of the patient. Diarrhoea was defined as a daily score ≥12. If liquid stools were observed more than five times a day or the total estimated volume of the stools was ≥2,000 mL/day, the patient was exam-

Table 1. Diarrhoea score as proposed by Hart and Dobb[6]

Consistency	Estimated volume (mL)		
	<200	200-250	>250
Formed	1	2	3
Semi-solid	3	6	9
Liquid	5	10	15

Table 2. Patient characteristics

	Fibre-free group (n=60)	Fibre-enriched group (n=60)
Age (yr) (mean±SD)	70±15	71±14
Gender (m/f) (n)	26/34	24/36
Weight (kg) (mean±SD)	76.7±9.8	76±10.6
BMI (kg/m^2) (mean±SD)	27.2±3.7	27±4.5
APACHE II Score (mean±SD)	15.7±2.6	15.7±2.9
Target energy intake(kcal/kg/day) (mean±SD)	2272±273	2282±295

ined for GI problems. If a problem was detected, nutrition was withdrawn. If no problem was detected, the nutrition infusion rate was decreased to half of the normal rate, and the patient was observed for diarrhoea for 8 h. After 8 h, if the diarrhoea decreased, nutrition infusion was returned to the original rate. If the severity of the diarrhoea persisted, the nutrition product was changed, and the patient was withdrawn from the study.

The patients were considered as tolerant of the enteral nutrition well if the nutrition feeds did not need any interruption as a consequence of the complications defined above.

As an important complication, pulmonary aspiration was also taken into account. It was diagnosed when enteral formula was found in the tracheal aspirate. Pulmonary aspirated patients were excluded from the study and managed according to a special aspiration pneumonia treatment protocol.

Daily biochemical parameters (haemoglobulin, total protein, albumin, prealbumin, total cholesterol, calcium, phosphate, magnesium, sodium, potassium, glucose, urea, creatinine, alanine aminotransferase and aspartate amino transferase) were recorded. The statistical package SPSS 20.0 for Windows (SPSS Inc, Chicago, IL) was used for the statistical analysis. All values are expressed as the means ± standard deviation. Qualitative data were analysed by the chi-square test. Quantitative data were analysed by analysis of variance or the Mann-Whitney U-test. The haemodynamic parameters obtained at various time intervals within the same group were compared with the baseline values using the paired *t*-test. As both parameters were normally distributed, the correlation coefficients and their significance were calculated using the Pearson test. A *p*-value of ≤0.05 was deemed significant.

Table 3. Gastrointestinal tolerance over five days

Daily GRV (mean±SD)	Fibre-free group (n=60)	Fibre-enriched group (n=60)	*p* value
Day 1	138±100	113±96	0.205
Day 2	136±115	127±116	0.748
Day 3	114±91	126±98	0.764
Day 4	117±114	129±100	0.819
Day 5	97±72	122±93	0.240

Table 4. Daily volume ratio (%) (mean±SD) according to groups and gastrointestinal complications (GIC)

	Fibre-free group (n=60)	Fibre-enriched group (n=60)	*p* value
Day 1	78.5±12.3	75.9±11.0	0.108
Day 2	81.4±11.9	83.4±11.2	0.310
Day 3	82.0±13.6	85.9±11.9	0.096
Day 4	81.0±13.5	86.4±12.6	0.021
Day 5	80.8±14.3	89.4±12.4	0.000
Mean	80.8±9.6	84.2±9.8	0.035

Table 5. Daily volume ratio (%) (mean±SD) according to gastrointestinal complications (GIC)

	Patients with GIC (n=71)	Patients without GIC (n=49)	*p* value
Day 1	72.8±12.2	83.6±7.3	<0.0001
Day 2	76.5±10.9	90.9±5.8	<0.0001
Day 3	78.1±13.0	92.3±6.4	<0.0001
Day 4	76.7±12.6	93.9±4.9	<0.0001
Day 5	77.5±13.2	96.2±4.3	<0.0001
Mean	76.3±7.6	91.4±4.1	<0.0001

RESULTS

A total of 120 patients were studied. After the initiation of the study, none of the patients were excluded from the study for the indications outlined in the methods section. The two groups did not differ with respect to age, sex, weight, BMI, APACHE II score or target caloric intake (Table 2).

There was no difference between the groups in the daily GRV measurements (Table 3). Only four patients' GRV values exceeded 500 mL for one day; three of those patients were in Group FF, and one was in Group FE.

The main goal of this study was to assess the efficiency of the nutrition solutions. This was established with daily VR measurements. In the first three days of the study, there was no difference in the VR values between the groups. However, on days four and five, Group FE had higher VR values, and this difference was statistically significant ($p<0.05$) (Table 4, 5). The data analysis of all patients collectively showed that VR was higher in the patients lacking GICs ($p<0.001$), and this relationship was consistent throughout the entire study. Seventy-one (59%) patients had at least one gastrointestinal complication; 44 (73%) of them were in Group FF, and 27 (45%) of them were in Group FE. This difference was statistically significant and was the second main result of the study ($p<0.01$). The most commonly observed gastrointestinal complication in this study was diarrhoea. Sixty patients (50%) had diarrhoea for at least one day of the study; 38 of them were in Group FF, and 22 of them were in Group FE, and this difference was statistically significant ($p<0.001$). The daily diarrhoea score was used to obtain more information about the diarrhoea. In the first two days, there was not a significant difference in the daily diarrhoea score between the groups. However, in last three days, Group FF had higher diarrhoea scores, and this difference was statistically significant ($p<0.01$). The mean diarrhoea scores over the five days of the study in

Table 6. Gastrointestinal complications over five days

	Fibre-free group (n=60)	Fibre-enriched group (n=60)	*p* value
Daily diarrhoea score (mean±SD)			
Day 1	8.5±6.9	7.1±7.1	0.055
Day 2	8.7±7.5	7.1±5.6	0.147
Day 3	10.2±8.0	7.6±6.1	0.009
Day 4	11.7±7.8	8.6±6.6	0.008
Day 5	12.0±8.4	7.3±5.9	<0.0001
Diarrhoea score for five days (mean±SD)	10.2±5.4	7.5±4.7	<0.0001
Patients at least 1 day with diarrhoea (n)	38	22	0.006
Regurgitation (n)	9	10	1.0
Vomiting (n)	10	9	1.0
Distension (n)	18	25	0.253
Constipation	2	2	1.0

Group FF and Group FE were 10.2±5.4 and 7.5±4.7, respectively, and this difference was statistically significant ($p<0.001$). Severe diarrhoea, as defined above, was not observed in any patients. There were no significant differences between the groups for the other gastrointestinal complications (vomiting, regurgitation, distention and constipation) (Table 6). Nine patients (15%) in Group FF and ten patients (16%) in Group FE had regurgitation. Ten patients (16%) in Group FF and nine patients (15%) in Group FE vomited. 18 patients (30%) in Group FF and 25 patients (42%) in Group FE had abdominal distention. Two patients (3%) in each group were constipated, and all of them were treated successfully with an enema or laxatives. Other complications were not severe and were managed with the protocols described above. The biochemical parameters on day one and day five were compared. There were no statistically significant differences in any of the biochemical parameters between the groups.

DISCUSSION

The patients studied were admitted to the ICU with acute cerebrovascular disease. We excluded patients with intestinal pathologies and infectious diseases, such as sepsis, as these comorbidities and the therapies used to treat them could affect intestinal function. The main outcome of the study was that of preferred nutrition feed for gastrointestinal function. We showed that fibre-free nutrition generated higher gastrointestinal complications, especially diarrhoea, than fibre-enriched nutrition. To demonstrate the consequences of the gastrointestinal complications like diarrhoea, volume ratio was used; it provided a measure of feed efficiency. The main result of this study was that fibre-enriched nutrition resulted in less gastrointestinal complications and higher VR values, which was predictive of more effective patient nutrition.

Montejo et al[7] found that the most frequent complication in enteral nutrition was high gastric residual volume. This is different from the results of our study and may be due to the use of a different nutrition solution or different GRV measurement methods. At present, a clear consensus regarding the measurement method and the limits of gastric residual volume has not been reached. In our clinical practice, enteral nutrition is started at a rate of 20 mL/h and is increased gradually. If, the gradual increment is not interrupted on account of intolerance and the patient receives the prescribed feed volume, daily GRV measurement is sufficient to anticipate upper gastrointestinal tract tolerance. When this was not the case, during the first days of enteral nutrition, we measured GRV frequently (three or four times a day). Additionally, the routine metoclopramide administration in our study may have been another factor that caused the low gastric residual volumes that we observed.

Chang et al[8] reported that drugs (e.g. antibiotics), infections, illness severity and enteral feedings are the causes of diarrhoea in the ICU. Whelan et al[9] reported that the frequency of diarrhoea in enteral-fed patients ranged from 2 to 95% and that this large variation was due to different definitions of diarrhoea and different measurement methods. In the present study, the most frequent complication was diarrhoea, and it occurred in 50% of patients. Enteral nutrition is a contributing factor to ICU diarrhoea because it alters gut physiology. Whelan et al[10] hypothesized that enteral feeding changes both transit time, secretory mechanisms and the microbiota in the gastrointestinal tract. Luft et al[11] showed the importance of enteral feeding solution and feeding equipment sterility by decreasing the frequency of diarrhoea using hygiene protocols. The properties of nutrition solutions that have been examined for their diarrhoeal effects are temperature, osmolality, fat content and caloric density, but strict guidelines for these properties of nutrition solutions have not been made.[12]

One of the most controversial components of feeding solutions is fibre. Dietary fibre has been shown to have various effects by multiple studies. Krusawa et al[13] and Cummings JH[14] showed that dietary fibre increases stool weight allowing for easier defecation. Salmeron et al[15] reported glucose regulating effects of dietary fibre. Fibres that promote beneficial bacterial growth, such as that of lactobacillus and bifidobacteria, are called prebiotics. Prebiotics improve gut barrier function and host immunity and reduce the overgrowth of pathogenic bacteria, such as clostridia.[16] Inulin and FOS are the main prebiotics in our study solution. As examples of the immunological support provided by prebiotics, it has been shown that FOS consumption increases T-lymphocytes in adults, increases antibody response to vaccines in infants and reduces antibiotic consumption.[17-19] Elia et al[20] reported a systemic review and meta-analysis that proved that fibre-enriched feeding formulas reduce diarrhoea incidence. Chittawatanarat et al[21] showed that mixed fibre formulas, like our formula, in particular, can reduce diarrhoea in septic ICU patients receiving broad spectrum antibiotics. Soluble fibres (e.g. pectin, FOS, inulin, guar gum) have antidiarrhoeal mechanisms. Namely, after soluble fibre fermentation by colonic anaerobic bacteria, short-chain fatty acids (SCFAs) are produced. SCFAs are beneficial for colonocytes and stimulate water uptake.[21,22] Majid et al[23] reported that fibres reduced diarrhoea incidence and acted as a type of prebiotic. Rushdi et al[24] performed a study with only one type of fibre, guar gum, and still found that fibre-enriched nutrition reduced diarrhoeal episodes. The required amount of fibre needed to decrease the incidence of diarrhoea has not yet been determined. In a meta-analysis, Elia et al[20] reported that the beneficial mean fibre intake amount is approximately 30 g/day in most studies. In the present study, the fibre-enriched group mean fibre intake was approximately 28 g per day, which is in agreement with the results of the meta-analysis.

Controversially, there have been studies that did not show beneficial effects of fibres. Hart et al[6] and Dobb et al[25] reported that fibre-enriched nutrition did not reduce diarrhoea frequency. These conflicting results may be due to differences in the types of fibres used in those studies.

Jack et al[26] reported that the consequences of diarrhoea are electrolyte imbalance, dehydration, perianal skin breakdown and wound contamination. In the present study, low risk ICU patients were examined in respect to gastrointestinal complications; thus, we did not observe these consequences of diarrhoea in our short study period. In our opinion, one of the most important consequences of diarrhoea is the compulsory cessation of enteral nutrition.

Majid et al thought that diarrhoea may contribute to malnutrition in ICU patients.[27]

In the present study, the two groups were similar in regards to the biochemical measurements at the beginning of the study, and no differences were found at the end of the study. Rushdi et al[24] reported higher calcium and magnesium levels in a fibre-enriched group compared with a control group, but did not find a difference in albumin level. These variable results between studies may be due to the different fibres used or to the small sample sizes of those studies.

For diarrhoea management in enteral-fed patients, various protocols have been used. Decreasing the nutrition infusion volume and nutrition interruption are the basics of diarrhoea management, and changing the feeding formula is another technique for diarrhoea management.[7] In these circumstances, energy intake and metabolic requirements (glucose, electrolytes and protein) must be replaced with intravenous solutions. Unnecessary intravenous access for parenteral replacement is a cause of ICU infections. Protein-energy malnutrition causes many complications in ICU patients, and mortality increases with these complications, especially infectious complications and immunosuppression.[2-5]

In conclusion, gastrointestinal complications have various harmful consequences in ICU patients. Diarrhoea is one of the most frequent complications in tube-fed patients and is a complicating factor for enteral nutrition management. On the basis of the present study, we suggest that ICU staff initiate enteral nutrition with fibre-enriched formulas rather than fibre-free formulas to avoid frequent feeding interruptions which cause protein-energy malnutrition in ICU patients.

AUTHOR DISCLOSURES

None.

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重症监护中的肠内营养选择：富含还是不含膳食纤维?

背景与目的：本研究的主要目的是观察一个富含纤维营养液对必要给与量的影响，这与机械通气的肠内营养患者能量摄入成正比。**研究设计与方法**：对需要机械通气和肠内营养鼻饲管的 120 例患者进行了研究。在进入 ICU 前，记录患者的年龄、性别、体重、身高、疾病、诊断和 APACHE II 评分。我们随机将患者分至两种饮食。对照组给予无膳食纤维营养液。研究组给与富含膳食纤维营养液。在每日生化检测时，记录处方量和实际给予量、胃残留量（GRV）、体积比（VR）、腹泻评分和胃肠道并发症（GIC）。**结果**：两组患者的年龄、性别、体重、BMI、APACHEⅡ评分、热量摄入或 GRV 均无统计学意义（$p>0.05$）。在第 4 和 5 天时，研究组的 VR（$p<0.05$）较高。71（59%）例患者至少有 1 种胃肠道并发症，其中对照组 44 例（73%），研究组 27 例（45%）。腹泻是最常见的 GIC。对照组 38 例、研究组 22 例患者有腹泻（$p<0.001$）。两组间呕吐和反流的发生率无统计学意义。**结论**：我们建议，对 ICU 患者启动肠内营养与富含膳食纤维的配方，而不是无膳食纤维配方，以避免频繁喂养中断导致蛋白质-能量营养不良。

关键词：富含纤维营养、体积比、腹泻、肠内营养、胃残留量