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Adequacy of early enteral nutrition in adult patients in the intensive care unit

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Abstract

Aims and objectives—To evaluate the adequacy of energy and protein intake of patients in a Korean intensive care unit in the first four days after initiation of enteral feeding and to investigate the factors that had impact on adequate intake.

Background—Underfeeding is a common problem for patients hospitalised in the intensive care unit and is associated with severe negative consequences, including increased morbidity and mortality.

Design—A prospective, cohort study was conducted in a medical intensive care unit of a university hospital in Korea.

Methods—A total of 34 adult patients who had a primary medical diagnosis and who had received bolus enteral nutrition for the first four days after initiation of enteral nutrition were enrolled in this study. The data on prescription and intake of energy and protein, feeding method and feeding interruption were recorded during the first four days after enteral feeding initiation. Underfeeding was defined as the intake <90% of required energy and protein.

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Contributions
Study design: HK (Kim), NS, EF, ME, CP, HK (Kwak); data collection and analysis: HK (Kim), NS, HK (Kwak) and manuscript preparation: HK (Kim), NS, EF, ME, CP, HK (Kwak).

Conflict of interest
There are no conflicts of interest concerning this study.

Results—Most patients (62%) received insufficient energy, although some (29%) received adequate energy. More than half of patients (56%) had insufficient protein intake during the first four days after enteral feeding was initiated. Logistic regression analysis showed that the factors associated with underfeeding of energy were early initiation of enteral nutrition, under-prescription of energy and prolonged interruption of prescribed enteral nutrition.

Conclusion—Underfeeding is frequent in Korean critically ill patients owing to early initiation, under-prescription and prolonged interruption of enteral feeding.

Relevance to clinical practice—Interventions need to be developed and tested that address early initiation, under-prescription and prolonged interruption of enteral nutrition. Findings from this study are important as they form the foundation for the development of evidence-based care that is badly needed to eliminate underfeeding in this large vulnerable Korean intensive care unit population.

Keywords

critical care; enteral nutrition; nursing practice; overfeeding; underfeeding

Introduction

Nutritional support is essential for critically ill patients in the intensive care unit (ICU). It provides energy, protein and other nutrients for patients who cannot be fed orally. Considerations in determining the type and amount of nutritional support depend on the patient's underlying medical condition, nutritional status and available route of nutrient delivery (McClave *et al.* 2009). The optimal nutrient route of administration in the ICU minimises feeding technique–related complications, thereby providing optimal nitrogen balance, maintaining lean body mass, and results in better clinical outcomes (Cerra *et al.* 1997, Cartwright 2004).

Enteral nutrition is preferred route of administration for critically ill patients who cannot tolerate oral feeding (McClave *et al.* 2009). However, it frequently fails to deliver sufficient nutritional requirements to the critically ill (Elpern *et al.* 2004, O'Leary-Kelley *et al.* 2005). An average of 37–68% of patients are fed less than their nutritional requirements with enteral nutrition (O'Leary-Kelley *et al.* 2005, Kim *et al.* 2010). An international multicenter observational study conducted in 158 ICUs from 20 countries also reported that the average adequacy of energy intake in patients was 52% (Cahill *et al.* 2010). This is a serious problem in critically ill patients because underfeeding and protein depletion are associated with the loss of lean body mass, including cardiac and respiratory muscles, prolonged weaning from mechanical ventilation, delayed wound healing, impaired immune host defences, increased rates of nosocomial infections, organ failure and increased hospital length of stay (McClave *et al.* 1998, Villet *et al.* 2005, Dvir *et al.* 2006).

To optimise patient outcomes, adequate nutritional support is clearly indicated in the critically ill. Monitoring and evaluating nutritional intake are key factors in determining adequate nutritional support and delivery. It is important to identify the causes of inadequate delivery of enteral nutrition.

Many studies have discovered multiple factors that affect the delivery of enteral nutrition in critically ill patients in the USA. These factors include: patient-related factors (age, gender, severity of disease, nutritional status, mechanical ventilation), feeding method (feeding formula, feeding tube location), feeding process (feeding initiation time, feeding administration rate), under-prescription by physicians and frequent interruption of enteral nutrition (McClave *et al.* 1999, De Jonghe *et al.* 2001, Esparza *et al.* 2001, Ibrahim *et al.* 2002, Krishnan *et al.* 2003, O'Leary-Kelley *et al.* 2005, Reid 2006, Desachy *et al.* 2008). However, the impact of these factors on the adequacy of nutritional intake is inconsistent in critically ill patients.

Similarly, under-prescription of enteral nutrition is a major reason for underfeeding in Korea (Park *et al.* 2001). Frequent interruptions of enteral nutrition are considered an important cause of underfeeding in the critically ill (Kim *et al.* 2010). There are limited data about the adequacy of enteral nutritional intake in Korean ICU patients. It is not clear which factors affect adequate nutritional support and delivery in this population. Identification of these factors will provide a basis for the development of nutritional interventions that will improve clinical outcomes and survival of enterally fed patients in the Korea ICU.

Aims

The objective of this study was to determine the adequacy of nutritional support by assessing energy and protein intake for the first four days after initiation of enteral nutrition and to identify the factors that affect adequate intake in Korean ICU patients receiving enteral nutrition. The specific aims were to determine: (1) the proportion of study subjects who were underfed, overfed or adequately fed in terms of energy, (2) the proportion of study subjects who were underfed and adequately fed in terms of protein, and (3) the contribution of factors that had an impact on the adequacy of energy intake.

Methods

Design and sample

A prospective, cohort study was conducted in the adult medical ICU of a tertiary care university hospital in Korea, from July to September 2010. Patients were eligible for the study if they were 18 years or older, hospitalised in the ICU, had a primary medical diagnosis, had physician orders to initiate enteral nutrition and were expected to require enteral tube feeding for at least four days. Patients were excluded if they were receiving parenteral or oral feeding as a main energy source and had a surgical intervention at the time of enrolment. The researcher (HK) screened medical ICU patients based on the inclusion criteria using the medical record. Potential subjects or their legal surrogates received information in the hospital about the study and were asked to provide written informed consent for participation in the study.

A total of 45 subjects met the inclusion criteria, consented to participate and were enrolled in the study. Eleven patients (24%) were withdrawn from the analysis for the following reasons: changed to parenteral nutrition ($n = 5$), shifted to oral feeding ($n = 3$), transferred from the unit ($n = 2$) or expired ($n = 1$) during the four-day study period. Thus, the sample for this study was 34 patients who received enteral nutrition for the first four days after initiation of enteral nutrition.

Variables and measures

Adequacy of energy intake—Energy intake was obtained daily from reviewing each patient's medical records. Energy intake via the enteral route was determined by multiplying the amount of enteral formula received by the energy content of the formula (Binnekade *et al.* 2005). In the ICU, dextrose is frequently used to mix antibiotics or manage hypoglycaemia. Dextrose and total parenteral nutrition are combined with enteral nutrition in some patients. As the enteral nutrition approaches goal rate, the parenteral nutrition is decreased until it is discontinued (Engel *et al.* 2003, Kim *et al.* 2010). Therefore, total energy intake included energy provided via enteral nutrition or combined enteral/parenteral nutrition, plus dextrose.

To assess the adequacy of energy intake, patients were categorised into three groups (adequate feeding, underfeeding, overfeeding). Adequate feeding of energy was defined as total energy intake between 90–110% of the energy requirement. Underfeeding was defined as intake <90% of energy requirements and overfeeding as intake more than 110% (Binnekade *et al.* 2005, O'Leary-Kelley *et al.* 2005).

Energy requirements were calculated using the Harris–Benedict equation (HBE) with a stress factor at enrolment (Clifton *et al.* 1984, Shanbhogue *et al.* 1987, Van den Berg & Stam 1988, Khorram-Sefat *et al.* 1999, Moriyama *et al.* 1999, Uehara *et al.* 1999). As a conservative approach, the lowest value in the stress factor range and adjusted body weight with a 50% correction factor for obese patients (BMI ≥ 25) (Amato *et al.* 1995) were used to calculate the requirements.

Adequacy of protein intake—Protein intake was obtained daily from the medical records. Protein intake via the enteral route was determined by multiplying the amount of enteral formula received by the protein content of the formula. Total protein intake included protein received via enteral nutrition or combined enteral/parenteral nutrition, plus 20% albumin. Provision of protein using parenteral nutrition follows the same approach as weigh provision of energy, and the parenteral feeding is decreased as enteral intake increases to meet nutritional requirements (Heidegger & Romand 2007).

Adequate protein intake was defined as total protein intake of more than 90% of protein requirements and underfeeding as intake <90% (Binnekade *et al.* 2005). Protein requirements were calculated using the American Dietetic Association's equation (Macias *et al.* 1996, Ishibashi *et al.* 1998, ADA 2000). The lower value in the stress condition range and the metabolically active weight for obese patients (Fuhrman 2003) were used as a conservative approach for calculating requirements.

Factors that impact the adequacy of early enteral nutrition—Factors that had an impact on the adequacy of energy intake for the study duration of four days were categorised as patient-related factors, feeding method, time to initiation of enteral nutrition, prescription by physicians and interruption of enteral nutrition. The operational definitions of factors are given below:

Patient-related factors: These factors include demographic data (age, gender, primary diagnosis), nutritional status [serum albumin, C-reactive protein (CRP), body mass index (BMI)], severity of disease and mechanical ventilatory support (Krishnan *et al.* 2003, Rubinson *et al.* 2004). They were obtained from the medical records at enrolment, except for severity of disease that was evaluated by the researcher using the Acute Physiology Chronic Health Evaluation II (APACHE II) score (Knaus *et al.* 1985). The BMI was classified using the criteria for Asians (Choo 2002). Supine knee height was measured using a knee height caliper to estimate height for the BMI calculation (ADA 2000, Hwang *et al.* 2009).

Feeding method factors: Feeding method factors consist of the size of the feeding tube and the type of feeding formula (Reid 2006, Bryk *et al.* 2008). This information was extracted daily from the medical records. Either 16 or 18 French feeding tubes were used. The feeding formulas are categorised as an isocaloric formula (Jevity, Glucerna, Nutren replate) or a calorically dense formula (Jevity 1.5, Glucerna 1.5, Nepro).

Time to initiation of enteral nutrition: This factor was defined as the total time from admission to the ICU to prescription by a physician, to insertion of the feeding tube, to confirmation of the feeding tube location, to initiation of enteral feeding (O'Meara *et al.* 2008). These data were extracted from the medical records of each patient at enrolment in the study.

Prescription by physician: Energy prescription and protein prescription were defined as the physician's order for calories and protein to be infused each day. They were obtained daily from the medical records. Adequate prescription of energy was defined as a prescription between 90–110% of energy requirements (McClave *et al.* 1998).

Interruption of enteral nutrition: Interruption of enteral feeding was defined as the number of minutes when the patient should have been receiving the prescribed enteral nutrition but was not. Enteral nutrition was expected to be infused at 8 am, 12 pm and 6 pm. over 30 minutes. Nurses recorded the time of withholding and restarting enteral nutrition using a standardised recording sheet for each interruption.

Procedures

In the ICU, enteral feeding was prescribed by the patient's physician; no standard prescription procedure was used by the physicians. During the transition period from parenteral nutrition to enteral nutrition, supplementary parenteral nutrition was provided to some patients until enteral nutrition came close to the goal. Enteral feeding administration was guided by the ICU enteral feeding nursing protocol. The enteral feeding protocol procedure indicates the nurse intermittently delivers a commercially prepared enteral formula that is ordered over 30 minutes, three times a day (8 am, 12 pm, 6 pm), with the head of the bed elevated 30–45°. Nurses record the starting time and gastric residual volume at each feeding time.

After obtaining written informed consent, patient-related data and time to initiation of enteral nutrition were obtained from the patient's medical record. Supine knee height was measured, and the APACHE II score was calculated by the researcher (HK) at enrolment. Feeding method data, feeding interruption data and data on the amounts of energy and protein prescribed and received by enteral route were obtained daily for four consecutive days by reviewing each patient's medical records. Data on the type and amount of fluids infused via the parenteral route were obtained daily from the medical records. Factors that had an impact on the adequacy of energy intake were recorded.

Ethical consideration

The study was approved by the Institutional Review Boards of the Korean university hospital (ref: 10–25) and a major West Coast university in the USA (ref: 10-00984). Written informed consent was obtained from all participants and/or legal surrogates in this study.

Data analysis

Data were analysed with SPSS 15.0 (SPSS Inc., Chicago, IL, USA). The level of statistical significance was set at $p < 0{\cdot}05$. The characteristics of the patients who were underfed/not underfed were compared using independent *t*-test and chi-square tests. Patients were categorised into three groups, adequately fed, underfed or overfed, based on the percentage of energy requirement received. They were also categorised into two groups, underfed or adequately fed, based on the percentage of protein requirement received. Frequency and percentage of the numbers of patients in each group were calculated to assess the adequacy of energy and protein intake.

To identify variables associated with the adequacy of energy intake, a nonparametric correlation matrix was constructed to test the relationship between variables. Gender (r = 0·42), time to initiation of enteral nutrition after ICU admission (r = 0·20), prescription (r = −0·61) and feeding interruption time (r = −0·37) were correlated with adequacy of energy intake with more than a small effect size (r = 0·2). Logistic regression analysis was conducted to assess the impact of these four specific factors on adequacy of energy intake.

Results

Sample characteristics

For the sample of 34 patients, their mean age was 70·8 (SD, 14·8) years and half were men. A total of 44% of patients were treated with mechanical ventilation. The mean APACHE II score was 13·0 (SD, 6·1), indicating a low severity of illness. Overall, patients were not malnourished according to mean serum albumin levels [3·3 (SD 0·8) g/dl], mean serum CRP levels [6·1 (SD 7·1) mg/dl] and body mass index (8·8% of patients were underweight). The majority of patients (74%) received isocaloric enteral feeding formula, and all were fed via nasogastric tube. Enteral feeding was started a median of 3·2 (range, 0·9–8·2) days after ICU admission.

Patients were classified into two groups, total energy intake <90% (n = 21) and more than 90% (n = 13) of required energy to compare the characteristics of the patients who were underfed and not underfed. Patient characteristics by group are summarised in Table 1. There were significantly more men with energy intakes <90% of energy requirements than with more than 90% (67% vs. 30% respectively, $p = 0{\cdot}01$). Patients who received <90% of their energy requirements had significantly lower energy prescriptions (81% vs. 102% of requirements, $p < 0{\cdot}01$) and longer enteral feeding interruptions (8·4 vs. 2·2 hours, $p = 0{\cdot}03$) compared to those who received more than 90% of energy requirements.

Adequacy of energy intake

In the 34 patients, 21 patients (62%) were underfed for energy; 10 patients (29%) had adequate energy intake; three patients (9%) were overfed during the four feeding days (Fig. 1). Upon further analysis (Table 1), 15 patients received supplementary energy from parenteral infusion (dextrose, MG-TNA, oliclinomel), in addition to enteral feeding. Specifically, 11 of the 15 patients received a mean of 5·6% of energy requirements from supplementary parenteral nutrition (MG-TNA, oliclinomel). Although there was no statistically significant difference in energy provided from parenteral infusion or parenteral nutrition between patients who were underfed and not underfed for energy, three patients who were overfed for energy received a mean of 19% of their energy requirements from parenteral nutrition.

Adequacy of protein intake

Fifteen of 34 (44%) patients had adequate protein intake, but 56% were underfed for protein during the entire study period (Fig. 1). There was no significant difference in protein received from intravenous infusion or parenteral nutrition between patients who were underfed or adequately fed for protein.

Factors that impact the adequacy of energy intake

The logistic regression model that included all factors (gender, time to initiation of enteral nutrition after ICU admission, energy prescription and feeding interruption time) was determined based on data from the nonparametric correlation matrix. It significantly predicted underfeeding of energy in critically ill patients receiving enteral nutrition [χ^2 (4) = 28·94, $p < 0{\cdot}01$]. The model explained 88% of the variance in underfeeding of energy.

As shown in Table 2, three factors made unique contributions to the model. Patients who were under-prescribed for energy were 16 times more likely to receive underfeeding of energy than those who had adequate or over prescription, controlling for all other factors in the model (95% CI, 1·75, 146·66). For every additional hour of delay in enteral feeding initiation after ICU admission, the odds of being underfed for energy decreased by 99%, after controlling for other factors (95% CI, 0·00, 0·77). For every additional hour of feeding interruption time, patients were 1% more likely to be underfed for energy, controlling for other factors in the model (95% CI, 1·00, 1·02). Therefore, patients who had enteral feeding initiated earlier with under-prescription of energy were more likely to be underfed for energy when compared to those who had enteral feeding initiated later but with adequate prescription or over prescription. Patients who had more prolonged interruptions of enteral feeding after initiation were more likely to be underfed for energy than those who had fewer feeding interruptions.

Discussion

To our knowledge, this study is the first study to identify the factors that impact adequate enteral intake in critically ill patients in Korea. Our findings showed that about two-thirds of patients failed to meet 90% of their energy requirements during the first four days after initiation of enteral nutrition. More than half of the patients received <90% of protein requirements during the study period. These results are consistent with a study by O'Leary-Kelley *et al.* (2005) that found 68% of patients who were treated with mechanical ventilation were underfed (energy intake <90% of energy requirement). Similarly, Engel *et al.* (2003) reported 65% of patients hospitalised in the surgical ICU did not reach 80% of their required energy. Our data confirm the findings from the previous study that 52% of patients in the neurosurgical ICU in Korea were underfed (energy received <80% of required energy) (Kim *et al.* 2010). Consistent with our study, these studies (Engel *et al.* 2003, O'Leary-Kelley *et al.* 2005, Kim *et al.* 2010) also included parenteral infusion provided for infusion of a sedative or parenteral supplementation, when calculating energy intake.

In the present study, parenteral infusion or parenteral nutrition provided small portions of energy and protein required and did not affect the adequacy of nutritional intake, although about half of patients received energy and protein from the parenteral route in our study. Under-prescription of energy and incomplete delivery of enteral nutrition were likely to contribute to increased proportions of underfeeding of energy of patients primarily receiving enteral nutrition. Furthermore, data that show a mean of 89% of energy requirements were prescribed supported the conclusion that under-prescription of energy was a factor contributing to underfeeding of energy in this study. The protein prescription rate was adequate (102% of required protein), indicating that there were other factors that may have contributed to underfeeding. Multiple factors for the failure to meet energy requirements have been identified in previous studies conducted in the USA (Ibrahim *et al.* 2002, Elpern *et al.* 2004, O'Leary-Kelley *et al.* 2005, Reid 2006, Desachy *et al.* 2008, Hsu *et al.* 2009). This present study adds further evidence by identifying the factors that contributed to underfeeding of energy in Korean medical ICU patients.

In our study, time to initiation of enteral nutrition after admission to the ICU, energy prescription of enteral nutrition and total interruption time of enteral nutrition significantly predicted underfeeding of energy and explained 88% of the variance in underfeeding of energy. Patients whose energy was under-prescribed for enteral nutrition were more likely to be underfed for energy compared to those who had adequate or over prescription. It is not particularly surprising that under-prescription of energy significantly contributed to underfeeding of energy, because enteral nutrition was the main energy source for these subjects. Although parenteral infusion (6·9%), especially parenteral nutrition (5·6%), increased the energy received a small amount, it did not significantly affect the adequacy of energy intake. In a prior study by Petros and Engelmann (2006), supplementary parenteral nutrition in the early phase of enteral nutrition was helpful in increasing nutritional intake in critically ill patients, but it did not significantly improve clinical outcomes. Rather, parenteral nutrition may contribute to overfeeding in enterally fed critically ill patients (Singer *et al.* 2009). This present study assessed the proportion of patients who were overfed for energy, because overfeeding of energy can induce complications such as hyperglycaemia, fatty liver and increased CO_2 production (Parrish & McCray 2003). Although only three patients were overfed for energy, all of them received parenteral infusion, particularly parenteral nutrition, providing about 20% of energy requirements in our study. In addition, Genton *et al.* (2004) indicated that prescribing higher energy than patients' required increased the amounts of energy received during the first five days of enteral nutrition. However, the effects on clinical outcomes were not tested. Therefore, it is important to prescribe enteral nutrition which meets patients' requirements rather than provide supplementary parenteral infusion or prescribe higher energy than requirements.

Continuing education for critical care physicians and nurses is required to raise the level of awareness and knowledge about enteral nutrition prescription, and to help in accurate assessment of nutritional requirements. The use of equations such as the HBE in the ICU can help accurately estimate energy requirements and preclude the need for special equipment (O'Leary-Kelley *et al.* 2005). Future study is warranted to validate the equation in Korean critically ill patients. In addition, further study is needed to explore the effects of higher energy prescription on outcomes in Korean ICU patients fed enterally.

Initiation of feeding within 48 hours after admission to the ICU is the current standard for nutritional support in the critically ill (Heyland *et al.* 2003, McClave *et al.* 2009). In the present study, patients were enterally fed within a median time of three days after ICU admission. Data from this study showed that delay in feeding was associated with adequate enteral intake. This finding contrasts with findings from previous studies that early initiation was associated with increased energy intake as compared to delayed initiation (Ibrahim *et al.* 2002, Charvat *et al.* 2008).

One possible explanation for our finding could be that early initiation might be associated with increased risk of gastrointestinal (GI) intolerance, which might increase underfeeding of energy. This is supported by a study of patients who started enteral nutrition on the first day after ICU admission. These patients had more diarrhoea than those who started on the fifth day (Ibrahim *et al.* 2002). In our study, however, initiation of enteral nutrition that started within three days after admission to the ICU was not significantly related to GI intolerance including high gastric residual volumes, diarrhoea and vomiting. It should be noted that it may not be possible to attain statistical significance for GI intolerance owing to the overall low incidence of diarrhoea and vomiting in our small sample ($n = 34$). Another possible explanation is that time to initiation was significantly associated with patient-related factors including gender, mechanical ventilatory support, APACHE II score and serum albumin levels, which might contribute to underfeeding of energy. In addition, attention of healthcare providers to enteral nutritional support could influence the time to initiation of enteral nutrition and adequacy of enteral nutritional intake. Therefore, future study is warranted to determine the contribution of feeding initiation time in a larger sample. Additional research on the attitudes of healthcare providers in the ICU about enteral nutritional support would indicate whether this affects the delivery of enteral nutrition.

Our findings also showed that as the duration of withholding enteral feedings increased, the possibility that patients were underfed for energy also rose. These findings are consistent with previous studies that demonstrated that frequent interruption of enteral feeding is a major reason for insufficient energy intake (Engel *et al.* 2003, Petros & Engelmann 2006, O'Meara *et al.* 2008). It accounts for about 70% of the variance in the required energy that is actually received (O'Leary-Kelley *et al.* 2005). In our study, enteral nutrition was provided with the intermittent bolus method, administered by gravity dip for patients with gastric feeding tubes three times per day. Although nurses could adjust the feeding formula withholding owing to some short interruptions because they were using an intermittent administration method, they could not replace the large volume withholding owing to long interruptions. Therefore, unnecessary prolonged interruptions should be avoided to insure adequate nutritional support.

Future studies are warranted to test strategies related to reducing unnecessary and prolonged interruptions of enteral nutrition. The reasons for feeding interruptions and administration methods of enteral feeding (continuous vs. intermittent) need to be considered when designing studies. This is because the reason for interruptions differs depending on the method of enteral feeding. Enteral feeding protocols addressing how to prevent or manage feeding interruptions need to be developed and implemented to provide adequate nutrition to critically ill patients.

Consistent with the earlier studies of Krishnan *et al.* (2003) and Rubinson *et al.* (2004), patient-related factors did not significantly predict underfeeding of energy in our study. In addition, gender did not significantly predict underfeeding of energy when controlling for other factors. However, a significant relationship ($r = 0{\cdot}39$, $p < 0{\cdot}05$) between gender and energy prescription may affect underfeeding of energy in this study. That is, gender may be a moderating factor, rather than a contributing factor for underfeeding.

The type of enteral feeding formula also did not predict underfeeding of energy in our study. Contrary to findings from prior studies that used calorically dense enteral feeding formula contributed to improved energy intake (Engel *et al.* 2003, Reid 2006), there was no relationship between energy density of the formula and adequacy of energy intake. It should be noted that, although calorically dense formulas tended to be provided to more patients who were adequately fed for energy (31%) than those who were underfed (24%), it failed to reach the statistical significance; again, this may be a sample size issue.

Findings from this present study need to be interpreted with caution owing to several study limitations. First, our subjects may not be representative of all critically ill patients in Korea because our study has a small sample size and consists of older people with an average age of 71 years. However, the sample is a homogenous group of the same number of men and women with primary medical problems receiving enteral nutrition via nasogastric tube, making it easy to interpret the findings. Second, there may be an intra- and inter-hospital variability because enteral nutrition protocols or nutritional therapy, including prescription, may differ between the ICUs in the hospital or between different hospitals in Korea. However, variability should not be a surprise because nutritional therapy is such a complex process, especially in the critically ill (Engel *et al.* 2003) and there currently are not consistent guidelines for prescription in Korean ICUs. Finally, this study used a prospective cohort approach that is not designed to provide data about causal effects. Although a causal relationship between contributing factors and underfeeding cannot be inferred, underfeeding in Korean critically ill patients can be predicted with these factors.

Conclusion

Korean ICU patients do not receive adequate energy and protein when fed enterally. This study showed there were three reasons for underfeeding of energy: early initiation of enteral nutrition, under-prescription of energy and prolonged interruption of prescribed enteral nutrition. The findings from our study reinforce the importance of increasing the delivery of enteral nutrition to provide adequate nutritional support to critically ill patients.

Relevance to clinical practice

Underfeeding has been a major concern in the enteral feeding of critically ill patients, although there is unanimous agreement that nutritional support is vital for positive clinical outcomes of patients. Ongoing evaluation of the adequacy of enteral nutritional intake is essential for early detection of underfeeding and timely intervention to mitigate problems with provision of adequate nutrition. Identifying the factors that influence adequate enteral nutritional support provides a foundation for interventions designed to improve enteral nutrition practices. The factors that have been identified can be targeted to modify nutritional interventions for critically ill patients.

In addition to under-prescription, frequent and prolonged interruption of enteral feeding was identified as an important factor contributing to inadequate nutritional intake. Some interruptions may be prevented with more careful clinical care. Well-developed feeding protocols that prevent and/or compensate for the interruptions of enteral feeding should improve the delivery of enteral nutrition by nurses. The protocols need to be standardised prescription of enteral nutrition and include monitoring the adequacy of enteral intake in critically ill patients.

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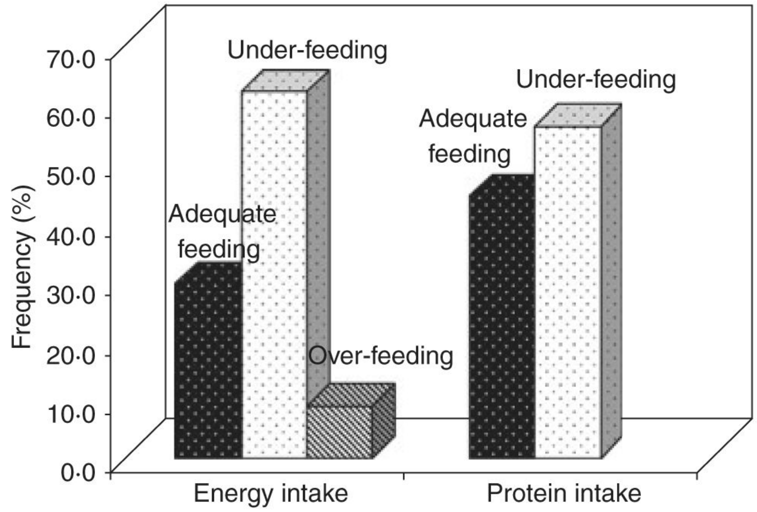

Figure 1.

Percentage of under-, over-, and adequate feeding in terms of energy and protein.

Table 1

Patient characteristics

Characteristics	I (*n* = 13)	II (*n* = 21)
Age, mean (SD), years	76·1 (6·1)	67·5 (17·6)
Gender (male/female)*	3/10	14/7
Diagnosis (%)		
Neurological	38·5	52·4
Respiratory	46·2	19·0
Sepsis	7·7	19·0
Gastrointestinal	0	9·5
Renal	7·7	0
Mechanical ventilation	7	8
APACHE II score, mean (SD)	12·2 (4·3)	13·5 (7·0)
Albumin, mean (SD), g/dl	3·3 (0·9)	3·4 (0·8)
C-reactive protein, mean (SD), mg/dl	8·1 (9·0)	4·8 (5·6)
Body mass index (%)		
Underweight	7·7	9·5
Healthy weight	53·8	28·6
Overweight	7·7	28·6
Mild obese	30·8	33·3
Nasogastric feeding tube	13	21
Feeding tube size, number		
16 French/18 French	7/6	10/11
Enteral feeding formula		
Isocaloric/calorically dense	9/4	16/5
Time to initiation of enteral feeding after ICU admission, median (interquartile range), days	4·0 (0·7–7·7)	1·5 (1·0–8·5)
% of required energy prescribed**, mean (SD), %	101·6 (9·0)	81·3 (16·6)
% of required protein prescribed, mean (SD), %	113·5 (27·0)	94·2 (37·2)
Total interruption time of enteral feeding*, mean (SD), hrs	2·2 (3·9)	8·4 (11·5)
Patients received energy via PI†,‡/PN§	7/5	8/6
% of required energy received via PI†, mean (SD)	8·7 (10·6)	5·8 (9·9)
% of required protein received via PI‡, mean (SD)	5·7 (8·5)	4·7 (8·8)
% of required energy received via PN§, mean (SD)	7·0 (11·0)	4·8 (9·1)

Characteristics	I (*n* = 13)	II (*n* = 21)
% of required protein received via PN[§], mean (SD)	5·6 (8·6)	4·5 (8·8)

I, energy intake/required ratio ≥90%; II, energy intake/required ratio <90%; APACHE II, acute physiology chronic health evaluation II.

[*] $p < 0·05$;

[**] $p < 0·01$.

[†] PI, parenteral infusion included dextrose, parenteral nutrition.

[‡] PI, parenteral infusion included 20% albumin, parenteral nutrition.

[§] PN, parenteral nutrition included MG-TNA, oliclinomel.

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Table 2

Factors associated with underfeeding in logistic regression

	OR	95% CI for OR	*p*
Gender	6·67	0·55–32·28	0·10
Time to initiation of enteral nutrition	0·01	0·00–0·77	0·04
Under-prescription	16·00	1·75–146·66	0·04
Interruption time of enteral nutrition	1·01	1·00–1·02	0·04
constant	0·20		0·17

OR, odds ratio; CI, confidence interval.