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Adequacy of nutritional intake and factors that impede adequate nutritional intake in ICU patients receiving enteral feeding

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Adequacy of Nutritional Intake and Factors that Impede Adequate Nutritional Intake in ICU Patients Receiving Enteral Feeding

by

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DISSERTATION

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Adequacy of Nutritional Intake and Factors that Impede Adequate Nutritional Intake in ICU patients Receiving Enteral Feeding

Hyunjung Kim, RN, PhD

Abstract

Background: Underfeeding is a common and severe problem for critically ill patients receiving enteral nutrition. There are many factors contributing to inadequate enteral nutrition intake in patients hospitalized in the intensive care unit (ICU). Little is known about the factors that impact adequacy of nutritional intake in Korean patients.

Objectives: This dissertation aimed to describe the adequacy of enteral nutritional intake and identify factors that impact adequate intake in critically ill patients receiving enteral nutrition. A particular focus was on identifying the contribution of the factors that had an impact on the adequacy of energy intake in the first four days after the initiation of enteral feeding in critically ill Korean patients.

Methods: The first paper was a literature review regarding barriers to adequate enteral nutritional intake. The second and third papers report data from a prospective cohort study. Data were collected from 34 critically ill adult patients hospitalized in the Korean medical ICU who were receiving bolus enteral nutrition. The data on nutritional intake, feeding methods, and feeding interruptions were recorded from medical records during the first four days after enteral feeding initiation.

Findings: The first paper demonstrated that under-prescription, late initiation, frequent interruptions of enteral nutrition and gradual progression of the feeding administration rate were barriers to adequate enteral intake. Nutrient-dense formulas and transpyloric feeding were associated with increased energy intake. The second paper showed that most critically ill Korean patients were underfed with enteral nutrition. Under-prescription, prolonged interruptions of enteral nutrition, and early initiation were associated with underfeeding in critically ill Korean patients. The third paper demonstrated that enteral nutritional intake was consistently insufficient across all four days. Prolonged feeding interruptions due to GI intolerance and procedures were the major contributors to inadequate nutritional intake in critically ill Korean patients. The findings suggest that healthcare providers awareness and knowledge of enteral nutrition should be improved. Standardized feeding protocols should be developed, tested, and implemented to provide adequate nutritional support to the critically ill.

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CHAPTER 1

Introduction

Background

Nutritional support is an essential aspect of care for critically ill patients (Marik & Zaloga, 2001). Optimal nutritional support minimizes breakdown of lean body mass, and reduces morbidity and mortality of intensive care unit (ICU) patients (Atkinson & Worthley, 2003). The success of nutritional support depends on how well energy and protein requirements are estimated and then matched by prescribing and delivering the needed nutrients.

Critically ill patients are hypermetabolic (Villet et al., 2005), typically manifested as an increased energy requirement compared to non-critically ill patients (Alexander, Susla, Burstein, Brown, & Ognibene, 2004). Adequate amounts of energy and protein are needed to meet increased hypermetabolic requirements, maintain lean body mass, and improve clinical outcomes (Dvir, Cohen, & Singer, 2006; Parrish, 2003). Most critically ill patients who are unable to take food orally receive enteral nutrition because of its beneficial physiological effects, improved health outcomes, and lower costs when compared to parenteral nutrition (ASPEN, 2002; Bourgault, Ipe, Weaver, Swarta, & O'Dea, 2007; van Caillie-Bertrand, 2002). Practice guidelines by American Society of Parenteral Eenteral Nutrition recommend choosing the optimal access site (gastric, duodenal, or jejunal) and enteral formula that meet the individual patient’s functions and requirements (ASPEN, 2002).

However, critically ill patients frequently receive inadequate enteral nutritional support during their ICU stay in both the United States (US) and Korea (Hise et al., 2007; Kim, Choi, & Ham, 2009; McClave et al., 1999; O'Leary-Kelley, Puntillo, Barr, Stotts, & Douglas, 2005; O'Meara et al., 2008). The adverse effects of underfeeding include loss of lean body mass, including cardiac and respiratory muscles, prolonged weaning from mechanical ventilation, delayed wound healing, impaired host defenses, increased nosocomial infections, renal failure, and increased ICU length of stay (Dvir et al., 2006; McClave et al., 1998; Villet et al., 2005).

Some patients admitted to ICU are malnourished. In the US, the prevalence of malnutrition at ICU admission ranges from 38 to 88% (Barr, Hecht, Flavin, Khorana, & Gould, 2004; Faisy, Rabbat, Kouchakji, & Laaban, 2000) and in one Korean ICU it is 87% (Lee, Choi, Kim, Lee, & Shin, 2003). During the ICU stay, the combination of an increase in metabolism and insufficient nutritional intake works synergistically to increase catabolism. If patients do not meet their nutritional requirements, the body uses endogenous sources, breaking down body tissues (Cartwright, 2004). In fact, the nutritional status of about two-thirds of ICU patients declines during their ICU stay (Barr et al., 2004). Malnutrition may result and is associated with deleterious clinical outcomes and increased mortality in ICU patients (Bond & Heitkemper, 2003).

Considering these adverse effects of malnutrition and inadequate nutritional intake, it is critical to provide sufficient energy, protein, and nutrients to critically ill patients. Multiple barriers that affect the adequacy of enteral nutritional intake in the critically ill have been identified (Desachy et al., 2008; Esparza, Boivin, Hartshorne, & Levy, 2001; Ibrahim et al., 2002; McClave et al., 1999; O'Leary-Kelley et al., 2005; Reid, 2006). Among these are patient-related factors (age, gender, severity of disease, nutritional status), feeding method factors (feeding formula, feeding tube site), feeding process factors (feeding initiation time, administration rate), under-prescribing, and frequent interruption of enteral nutrition. Study findings consistently indicate that the combination of under-prescription and incomplete delivery of prescribed nutrients result in grossly inadequate nutritional support (Bourgault et al., 2007; De Jonghe et al., 2001). Studies also suggest that enteral nutritional delivery can be maximized by preventing unnecessary interruptions (McClave et al., 1999; O'Leary-Kelley et al., 2005).

However, these factors have been identified in studies conducted in the ICU in the US. Little is known about which factors influence the adequacy of nutritional intake in Korean critically ill patients. A recent study by Kim and colleagues (2010) demonstrated the reasons for feeding interruptions in patients hospitalized in a neurosurgical Korean ICU. However, only two studies are published that evaluated the adequacy of enteral nutrition in the Korean population (Kim et al., 2010; Park, Lee, & Lim, 2001). Therefore, research is needed to evaluate the adequacy of enteral feeding in Korean ICU patients.

Dissertation Aims

The purpose of this dissertation is to describe the adequacy of nutritional intake with a focus on identifying factors that impact nutritional adequacy in the critically ill patients receiving enteral nutrition. The dissertation is organized into five chapters.

Chapter 1 serves as the introduction to the dissertation and provides a brief background.

Chapter 2 presents a current review of studies that address the factors that affect enteral nutritional intake in the critically ill. Relevant gaps in the literature are identified.

Chapter 3 presents the findings of a prospective, cohort study in critically ill patients hospitalized in the Korea ICU. The purpose of this paper was (1) to describe the proportion of patients who were underfed, overfed, or adequately fed in terms of energy and protein of enteral feeding; and (2) to identify the contribution of factors that had an impact on the adequacy of enteral nutritional intake for the first four-days after initiation of enteral feeding.

Chapter 4 presents the data from the same Korean ICU patients with a focus on the nutritional intake day by day and reasons for interruptions of enteral nutrition. The purpose of this paper was (1) to evaluate the amount of energy and protein prescribed and received across the first four days after initiation of enteral feeding; and (2) to determine the relationship between interruption time by each reason for the interruptions and the energy received on the day feeding was interrupted.

Chapter 5 summarizes the findings from the three papers on the nutritional adequacy in the critically ill and presents clinical implications and recommendation for future research.

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CHAPTER 2

Why Don't Critical Care Patients Receive Adequate Enteral Nutrition?

A Review of the Literature

Abstract

Enteral nutrition is frequently used to provide nutrients for critically ill patients. However, data show that only about half of critically ill enterally fed patients receive their energy requirements. Underfeeding is associated with detrimental clinical outcomes including infection, pressure ulcers, impaired wound healing, prolonged hospital stays, and increased morbidity and mortality. This literature review was conducted to identify major barriers contributing to inadequate enteral nutrition intake in critically ill adults and to identify relevant gaps in the research literature. Studies (n=30) reviewed addressed adult critical care patients, published since 1999, and written in English. The studies reported multiple barriers to achieving adequate enteral intake including patient-related factors, feeding method factors, feeding process factors, under-prescription, and frequent interruption of enteral nutrition. Patient-related factors did not explain inadequate enteral nutritional intake. The primary feeding method barriers were delayed initiation of enteral nutrition and slow advancement of infusion rate. The combination of under-prescription and incomplete delivery of prescribed enteral nutrition also was a barrier. Frequent interruption of enteral nutrition caused by diagnostic tests, surgical procedures, gastrointestinal intolerance, feeding tube problems, and routine nursing procedures also was a barrier to sufficient delivery of enteral nutrition. Findings indicate that there are not standardized protocols to address these barriers to providing adequate enteral intake. Such protocols must be developed, implemented, and tested to address under-nutrition and mitigate the negative consequences of inadequate enteral intake.

Keywords: Energy intake; Enteral nutrition; Intensive care units; Nutritional adequacy; Protein intake

Introduction

Malnutrition is a common and severe problem in patients in critical care units, occurring in 38% to 88% of patients (Barr, Hecht, Flavin, Khorana, & Gould, 2004; Faisy, Rabbat, Kouchakji, & Laaban, 2000). It is associated with detrimental clinical outcomes such as higher risk of infection and pressure ulcers, reduced wound healing, prolonged hospital stays, increased morbidity and mortality as well as increased costs for care (Martin, Doig, Heyland, Morrison, & Sibbald, 2004; Thomas, 2001). The combination of increased resting energy expenditure and inadequate nutritional delivery contribute to the increased risk of malnutrition in critically ill patients (Parrish & McCray, 2003). Adequate nutritional support is crucial to the prevention and treatment of malnutrition.

Enteral nutrition is the preferred route of nutritional support in critically ill patients, but it is frequently associated with underfeeding (McClave et al., 1999; O'Leary-Kelley, Puntillo, Barr, Stotts, & Douglas, 2005). Since Mandel and Worthley (1986) first reported the inadequacy of enteral nutritional intake in patients on general wards and intensive care units (ICUs), underfeeding continues to be a frequent problem in critically ill patients undergoing enteral feeding (Hise et al., 2007; Kearns et al., 2000; Roberts, Kennerly, Keane, & George, 2003). Over time, studies of critically ill patients have identified likely barriers for inadequate enteral nutritional intake (McClave et al., 1999; O'Leary-Kelley et al., 2005; O'Meara et al., 2008), yet few consistent findings have been demonstrated. Understanding the barriers to adequate enteral nutrition in critically ill patients is essential for healthcare providers to optimize nutritional support. Protocols can be developed which address these barriers and implemented to ensure adequate nutritional support. The purpose of this literature review is to identify major barriers contributing to inadequate enteral nutrition intake in critically ill adults and to identify relevant gaps in the research literature.

Search Strategy

A literature search was performed using four databases (PubMed, CINAHL, MD Consult, and PsychINFO). Search terms used included intensive care units by: enteral nutrition, energy intake, caloric intake, protein intake, energy balance, hypocaloric intake, hypercaloric intake, and nutritional adequacy. Reference lists and related articles were also searched for additional studies. Parameters set for the literature search were: adult patients (older than 19 years), 1999-2011, journal research article, and English language. Reviews, commentaries, editorials, letters, and practical guideline articles were excluded. The time frame searched was selected because the reasons for and duration of interruptions of enteral nutrition in critically ill patients were first delineated in 1999 by McClave et al (1999), and there have been subsequent studies after this time.

Many studies overlapped and consisted of multiple publications and were retrieved based on several search terms. From 327 initial articles, a total of 30 studies met the search criteria and were reviewed for this paper; 11 were experimental studies; two were quasi-experimental studies; and 17 were non-experimental studies.

Results

Adequacy of Enteral Nutrition

Although enteral nutrition has been considered the gold standard for nutritional therapy in critically ill patients because of its favorable effects, it does not always provide the desired energy requirements (O'Leary-Kelley et al., 2005). Average energy intakes provided by enteral nutrition are between 50% and 95% of requirements for critically ill patients (De Jonghe et al., 2001; Desachy et al., 2008; Krishnan, Parce, Martinez, Diette, & Brower, 2003; Rice, Swope, Bozeman, & Wheeler, 2005; Rubinson, Diette, Song, Brower, & Krishnan, 2004). In addition, only 14% to 52% of patients in the ICU achieved their goal energy intakes with enteral nutrition (Binnekade, Tepaske, Bruynzeel, Mathus-Vliegen, & de Haan, 2005; Kim, Shin, Shin, & Cho, 2010; McClave et al., 1999; O'Leary-Kelley et al., 2005; Rice et al., 2005). Among the studies that reported energy adequacy in critically ill patients, only one study reported an energy intake of 100% of requirements (Neumann & DeLegge, 2002). Three studies documented overfeeding in 1.7% of patients (O'Leary-Kelley et al., 2005), in 10.7% of patients (Kim et al., 2010), and in 19% of the total feeding days (Reid, 2006). Mean protein intake ranging from 38% to 82% of requirements have also been reported in critically ill patients with enteral nutrition (Binnekade et al., 2005; Reid, 2006; Taylor, Fettes, Jewkes, & Nelson, 1999). These data indicate that using enteral nutrition often results in inadequate achievement of energy and protein requirements in critically ill patients. Further investigations have identified potential barriers to the delivery of adequate enteral nutrition.

Barriers to the Delivery of Enteral Nutrition

Many studies have evaluated the barriers that affect the delivery of enteral nutrition in critically ill patients. The barriers that have an impact on the adequacy of enteral nutrition have been classified as patient-related factors, feeding method factors (feeding formula, feeding tube site), feeding process factors (feeding initiation time, administration rate), under-prescription by physicians, and frequent interruption of enteral nutrition (Table 1).

Patient-related factors. Patient-related factors such as age, gender, nutritional status, severity of illness, and mechanical ventilatory support may affect the delivery of enteral nutrition. Krishnan et al (2003) examined the relationship between nutritional status (measured with serum albumin levels and body mass index [BMI]), severity of illness (simplified acute physiology scores [SAPS] II), and energy intake in patients hospitalized in a medical ICU. Although the mean energy intake was only 50.6 % of the American College of Chest Physicians (ACCP) targets, it was not associated with SAPS II or markers of nutritional status. Similar findings were seen in the study conducted by Rubinson et al (2004) where mean energy intake was 49.3% of ACCP recommendations. Baseline patient characteristics including age, SAPS II, gender, serum albumin level, BMI, and duration of mechanical ventilation were similar across categories of energy intake and did not explain differences in energy intake.

Two studies (Krishnan et al., 2003; Rubinson et al., 2004) used a prospective cohort design and included patients hospitalized in medical ICUs with mean ages of 54 and 52.6 years. Sample sizes were large (n=187 and 138 respectively) and study periods were 4 to 6 days. These studies were limited by including only patients in medical ICUs and by their short duration. Furthermore, 10% and 18% of patients received only parenteral nutrition. Separate analyses were not done by feeding method, so the relationship between patient factors and energy intake from enteral nutrition could not be determined. Despite these limitations, they suggest that patient-related factors do not adequately explain the inability to meet energy goals in critically ill patients.

Feeding formula. Isotonic formula is a standard for enteral nutrition for critically ill patients, but nutrient-dense formulas are preferred in some ICU settings to facilitate nutrient delivery using smaller fluid volumes (Nisim & Allins, 2005). Bryk and colleagues (2008), in a study of 117 patients in surgical and trauma ICUs, demonstrated that calorically dense enteral formula did not increase the delivery of energy compared with isotonic formula. This study was limited by its retrospective research design.

A prospective study in critically ill patients demonstrated that use of nutrient-dense enteral formulas resulted in overfeeding (Reid, 2006). The highest energy and protein intakes were achieved with nutrient-dense formulas rather than standard formulas. There were significant differences in energy intake (1600 vs. 965 kcal/day) and protein intake (60 vs. 36.4 g/day) between the groups. Patients on nutrient-dense formulas received more energy than their requirements, yet only 82% met their protein requirements. This finding suggests that protein requirements and intake should be assessed separately from energy intake. Yet, the descriptive study design precludes inferring a causal relationship between overfeeding and nutrient-dense enteral feeding.

To conclude, one prospective study (Reid, 2006) suggests that nutrient-dense enteral formulas provide more energy and protein contents compared to standard formulas, despite inconsistent findings in a retrospective study (Bryk et al., 2008). Evidence needs to be obtained through randomized clinical trials (RCTs) to validate this suggestion.

Feeding tube location. The nasoenteric tube inserted into the stomach, duodenum, or the jejunum is the most common method used to provide enteral nutrition. Feeding into the duodenum or jejunum (transpyloric feeding) can reportedly avoid the problem of impaired gastric emptying and may increase the amount of enteral nutrition delivered to the patients (Heyland, Dhaliwal, Drover, Gramlich, & Dodek, 2003). Favorable effects of transpyloric feeding on energy and protein intake were reported in three studies conducted in medical ICUs. In a study by Kearns et al (2000), small intestine fed patients received greater energy (1157 vs. 812 kcal/d) and protein (44 vs. 31g/d) compared to gastric fed patients. The higher energy intake in the intestine-fed patients compared to the gastric-fed patients was because more in the second group had feedings withheld due to high gastric residuals. Consistent with the findings of this study, Esparza et al (2001) reported higher energy intake in transpyloric fed patients than in gastric fed patients. This study was conducted in a sample of 51 patients, over a relatively long period (8 days), but 40% of the patients dropped out. Although high attrition rates can cause bias and limit the reliability of the conclusions, the attrition rates were identical in both groups. However, it is not clear if the characteristics of those who dropped out were similar. Hsu and colleagues (2009) also reported a higher energy (1658 vs. 1426 kcal/day) and protein intake (67.9 vs. 58.8 g/day) as well as shorter time to feeding goal rate (32.4 vs. 54.5 hours) in duodenal feeding compared to gastric feeding. The authors concluded that duodenal feeding might be more efficient because of the greater peristaltic activity of the duodenum (Dive, Moulart, & Jonard, 1994).

Similarly, in a descriptive study by Binnekade et al (2005), the percentage of days with energy goal achievement was lowest in critically ill patients with gastric tubes (49%), and highest in those with duodenal/jejunal tubes (58%) and needle catheter jejunostomies (76%). They reported that aspirated gastric residual volumes were discarded rather than refed; this could explain the low rates of energy goal achievement. Although the study has a large number of participants (n=403), selection bias is a possible threat because of the lack of randomization.

In contrast, a RCT by Bovin and Levy (2001) demonstrated that gastric feeding was superior to transpyloric feeding for energy balance (74 vs. 68% of requirements) in critically ill patients. Another RCT, conducted by White et al (2009), showed that patients with gastric feeding had lower energy deficits (73 vs. 167 kcal) and reached the feeding goal rate earlier (8.7 vs. 12.3 hrs) than those with post-pyloric feeding. However, the gastric-fed patients was not sick, as shown by their lower acute physiology and chronic health evaluation II (APACHE II) scores; they also had feedings initiated more quickly than those in the post-pyloric feeding group. These characteristics are potential moderating and mediating factors.

Furthermore, no significant differences were found between the gastric and transpyloric groups in energy and protein intake in three RCTs and one meta-analysis (Davies et al., 2002; Day et al., 2001; Marik & Zaloga, 2003; Neumann & DeLegge, 2002). Sample sizes were not adequate in any of these RCTs; thus the studies may not have adequate power to find the difference between gastric feeding and transpyloric feeding if it was present. In addition, despite being a meta-analysis, only 238 patients were included in the analyses by Marik and Zaloga (2003). The sample was also heterogeneous.

In the studies of the effect of feeding tube location (Boivin & Levy, 2001; Day et al., 2001; Esparza et al., 2001; Kearns et al., 2000; Neumann & DeLegge, 2002; White et al., 2009), none of the groups achieved the average recommended energy or protein intake except for the study by Neumann and DeLegge (2002). These data suggest that factors other than tube site influence the inadequacy of enteral nutrition intake.

Early vs. late feeding initiation. American Society of Parenteral and Enteral Nutrition (ASPEN) recommends that nutrition support should be started within 24 to 48 hours after admission to the ICU (ASPEN, 2002). Several studies in critically ill patients have examined whether administration of early enteral nutrition is associated with improved nutrient intake compared with delayed enteral nutrition. In a RCT of 28 patients with multiple injuries, Kompan et al (1999) provided enteral nutrition within 6 hours or more than 24 hours after admission to the ICU. They showed an energy intake of 80.5% of requirements in the early group and 60.9% in the later feeding group. Even in the later feeding group, the patients received enteral nutrition earlier than reported in other studies with enteral nutrition administration on days 3 to 5 after ICU admission (Ibrahim et al., 2002; Roberts et al., 2003). The difference in definition of later initiation among studies may influence the effect of later initiation of enteral nutrition.

Ibrahim et al (2002) provided enteral nutrition to patients in a medical ICU on either day 1 or day 5 after admission. Mean energy intake (2370 vs. 629 kcal, respectively) and protein intake (93.6 vs. 26.7g, respectively) were greater for patients in the early feeding group compared to those in the later feeding group. However, the early group had a higher incidence of ventilator-associated pneumonia, diarrhea, and prolonged length of stay (LOS) in the ICU. The findings indicate that the potential for complications associated with early enteral nutrition needs to be considered with the expected benefits of nutrient intake. Several limitations are noted in these studies which may contribute to study bias. These include: a single ICU setting, no blinding, small sample size, and quasi-experimental design.

In contrast to the above studies, energy intake was equivalent in the two groups (nutrition support initiation within 3 days after admission and more than 3 days afterwards) studied by Roberts et al (2003). However, it is not possible to generalize these findings as this study was conducted with various populations, there was a small sample size (n = 50), and subjects were not prospectively randomized to groups.

Early initiation of enteral intake may contribute to increased energy intake, although there is no standard definition for early and later enteral feeding. This conclusion is consistent with the recommendation of ASPEN about the early initiation of enteral nutrition in the critically ill (ASPEN, 2002).

Feeding administration rate. Stable patients tolerate a fairly rapid progression of enteral nutrition, reaching their nutritional goal within 24 to 48 hours of initiation (ASPEN, 2002). Desachy et al (2008) demonstrated that when feeding was provided immediately at optimal flow rates, there was a significant improvement in energy intake compared to a gradual increase in rate of feeding (95% vs. 76% of requirements), even although high gastric residual volumes were more frequent. Similarly, patients receiving enteral nutrition with rapidly increasing administration rates in a medical ICU had greater energy intake than those with gradual increase in rates (23.2 vs. 10.4 kcal/kg/day) (Petros & Engelmann, 2006). There was greater energy intake (60% vs. 37% of requirements) and protein intake (69% vs. 38% of requirements) in head injured patients with the provision of immediate goal rate when compared to those with the gradual increasing rate (Taylor et al., 1999).

In conclusion, providing enteral nutrition using an immediate goal rate or rapid increasing rate improves energy intake in critically ill patients compared to that with a gradual increasing rate. However, enteral nutrition regimens with strictly defined protocols were followed in studies by Desachy et al (2008) and Taylor et al (1999) and resulted in greater intake. In addition, prokinetics were provided in the study by Desachy et al (2008). Consistently following nutrition protocols and the use of prokinetics could be moderators in improving energy intake. These study findings need to be confirmed in studies where prokinetics are not used.

Under-prescription by healthcare providers. Although technical problems in administration of enteral nutrition contribute to the inadequately delivered energy intake, under-prescription also needs to be considered. In a study by McClave et al (1999), physicians prescribed a daily mean volume that was 65.6% of the requirements, but only 78.1% of the volume prescribed was infused in critically ill patients in a medical ICU and coronary care unit. Thus, patients received a mean volume that was 51.6% of goal. Similar results were demonstrated by De Jonghe (2001), with 78% of the energy requirements prescribed, and 71.2% of the requirements effectively delivered.

However, physicians may be unaware of the actual nutrition received by the patient. Failure to recognize that the prescribed amount of enteral nutrition has not been administered (McClave et al., 1999), combined with under-prescription and poor delivery of prescribed energy results in inadequate nutritional support.

Frequent interruption of enteral nutrition. Enteral nutrition is usually withheld in patients in critical care until emergent medical problems are stabilized; often it is not started or restarted for days (Rice et al., 2005). Across several studies, enteral nutrition was interrupted in critically ill patients on average 2.3 to 7.0 hours daily per patient (Elpern, Stutz, Peterson, Gurka, & Skipper, 2004; O'Leary-Kelley et al., 2005; O'Meara et al., 2008; Rice et al., 2005). Feeding was on hold for 19.6% to 32% of the total feeding time (McClave et al., 1999; Petros & Engelmann, 2006). Patients received only 50 to 76% of the energy required in the studies (Elpern et al., 2004; Kim et al., 2010; Rice et al., 2005). Major reasons for interruptions are summarized in Table 2.

Most interruptions in feeding occur because of procedures and tests at the bedside and in the operating room. McClave et al (1999) reported that the longest cessation of enteral nutrition was due to procedures, accounting for 35% of the interruption time (the total time that feeding was withheld). Procedures and tests resulted in discontinuation of enteral nutrition in 39% and 27% of patients. About 66% of events (the occurrence that caused the feeding to be withheld) were avoidable and potentially correctable. In a study by O’Leary-Kelly et al (2005), more than 40% of patients were affected by procedures or scheduled surgery, accounting for 24.8% of the interruption time. Similar results were reported in studies by Kim et al (2010) (30% of events), Rice et al (2005) (41% of events), Elpern et al (2004) (35.7% of the interruption time), and Boivin and Levy (2001) (36% of events). Most procedures and radiologic studies requiring the patient to be in a supine position may lead to the cessation of enteral feeding for fear of aspiration. However, ICU patients frequently have diagnostic tests and procedures that require withholding of enteral nutrition for several hours (O'Leary-Kelley et al., 2005). In addition, some procedures require fasting. Furthermore, enteral nutrition may not be immediately restarted after a procedure is completed. In addition, ICU nurses may not compensate for the formula volume delayed by procedures or tests. If procedures and tests could be completed when scheduled rather than being delayed, unnecessary withholding of enteral nutrition could possibly be prevented. Well-designed protocols to replace volumes held due to interrupted enteral nutrition may guide healthcare providers in helping patients achieve goal volumes after procedures.

Studies have demonstrated that a significant percentage of ICU patients develop gastrointestinal (GI) intolerance, resulting in the interruption of enteral nutrition (O'Leary-Kelley et al., 2005; Petros & Engelmann, 2006; Roberts et al., 2003). High gastric residuals (GRs) and GI intolerance including diarrhea, vomiting, emesis, abdominal pain, or distention were the most common factors cited by Roberts et al (2003) (66% of patients), and Petros and Engelmann (2006) (41.5% of events). Similarly, O’Leary-Kelly et al (2005) found GI intolerance occurred in 36.7% of patients, but accounted for 19.8% of the interruption time. Kim et al (2010) reported lower rates of GI intolerance, 15.2 % of patients and 10.5% of events. Although elevated GRs is a frequent cause for interruption of enteral nutrition, very little data support the use of GRs to monitor enteral nutrition (McClave et al., 1999). Patients who are more critically ill may have more GI dysfunction which may lead to inadequate nutrition support compared to those who are less ill (Roberts et al., 2003). Therefore, it is necessary to consider the severity of disease when evaluating GI function. It is important to study reliable markers of intolerance to enteral nutrition. The use of prokinetics may also improve tolerance.

Feeding tube patency or displacement are also important factors that affect adequacy of enteral nutrition. In the McClave et al (1999) study, dislodgement of the feeding tube occurred in 41% of the patients, but accounted for only 7% of withheld feedings. These findings are in contrast to those of O’Meara et al (2008). In their study, the longest interruptions were due to problems related to the feeding tube and these accounted for 25.6% of the interruption time (17.3% of events). The time required to replace the tube often led to delays in feeding of up to 8 hours. Multiple steps for tube replacement including tube insertion, radiological check, physician’s confirmation, and actual provision of enteral nutrition after confirmation could increase the interruption time. Therefore, there is a need to simplify or modify the process for tube replacement (O'Meara et al., 2008).

Routine nursing procedures (i.e., patient baths, dressing changes, changing of bed linens) also led to interruption of enteral nutrition. Interruptions occurred in 33.3% of patients, but accounted for only 2.5% of the interruption time in the O'Leary-Kelly et al study (2005). Nursing procedures accounted for 24.8% of the total interruptions, but only 2.3% of the interruption time in the study by O'Meara et al(2008). Moreover, nursing procedures accounted for 30% of the patients and 1.4 hours of the total feeding time in the classic McClave et al (1999) study. Although all patients received routine nursing procedures, the researchers did not record interruptions of less than 15 minutes. The time limitation could lead to under-estimation of feeding interruption. McClave et al (1999) suggest that these interruptions could be avoided or corrected 99% of the time by strict protocols for infusion of enteral nutrition. Enteral nutrition is often discontinued whenever patients are placed in the supine position for routine nursing care because of fear of aspiration. Swanson and Winkelman (2002) suggest that placing the patient briefly in the supine position for routine nursing care should not require cessation of enteral nutrition. The effect of this positioning recommendation on aspiration rate has not been tested.

Other interruptions in enteral nutrition in critically ill patients are due to airway management, hemodynamic instability, suspected GI bleeding, equipment or formula problems, high blood sugar levels, high bilirubin levels, dialysis, medications, and transfers (Kim et al., 2010; McClave et al., 1999; O'Leary-Kelley et al., 2005; O'Meara et al., 2008; Rice et al., 2005). Other interruptions also include unexplained stopping of feedings by nurses, physicians, or dietitians (O'Meara et al., 2008).

To conclude, frequent interruptions of enteral nutrition may be a critical barrier of adequate enteral nutritional support. Procedures, diagnostic tests, GI intolerance, problems of the feeding tube, and routine nursing procedures are major reasons for interruptions (McClave et al., 1999; O'Leary-Kelley et al., 2005; O'Meara et al., 2008). Almost all studies evaluated interruptions and nutritional adequacy over 2 to 4 days except for Petros and Engelmann (2006) (7 days), Kim et al (2010) (7 days), and O’Meara et al (2008) (10 days). Most addressed acutely ill patients and there might be differences in results between acutely and chronically ill patients. Additional study is needed to address longer term recording of the relationship between feeding interruptions and nutritional adequacy for chronically critically ill patients.

Effects of Inadequate Nutrition in ICU Patients

Patients hospitalized in the ICU who are underfed resulting from insufficient enteral feeding intakes are at risk for malnutrition and deleterious clinical outcomes. In a study by McClave et al (1999) , decreasing the percentage of energy received was associated with decreasing serum albumin levels. Despite widely held beliefs, several studies have found no relationship between underfeeding and nutritional status over 3 to 10 days measured with serum albumin, prealbumin, body weight, and BMI (Day et al., 2001; Dickerson, Boschert, Kudsk, & Brown, 2002; Krishnan et al., 2003; Singh, Gupta, Aggarwal, Agarwal, & Jindal, 2009; Taylor et al., 1999; Villet et al., 2005). These findings are logical as they reflect the half life of the plasma proteins and the body’s compensatory response to acute starvation (Sabol, 2004).

Although there were no relationships between length of ventilation, infectious complications, LOS in the ICU, and energy deficit in some studies (Dickerson et al., 2002; Dvir, Cohen, & Singer, 2006; Kompan et al., 1999; Krishnan et al., 2003; Roberts et al., 2003; Singh et al., 2009), several studies demonstrated a positive correlation between negative energy balance and these clinical outcomes (Dvir et al., 2006; Roberts et al., 2003; Villet et al., 2005). Moderate energy intake was associated with positive outcomes i.e., a greater likelihood of spontaneous ventilation, a lower risk of blood infection, and a shorter LOS in the ICUs (Hise et al., 2007; Krishnan et al., 2003; Rubinson et al., 2004).

Across several studies, negative energy balance was positively related to total complication rate and organ failure, especially adult respiratory distress syndrome and renal failure (Dvir et al., 2006; Kompan et al., 1999; Villet et al., 2005). Although energy deficits were not correlated with mortality in some of the studies (Dickerson et al., 2002; Villet et al., 2005), one cohort study reported that lower energy intake was related to a higher likelihood of death (Singh et al., 2009). In another cohort study, patients with higher level energy intake had a higher odds of death than those with modest energy levels (Krishnan et al., 2003).

The heterogeneity of the ICU patients may contribute to difficulty in interpreting the effects of inadequate nutritional support on nutritional changes and clinical outcomes. Although descriptive studies cannot explain the causal relationship between levels of energy intake and clinical outcomes, many studies demonstrated that lower levels of energy intake had detrimental effects on ICU patients. Therefore, RCTs are needed to determine whether higher energy intake decreases morbidity and mortality in critically ill patients.

Discussion

This review confirms that negative energy balance and negative protein balance are common in enterally-fed patients who are critically ill. The average energy intake was 50% to 95% of requirements and only 14% to 52% of patients achieved their goal energy intake during the ICU stay (Desachy et al., 2008; Kim et al., 2010; Krishnan et al., 2003; McClave et al., 1999; Rice et al., 2005). The average protein intake was 38% to 82% of requirements (Binnekade et al., 2005; Reid, 2006; Taylor et al., 1999). These studies evaluated the adequacy of enteral nutritional intake during various study periods from 3 to 30 days; however most energy deficits occur during the first 3 days of hospitalization (Dvir et al., 2006). Furthermore, the studies used different methods for evaluation of energy or protein requirements and included heterogeneous ICU patients. Regardless of these limitations, it is evident that a large proportion of critically ill patients are underfed.

A review of the literature indicates that there are multiple barriers that impact the delivery of adequate enteral nutrition in critically ill patients. Of the patient factors, nutritional status and severity of illness do not explain inadequacy of enteral nutrition (Krishnan et al., 2003; Rubinson et al., 2004). Among feeding method factors, nutrient-dense formula was associated with overfeeding in energy requirements in one study (Reid, 2006). Two studies showed that transpyloric feeding was not harmful to ICU patients and could have favorable effects on energy and protein intake (Boivin & Levy, 2001; Esparza et al., 2001).

Of the feeding process factors, early initiation of enteral nutrition and rapid progression to goal rates contributed to the achievement of goal energy and protein intakes compared to late initiation and gradually increasing the rate of enteral nutrition

(Desachy et al., 2008; Ibrahim et al., 2002; Taylor et al., 1999). Under-prescription of enteral nutrition combined with insufficient delivery of prescribed nutritional goal resulted in inadequate nutritional intake (De Jonghe et al., 2001; McClave et al., 1999). In addition, study findings consistently indicated that repeated interruption of enteral nutrition resulted in significant underfeeding in patients hospitalized in the ICU (Kim et al., 2010; McClave et al., 1999; O'Leary-Kelley et al., 2005; O'Meara et al., 2008). Interruptions were mainly caused by diagnostic or surgical procedures, GI intolerance of enteral nutrition, displacement or obstruction of the feeding tube, and routine nursing procedures.

Different indications for disposition of gastric residual volumes and the use of prokinetics may be moderating factors in the amount of energy delivered. Prokinetic agents increase energy intake by improving the gastric emptying rate. If the permitted limit for gastric residual volumes is too low, it can lead to frequent and unnecessary interruptions of enteral nutrition. However, there is a lack of research evaluating gastric residuals as a measure of tolerance to enteral nutrition (Elpern et al., 2004).

Interruption of enteral nutrition is often due to avoidable causes, such as routine nursing procedures, and surgical or diagnostic procedures (McClave et al., 1999). This suggests that the manner in which enteral nutrition is delivered needs to be modified to promote adequate intake. In addition, when an interruption occurs, enteral nutrition may be started at a slower rate than before the interruption, then increased to the target rate. This rate dependent strategy can result in an even greater deficit in intake (O'Meara et al., 2008). Thus, the development of standardized feeding protocols to prevent unnecessary cessation and to replace enteral nutrition volume caused by interruptions may maximize the delivery of enteral nutrition in ICUs; these approaches need to be developed and implemented.

Although barriers including patient-related factors, under-prescription, and frequent interruptions can contribute to inadequate nutritional intake of patients in the ICU, a cause and effect relationship between these factors and nutritional adequacy cannot be inferred because these factors were not evaluated in the experimental designs. Furthermore, RCTs had small samples and were heterogeneous, so they were most likely under-powered to detect the effect of the intervention being studied. These limitations may have lead to inconsistent or inaccurate findings.

Despite the importance of effective management of enteral nutrition, only one study achieved the required energy or protein intake in participants during the study period (Neumann & DeLegge, 2002). Underfeeding has its greatest impact on clinically important outcomes including infectious complications, organ failure, total complication rates, and mortality in critically ill patients (Dvir et al., 2006; Singh et al., 2009; Villet et al., 2005). However, the combination of heterogeneity of ICU populations may have lead to inconsistency in the results of inadequate nutritional support. Relatively little is known about the relationships between protein balance and clinical outcomes in patients who are fed enterally. There is as yet no answer to the question “How much enteral nutrition is optimal for the critically ill patients.”

Conclusion and Implications

Although enteral nutrition administration has improved over the years in terms of skills, materials and formulas (Binnekade et al., 2005), this review paper has highlighted major barriers contributing to inadequate enteral nutrition in critically ill patients.

Inadequate enteral nutrition is associated with many barriers and the contribution of these varied across studies. Significant barriers are interruptions of enteral nutrition and they may be avoided or compensated for by implementing protocols for nutritional support.

There are several recommendations for future research resulting from this review of the literature. Coherent research that demonstrates the barriers that are responsible for the delivery of enteral nutrition in ICU patients is required. Studies which address each barrier and ways to prevent it are needed. Accordingly, standardized protocols for the delivery of enteral nutrition in critically ill patients must be developed, implemented, and tested.

Several implications for clinical practice follow from this review. Adequate enteral nutrition prescription is needed to meet the nutrient requirements of critically ill patients. Interventions are needed to assure that the prescribed enteral nutrition is delivered without unnecessary interruptions. Health care providers should continuously monitor the adequacy of nutritional support and clinical outcomes in critically ill patients.

This review provides a foundation for the development of interventions designed to improve enteral nutrition practices. The goal is to decrease the incidence of underfeeding associated with inadequate delivery of enteral nutrition and to optimize nutrition in the critically ill. Healthcare providers in the ICU are well equipped with the knowledge and skills needed to develop and implement enteral nutrition protocol, thereby influencing patient nutrition and clinical outcomes.

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Table 1

Adequacy of Enteral Nutrition and Related Barriers in Critically Ill Patients

Author/ Year	Population		Independent variables						Dependent variables				
									Energy		Protein		
	n	ICU	Patient factors	Method factors	Process factors	Under order	Inter-ruption	Other	Intake (balance)	% goal (patients)	Intake (balance)	% goal (patients)	Other
Randomized controlled trial													
Taylor[22] (1999)	82	NICU, Trauma ICU			Goal vs. gradual rate					60 vs. 37%		69 vs. 38%	
Kompan[35] (1999)	28	SICU			Initiate: <6h vs. >24h				1340±473 vs. 703±701kcal	80.5 vs. 60.9%			
Kearns[10] (2000)	44	MICU		G vs. D					812±122 vs. 1157±86kcal	47 vs. 69%	31±5 vs. 44±4g/d		
Day[32] (2001)	25	NICU		G vs. D					NS	NS (None)	NS	None	
Esparza[26] (2001)	51	MICU		G vs. T						64% vs. 66%			Aspiration: NS
Boivin[29] (2001)	40	Mixed ICUs		G vs. T						74 vs. 68%			
Neumann[20] (2002)	60	MICU		G vs. D					NS	100 vs.100%			Achieved goal rate: 28.8 vs. 43.0hr
Davies[31] (2002)	73	Mixed ICUs		G vs. J					NS				GRV: 32 vs. 74% of patients
Desachy[17] (2008)	100	MICU, SICU			Goal vs. gradual rate				1715±331 vs. 1297±331 kcal (-406±729 vs.-2310±1340kcal)	95% vs. 76%			High GRV: 26 vs. 10%
White[30] (2009)	104	General ICU		G vs. P					(-73 vs. -167kcal)				Achieved target goal: 8.7 vs. 12..3 h
Hsu[27] (2009)	121	MICU		G vs. D					1426±110 vs. 1658±118 kcal		58.8±4.9 vs. 67.9±4.9 g		Achieved target goal: 54.5 vs. 32.4 h
Quasi-experimental study													
Ibrahim[36] (2002)	150	MICU			Initiate: 1d vs. 5d				2370±2000 vs. 629±575 kcal		93.6±77.2 vs. 26.7±26.6g		Pneumonia: 49.3 vs.30.7%

Author/ Year	Population		Independent variables						Dependent variables				
									Energy		Protein		
	n	ICU	Patient factors	Method factors	Process factors	Under order	Inter-ruption	Other	Intake (balance)	% goal (patients)	Intake (balance)	% goal (patients)	Other
													Diarrhea: 13.3 vs. 4.0% LOS: 13.6 vs. 9.8 d
Rice[14] (2005)	55	MICU, SICU, Trauma, NICU					+	ICU	NS (with ICU)	Overall 50~70% (Overall 25%)			Achieved goal rate: 23h vs. 43h Average stop: 8h (for first 48h)
Prospective descriptive study													
Krishnan[15] (2003)	187	MICU	Alb, BMI, SAPS						NS	Overall 50.6%			
Rubinson[16] (2004)	138	MICU	Alb, BMI, SAPS					Age, Gender, LOV	NS	Overall 49.4%			
Villet[41] (2005)	48	SICU						Time flow	(-1270kcal/d vs. -625kcal/d) (1wk vs. 4wk)				
Dvir[44] (2005)	50	General ICU						Time flow	(Mean cumulative: -4767kcal)				High negative energy balance: 1-3 days
Hise[11] (2007)	77	MICU, SICU						ICU	(-1045 kcal/d: SICU, -784 kcal/d: MICU)	50%: SICU; 56%: MICU			
McClave[6] (1999)	44	MICU, CCU				+	+			(Overall 14%)			Order: 65% of requirement Interruption: 83.7% of patients 19.6% of feeding time
De Jonghe[13] (2001)	51	MICU				+				Overall 71.2%			Order: 78% of requirement
Elpern[38] (2004)	39	MICU					+			Overall 64%			Average stop 2.3h/patient/d
O'Leary-Kelley[7] (2005)	60	MICU, SICU, CCU					+			(Overall 30%)			Underfeeding: overfeeding = 68.3%: 1.7% of patients Average stop: 7h/d
Reid[21] (2006)	32	General ICU		Standard vs. caloric dense			+		975 vs. 1600 kcal (Overall median balance: -3985kcal)	60 vs. 103%	36.4 vs. 60g	51 vs. 82%	Underfeeding: 50% of feeding days Overfeeding: 19% of feeding days

Author/ Year	Population		Independent variables						Dependent variables				
									Energy		Protein		
	n	ICU	Patient factors	Method factors	Process factors	Under order	Inter- ruption	Other	Intake (balance)	% goal (patients)	Intake (balance)	% goal (patients)	Other
Petros[37] (2006)	61	MICU					+		23.2±7.5kcal/kg/d vs. 10.4±6.1kcal/kg/d				Interruption: 32.1% of feeding days
O'Meara[12] (2008)	59	MICU/					+	Time flow	(Negative balance on all study days)				Initiation time: 39.7h Average stop: 1.13/d/pt, 6h/d/pt
Kim[19] (2010)	47	NICU					+			Overall 76.5% (Overall 52.1%)			Underfeeding: 37.2% of patients Overfeeding: 10.7% of patients
Retrospective descriptive study													
Roberts[9] (2003)	50	MICU, SICU, Trauma, CCU/			Initiate: 3d vs. later		+		(3d vs. later: NS)	Overall 77.4%		Overall 58.2%	
Binnekade[18] (2005)	403	General ICU	SAPS	G vs. D vs. NJC, Formula kinds				Time flow		G vs. D vs. NCJ: 49% vs. 58% vs. 76% [1d vs. 5d : 39% : 51%]		Overall 54%	Success factor (OR): Semi-elemental formula (3.02), Caloric dense formula (1.62), Low GRV (1.51)
Bryk[24] (2008)	117	SICU, Trauma		Standard vs. caloric dense					NS				Caloric dense: Increased length of stay, ventilator days
Meta-analysis study													
Marik[33] (2003)	238 (5studies)	Mixed ICUs		G vs. P									WMD NS

+, reported; *, median age (range); NS, non significant; ICU, intensive care unit; MICU, medical ICU; SICU, surgical ICU; NICU, neurologic ICU; CCU, coronary care unit; EN, enteral nutrition; PN, parenteral nutrition; HBE, Harris-Benedict equation; ACCP, American College of Chest Physicians; BMI, body mass index; SAPS, simplified acute physiology score; CIS, computerized information system; GRV, gastric residual volume; Alb, albumin; Prealb, prealbumin; NCJ, needle catheter jejunostomy; OR, odds ratio; WMD, weighted mean difference

Table 2

Type of Interruption for Enteral Nutrition

			Type of interruption									
Author	Year		Feeding tube problem	Gastric residual	GI intolerance	Procedure	Surgery	Radiology	Nursing care	Hemo-dynamic	Airway	Other
McClave[6]	1999	% of patients affected	41	45	†	39		27	30	†	NR	31
		% of total interruption time	7.7	15.1	†	35.0		4.6	1.4	†	NR	36.2
		% of avoidable	67	70	†	80		52	99	†	NR	52
Boivin[29]	2001	% of total interruption events	19	17	NR	NR	13	23	11	4	12	NR
Roberts[9]	2003	% of patients affected	NR	38	28	NR	NR	NR	NR	NR	NR	NR
Elpern[38]	2004	% of total interruption time	2.7	11.5	9.2	35.7			NR	13.5	NR	11.2
Rice[14]	2005	% of total interruption events	3	4	5	41			2	6	15	3
O'Leary-Kelley[7]	2005	% of patients affected	24.9	21.7	15.0	15.0	23.3	13.3	33.3	NR	30	21.6
		% of total interruption time	11.1	6.6	13.2	1.4	23.4	6.9	2.5	NR	28.8	5.9
Reid[21]	2006	% of total interruption events	5	14	7	8		3	16	NR	21	12
Petros[37]	2006	% of total interruption events	6.0	31.9	9.6	30.7		10.8	NR	NR	NR	10.8
		% of total interruption events*	2.7	4.0	0	21.4		60.0	NR	NR	NR	11.9
O'Meara[12]	2008	% of total interruption events	17.3	9.7	NR	10.9	5.2	4.5	24.8	2.1	14.2	11.3
		% of total interruption time	25.6	13.3	†	7.9	7.7	5.0	2.3	3.7	11.7	22.8
Kim[19]	2010	% of patients affected	NR	8.7	6.5	4.3	6.5	4.3	NR	6.5	19.6	15.2
		% of total interruption events	NR	6.5	4.0	4.0	24.2	1.6	NR	10.5	25.8	23.4

Other: transfer, high blood sugar, high bilirubin, dialysis, medication, GI bleeding, equipment/formula problem, ICU doctors, dietitian

*, compensation for reduction due to diarrhea or high gastric residual volume; †, categorized into "other" in original paper although categorized into a specific type of interruption in this review; GI, gastrointestinal; NR, not reported

CHAPTER 3

Adequacy of Early Enteral Nutrition in Adult Patients in the Intensive Care Unit

Abstract

Background: Underfeeding is a common problem for patients hospitalized in the intensive care unit (ICU) and is associated with severe negative consequences, including increased morbidity and mortality.

Objectives: To evaluate the adequacy of energy and protein intake of patients in a Korean ICU in the first four days after initiation of enteral feeding and to investigate the factors that had impact on adequate intake. Adequacy was defined as underfed and adequately fed.

Methods: A prospective, cohort study of 34 consecutive patients receiving bolus enteral nutrition was conducted in a Korean medical ICU. 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 less than 90% of required energy and protein.

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 4 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 due to early initiation, under-prescription, and prolonged interruption of enteral feeding. Future research is needed to develop and test enteral feeding protocols to provide adequate nutritional support to this Korean ICU population.

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 (ASPEN, 2002). The optimal nutrient route of administration in the ICU minimizes feeding technique related complications, thereby providing optimal nitrogen balance, maintaining lean body mass, and results in better clinical outcomes (Cartwright, 2004; Cerra, Benitez, & Blackburn, 1997).

Enteral nutrition is preferred route of administration for critically ill patients who cannot tolerate oral feeding (ASPEN, 2002). 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% to 68% of patients are fed less than their nutritional requirements with enteral nutrition (Kim et al., 2010; O'Leary-Kelley et al., 2005). 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 defenses, increased rates of nosocomial infections, organ failure and increased hospital length of stay (Dvir et al., 2006; McClave et al., 1998; Villet et al., 2005). .

To optimize 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 United States (US). 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 (De Jonghe et al., 2001; Desachy et al., 2008; Esparza et al., 2001; Ibrahim et al., 2002; Krishnan et al., 2003; McClave et al., 1999; O'Leary-Kelley et al., 2005; Reid, 2006). 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, Lee, & Lim, 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 which will improve clinical outcomes and survival of enterally fed patients in the Korea ICU.

The objective of this study was to determine the adequacy of nutritional support by assessing energy and protein intake for the first 4 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, hospitalized 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 4 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 enrollment. 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 4-day study period. Thus, the sample for this study was 34 patients who received enteral nutrition for the first 4 days after initiation of enteral nutrition.

Variables and Measures

Adequacy of energy intake. To assess the adequacy of energy intake, patients were categorized into three groups (adequate feeding, underfeeding, overfeeding).

Adequate feeding of energy was defined as total energy intake between 90 and 110% of the energy requirement. Underfeeding was defined as intake less than 90% of energy requirements, and overfeeding as intake more than 110% (O'Leary-Kelley et al., 2005).

Energy requirements were calculated using the Harris-Benedict equation (HBE) with a stress factor at enrollment (Clifton et al., 1984; Khorram-Sefat, Behrendt, Heiden, & Hettich, 1999; Moriyama et al., 1999; Shanbhogue, Bistrian, & Jenkins, 1987; Uehara, Plank, & Hill, 1999; Van den Berg & Stam, 1988). 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, Keating, Quercia, & Karbonic, 1995) were used to calculate the requirements.

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 hypoglycemia. Dextrose and total parenteral nutrition are combined with enteral nutrition in some patients. As the enteral nutrition approaches goal rate, the parenteral nutririon is decreased until it is discontinued (Engel et al., 2003; Kim et al., 2010). Therefore, total energy intake included energy provided via the parenteral route such as dextrose and supplementary parenteral nutrition [MG-TNA(MG-total nutrient admixture), oliclinomel], in addition to enteral energy intake.

Adequacy of protein intake. Adequate protein intake was defined as total protein intake of more than 90% of protein requirements and underfeeding as intake less than 90% (Binnekade et al., 2005). Protein requirements were calculated using the American

Dietetic Association's equation (Clifton et al., 1984; Gabuzda & Shear, 1970; Ishibashi, Plank, Sando, & Hill, 1998; Klein & Koretz, 1994; Levey et al., 1996; Macias et al., 1996). 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.

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 the parenteral route such as 20% albumin and supplementary parenteral nutrition (MG-TNA and oliclinomel), in addition to enteral feeding. 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).

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 4 days were categorized 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 enrollment, except for severity of disease which was evaluated by the researcher using the Acute Physiology Chronic Health Evaluation II (APACHE II) score (Knaus, Draper, Wagner, & Zimmerman, 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, Kim, Kang, & Kang, 2009).

Feeding method factors. Feeding method factors consist of the size of the feeding tube and the type of feeding formula (Bryk et al., 2008; Reid, 2006). This information was extracted daily from the medical records. The feeding tubes used were either 16 or 18 French. The feeding formulas are categorized 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). The data was extracted from the medical records of each patient at enrollment 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 and 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 a.m., 12 p.m., and

6 p.m. over 30 minutes. Nurses recorded the time of withholding and restarting enteral nutrition using a standardized recording sheet for each interruption.

Procedures

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

After obtaining written informed consent, patient-related data and feeding initiation time 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 enrollment. 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.

Data Analysis

Data were analyzed with SPSS 15.0. The level of statistical significance was set at

$p<0.05$. The characteristics of the patients who were underfed/not underfed were compared using independent t-test and chi-square tests. The analysis plan for each aim is described below.

Aim 1: To determine the proportion of study subjects who are underfed, overfed, and adequately fed in terms of energy for the entire 4 days. Total energy intake was calculated as a mean value for 4 days. The ratio of energy intake in kilocalories to energy requirements was then multiplied by 100. Patients were categorized into three groups based on the percentage of energy requirement received. Frequency was used to determine the number of patients in each group, and percentage of patients in each group was evaluated.

Aim 2: To determine the proportion of study subjects who are underfed and adequately fed in terms of protein for the entire 4 days. Total protein intake was calculated as a mean value for 4 days. The percentage of the protein requirement received was then calculated. Patients were categorized 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.

Aim 3: To identify the factors that impact the adequacy of energy intake for the entire 4 days. To identify variables associated with the adequacy of energy intake, a nonparametric correlation matrix was constructed to test the relationship among 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

For the sample 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 C-reactive protein 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 less than 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 summarized in Table 1. There were significantly more men with energy intakes less than 90% of energy requirements than with more than 90% (67% vs. 30% respectively, $p = .01$). Patients who received less than 90% of their energy requirements had significantly lower energy prescriptions (81% vs. 102% of requirements, $p < .01$), and longer enteral feeding interruptions (8.4 vs. 2.2 hours, $p = .03$) compared to those who received more than 90% of energy requirements.

Findings by Study Aim

Aim 1 was to determine the proportion of study subjects who are underfed, overfed, and adequately fed in terms of energy for the entire 4 days. Patients were categorized into three groups for adequacy of energy intake, according to the percentage of energy requirement received. The adequacy of energy intake is shown in Figure 1. In the 34 patients, 21 patients (62%) were underfed; 10 patients (29%) had adequate energy intake; three patients (9%) were overfed during the four feeding days.

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, three patients who were overfed received a mean of 19% of their energy requirements from parenteral nutrition.

Aim 2 was to determine the proportion of study subjects who are underfed and adequately fed in terms of protein for the entire 4 days. Patients were categorized into two groups, based on the percentage of protein requirement received. Fifteen of 34 (44%) patients had adequate protein intake, but 56% were underfed for the entire study period (Figure 1). There was no significant difference in protein received from intravenous infusion or parenteral nutrition between patients who were underfed or adequately fed.

Aim 3 was to identify the factors that impact the adequacy of energy intake for the entire 4 days. 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 in critically ill patients receiving enteral nutrition [χ^2 (4) = 28.94, p<.01]. The model explained 88% of the variance in underfeeding.

As shown in Table 2, three factors made unique contributions to the model. Patients who were under-prescribed were 16 times more likely to receive underfeeding 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, patients were 99% less likely to be underfed, 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, controlling for other factors in the model (95% CI, 1.00, 1.02). Therefore, patients who had enteral feeding initiated earlier with under-prescription were more likely to be underfed 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 than those who had fewer feeding interruptions.

Discussion

To our knowledge, this study is the first study to identify the factors that impact adequate enteralintake 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 4 days after initiation of enteral nutrition. More than half of the patients received less than 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 hospitalized 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 less than 80% of required energy) (Kim et al., 2010). Consistent with our study, these studies (Engel et al., 2003; Kim et al., 2010; O'Leary-Kelley et al., 2005) 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 and incomplete delivery of enteral nutrition were likely to contribute to increased proportions of underfeeding 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 was a factor contributing to underfeeding 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 US (Desachy et al., 2008; Elpern et al., 2004; Hsu et al., 2009; Ibrahim et al., 2002; O'Leary-Kelley et al., 2005; Reid, 2006). 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 and explained 88% of the variance in underfeeding. Patients whose energy was under-prescribed for enteral nutrition were more likely to be underfed compared to those who had adequate or over prescription. It is not particularly surprising that under-prescription significantly contributed to underfeeding, 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, because overfeeding can induce complications such as hyperglycemia, fatty liver, and increased CO_2 production (Parrish & McCray, 2003). Although only three patients were overfed, 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 5 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 (ASPEN, 2002; Heyland et al., 2003). In the present study, patients were enterally fed within a median time of 3 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 (Charvat, Kratochvil, Martinkova, Masopust, & Palova, 2008; Ibrahim et al., 2002).

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. This is supported by a study of patients who started enteral nutrition on the first day after ICU admission. These patients had more diarrhea than those who started on the fifth day (Ibrahim et al., 2002). In our study, however, initiation of enteral nutrition that started within 3 days after admission to the ICU was not significantly related to GI intolerance including high gastric residual volumes, diarrhea, and vomiting. It should be noted that it may not be possible to attain statistical significance for GI intolerance due to the overall low incidence of diarrhea 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. 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 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; O'Meara et al., 2008; Petros & Engelmann, 2006). 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 time for some short interruptions because they were using an intermittent administration method, they could not replace the large volume that had to be replaced due to long interruptions. Therefore, unnecessary prolonged interruptions should be avoided to insure adequatenutritional 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 in order 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 in our study. In addition, gender did not significantly predict underfeeding when controlling for other factors. However, a significant relationship (r=0.39, p<.05) between gender and energy prescription may affect underfeeding in this study. That is, gender may be a moderating factor, rather than a contributing factor for underfeeding.

Feeding method factors also did not predict underfeeding 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 (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 due 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 among the ICUs in the hospital or among 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 which 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

This study has highlighted that a large portion of critically ill patients receiving enteral nutrition do not receive their energy and protein requirements. Relevant reasons for inadequate nutritional intake in Korean medical ICU patients include 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. The factors that have been identified can be targeted in order to modify and improve nutritional interventions for critically ill patients.

Standardized nutritional protocols including the management of factors that contribute to underfeeding should be developed and tested in a diverse ICU population. The protocols need to describe the standardized prescription of enteral nutrition and the management to avoid unnecessary withholding of enteral feeding. Research also is needed to address the enteral feeding knowledge and attitudes of ICU healthcare providers. Further research is needed to validate whether later initiation of enteral nutrition results in less GI intolerance and therefore greater energy intake.

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Table 1

Patient Characteristics

Characteristic	I (*n*=13)	II (*n*=21)
Age, mean (SD), years	76.1 (6.1)	67.5 (17.6)
Gender (male/female), Number*	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, Number	7	8
APACHE II[1)] 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, Number	13	21
Feeding tube size, Number		
16 French/18 French	7/6	10/11
Enteral Feeding formula, Number		
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[2)3)] /PN[4)], Number	7/5	8/6
% of required energy received via PI[2)], mean (SD), %	8.7 (10.6)	5.8 (9.9)
% of required protein received via PI[3)], mean (SD), %	5.7 (8.5)	4.7 (8.8)
% of required energy received via PN[4)], mean (SD), %	7.0 (11.0)	4.8 (9.1)
% of required protein received via PN[4)], mean (SD), %	5.6 (8.6)	4.5 (8.8)

I, energy intake/required ratio ≥ 90%; II, energy intake/required ratio < 90%;
*, p<.05; **, p<.01
1) APACHE II, acute physiology chronic health evaluation II;
2) PI, parenteral infusion included dextrose, parenteral nutrition
3) PI, parenteral infusion included 20% albumin, parenteral nutrition
4) PN, parenteral nutrition included MG-TNA, oliclinomel

Table 2

Factors Associated with Underfeeding in Logistic Regression

	OR[1)]	95% CI[2)] for OR[1)]	*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

1)OR: odds ratio
2) CI: confidence interval

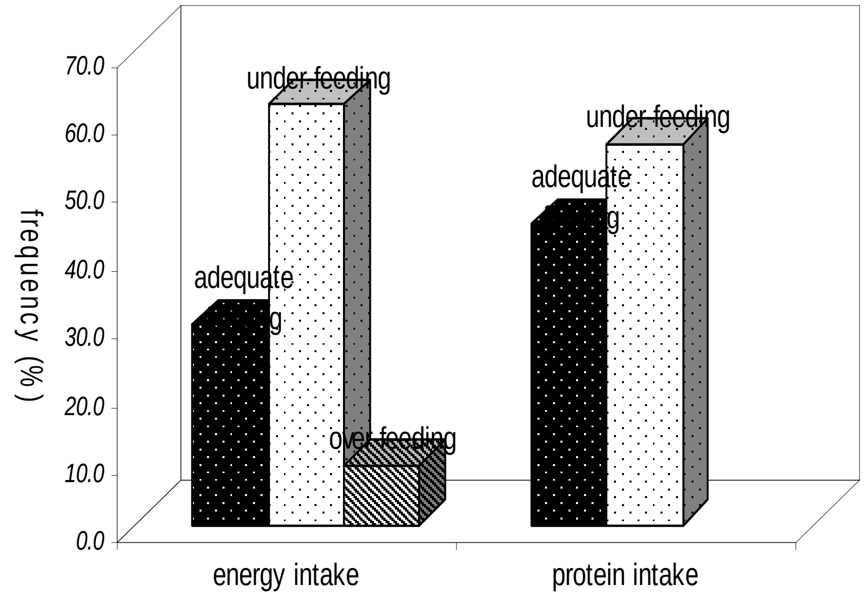

Figure 1

Percentage of Under-, Over-, and Adequate Feeding in Terms of Energy and Protein

CHAPTER 4

Evaluation of Enteral Nutritional Intake of Patients in Korean Intensive Care

Abstract

Background: Adequate nutritional support is important for maximizing clinical outcomes in critically ill patients. Patients frequently receive inadequate nutritional intake with enteral nutrition.

Objective: To assess the nutritional intake of energy and protein across the first four days after initiation of enteral feeding and to examine the relationship of intake with interruptions of enteral feeding in Korean ICU patients.

Methods: This was a prospective cohort study of 34 critically ill adults who had a primary medical diagnosis and received bolus enteral feeding. Energy and protein requirements were determined using the Harris-Benedict equation and the American Dietetic Association's equation. The amounts of energy and protein prescribed and received, and reasons for and amounts of interruptions in enteral feeding were recorded for four consecutive days immediately after enteral feeding initiation.

Results: Although the differences between requirements and intakes of energy and protein decreased significantly over time, patients did not receive required energy and protein intake during the 4 days of the study. Energy prescribed was consistently less than required on each of the four days. Enteral nutrition was withheld during a mean of 6 hours per patient for the 4 days. Prolonged feeding interruptions due to gastrointestinal intolerance (r=-0.874, p<.001) and procedures (r=-0.839, p=.005) were negatively associated with the percent of prescribed energy received.

Conclusion: Enteral nutritional intake is insufficient in bolus fed Korean ICU patients, resulting from prolonged feeding interruptions combined with under-prescription of enteral nutrition. Feeding interruptions due to gastrointestinal intolerance

and procedure were the main contributors to inadequate energy intake. Study data point to the need to improve the adequate prescription and delivery of enteral feeding to mitigate inadequate intake.

Introduction

Nutritional support is vital care for critically ill patients. When nutritional support is appropriately administered, it can enhance immunity and wound healing, prevent loss of and restore lean body loss, and decrease the risk of nosocomial infection and multiple organ failure (Day et al., 2001; Parrish & McCray, 2003). Protein is an especially important nutrient because it is required to maintain body structures, facilitate mobility, stimulate antimicrobial functions, and provide substrate for synthetic function, including wound healing (Parrish & McCray, 2003; Stipanuk, 2006).

Despite the importance of adequate nutritional intake, critically ill patients receiving enteral nutrition frequently receive less enteral nutrition than recommended (Desachy et al., 2008; Krishnan et al., 2003; Rice et al., 2005). Mean energy intake ranging from 50% to 95% of requirements and protein intake between 38% and 82% of requirements have been provided by enteral nutrition to critically ill patients (Desachy et al., 2008; Reid, 2006; Rubinson et al., 2004; Taylor et al., 1999).

Similarly, underfeeding in critically ill patients with enteral nutrition is a common problem in Korea (Kim, Choi, & Ham, 2009). Estimates of only 69 to 77 % of the required energy and about 65% of the required protein are prescribed for enteral nutrition in critically ill patients (Kim et al., 2009; Kim et al., 2010; Park et al., 2001). In addition, the amount of energy received is less than the prescribed energy. There is a paucity of data about actual intake; however, the authors of one study reported enteral nutrition intake in critically ill patients that only 87% of the prescription was delivered (Park et al., 2001). While there are limited data about actual prescribing patterns, personal clinical experience indicates that the prescription of enteral nutrition varies widely. This may be due to the fact that there is no standardized protocol for the prescription of enteral nutrition and it is determined independently by each physician in the intensive care unit (ICU). When inadequate volumes are prescribed, insufficient nutritional intake results in ICU patients in Korea. Incomplete delivery of enteral nutrition prescribed may also contribute to underfeeding in this population.

Several factors impact the adequacy of enteral nutritional intake in ICU patients in the United States (US). Under-prescription combined with insufficient delivery of prescribed nutrients results in inadequate nutritional intake (De Jonghe et al., 2001). A large volume of enteral nutrition is wasted because of inappropriate stopping and delay in restarting enteral nutrition. Interruptions of enteral nutrition due to gastrointestinal (GI) intolerance of enteral tube feedings, displacement or obstruction of the feeding tube, airway management, diagnostic or therapeutic procedures, and routine nursing procedures result in significant underfeeding in ICU patients (De Jonghe et al., 2001; McClave et al., 1999; O'Leary-Kelley et al., 2005; O'Meara et al., 2008). McClave and colleagues (1999) suggest that some interruptions of enteral nutrition are avoidable, and preventing them will maximize nutritional delivery.

Although studies have examined the enteral nutritional intake and enteral feeding interruptions in critically ill patients in the US, they did not evaluate the actual relationship between them. There are also little data about the enteral nutritional intake in Korean ICU patients. Only one study (Kim et al., 2010) reported the reasons for feeding interruptions that can affect insufficient delivery of enteral nutrition in this population. Therefore, evaluating the enteral nutritional intake and identifying the reasons for enteral feeding interruptions are essential for developing an evidence-based enteral nutritional care protocol in ICUs in Korea.

The purpose of this prospective, cohort study was to evaluate the trends in the amount of energy and protein prescribed and received across the four days after initiation of enteral feeding in Korean medical ICU patients. The relationship between interruption time that enteral feeding was withheld and energy received was also investigated.

The specific aims of the study in patients in the Korean medical ICU during the first four days after initiation of enteral feeding were to determine whether:

1. prescribed energy for enteral nutrition meets energy requirements on each day.
2. energy received by enteral nutrition meets energy required on each day.
3. prescribed protein for enteral nutrition meets protein requirements on each day.
4. protein received by enteral nutrition meets protein requirements on each day, and

to evaluate

5. the relationship between total interruption time of enteral nutrition and mean energy received for the entire 4 days.
6. the relationship between interruption time by each reason for the interruptions and the energy received on the day feeding was interrupted.

Methods

This prospective cohort study examined the adequacy of energy and protein prescribed and received over the first four days after initiation of enteral nutrition in Korean patients in a medical ICU. Data were collected from July 2010 to September 2010.

Setting and Sample

Patients were recruited from the ICU (18 beds) of a tertiary care university hospital in Daejon, Korea. The sample was composed of adult medical ICU patients (>18 years) who were prescribed enteral feeding and required enteral tube feeding for at least 4 days. Patients were excluded if they were receiving parenteral or oral feeding as main energy source, or who had a surgical intervention at the time of enrollment. The four day study period was chosen because enteral nutrition is usually stabilized within 4 days after initiation and should be provided adequately within 3 days (Petros & Engelmann, 2006; Umali et al., 2006).

The nQuery Advisory software (Statistical Solutions, Saugus, MA) was used to calculate the sample size. When using the repeated measures analysis of variance (ANOVA), the estimated sample size was 28 subjects to detect a difference in means across the levels of the repeated measures factor characterized by an effect size of 0.106 assuming that the measure of sphericity of the covariance matrix, epsilon, is 1.00 (α=0.05; β=0.20). To allow for potential attrition, this study aimed for a sample of at least 34 patients.

Variables and Measures

Required energy was defined as energy requirements in calories calculated using the Harris-Benedict equation (HBE) with a stress factor (1.0-1.6) (Clifton et al., 1984; Khorram-Sefat et al., 1999; Moriyama et al., 1999; Shanbhogue et al., 1987; Uehara et al., 1999; Van den Berg & Stam, 1988). A conservative approach was used to calculate requirements; specifically the lowest factor was utilized to calculate the stress factor when there was a range of values. When 2 or more stress factors were present, the lower value of the range of the stress factor with the higher value was used. Ideal body weight used to calculate adjusted body weight was determined from the average height and weight charts for Korean men and women at different ages (Ministry for Health, 2001). Adjusted body weight with a 50% correction factor (Amato et al., 1995) was used with those who were obese (BMI$\geq$25 kg/m^2) (Choo, 2002) to reduce overestimation. Required energy was calculated at enrollment based on patients' medical records.

Prescribed energy was defined as physician's order for calories to be infused each day. It was collected daily from the medical record.

Received energy was calculated by multiplying the volume of enteral formula received by the calorie content of the enteral formula (Binnekade et al., 2005). The type and volume of enteral formula received were recorded daily from the medical record.

Required protein was defined as protein requirements in grams calculated using the American Dietetic Association's equation (Clifton et al., 1984; Gabuzda & Shear, 1970; Ishibashi et al., 1998; Klein & Koretz, 1994; Levey et al., 1996; Macias et al., 1996). It was determined at enrollment using the medical record. A conservation approach was used in that the lowest value was utilized to calculate the contribution of medical conditions to protein required when there was a range of values. If more than one condition was present, the condition with the highest value was selected and the lowest stress factor in that range was used. In obese patients, metabolically active weight was used to calculate protein requirement (Fuhrman, 2003).

Prescribed protein was defined as physician's order for protein to be infused daily in grams of protein/cc of the enteral formula. It was calculated daily using the data on the type and volume of enteral formula prescribed from the medical record,

Received protein was calculated daily by multiplying the volume of enteral formula received by the protein content per cubic centimeter of the enteral formula provided. Data on the type and volume of enteral formula received were extracted daily from the medical record.

Interruption time of enteral feeding was defined as the number of minutes when a patient should be fed but not receiving feeding due to GI intolerance [high gastric residual volumes (GRVs), diarrhea, and vomiting], GI hemorrhage, feeding tube problem (absence, occlusion, and malposition of the feeding tube), procedures (diagnostic or therapeutic procedures, radiology, and surgery), routine nursing care requiring a supine position (bathing, skin care, changing of bed linens, position changes, and diaper changes), airway management (endotrachial tube intubation and management of the tube, planned extubation and tracheostomy) or other reasons. The expectation was that enteral feeding prescribed was infused in 30 minutes at 8am, 12pm, and 6pm. If enteral feeding was stopped during feeding or feeding was not restarted at the time scheduled after previous feeding, the bedside nurse recorded the reason for withholding of enteral nutrition, and the time of stop and restart of enteral nutrition using a standardized recording sheet.

Demographic and Clinical Characteristics: These included patient medical ID number, age, gender, diagnossis; hospital admission date, ICU admission date, and date mechanical ventilation was started; body weight, serum albumin, and C-reactive protein (CRP), assessed by review of medical records and recorded on a standardized form. Acute Physiology and Chronic Health Evaluation II (APACHE II) was assessed by the researcher to evaluate the severity of illness of the patient at enrollment (Knaus et al., 1985). Supine knee height was measured using a knee height caliper at enrollment to estimate height for the calculation of required energy and body mass index (BMI)

(Hwang et al., 2009). BMI was calculated and categorized using the criteria for Asians (Choo, 2002).

Enteral feeding characteristics: Dimensions include how soon after ICU admission enteral feeding was started (the time interval from admission to the ICU to actual initiation of enteral feeding), and location and size of enteral feeding tube. These data were obtained from medical records at enrollment. Gastric residual volume (volume of gastric contents aspirated from the feeding tube by the nurses immediately before each feeding), diarrhea [more than three liquid stools per day that lead to interruption of enteral feeding (McClave et al., 1999)], and vomiting were obtained daily from the medical record.

Procedures

After institutional review board (IRB) approval from a major west coast university in the United States and the Korean hospital's IRB, medical ICU patients were screened by the researcher using their medical records. The researcher explained the study to those who met the inclusion criteria and obtained written informed consent from the patient or their legal surrogate, when patients could not consent for themselves.

According to the nursing protocol of the medical ICU, enteral feeding was administered intermittently by the gravity method. Usually, a total of 3 bottles were administered at 8am, 12pm, and 6pm, over a 30 minutes infusion period, with the head of the bed elevated 30 to 45°.

Demographic, clinical and enteral feeding method data were obtained from the patient's medical records at enrollment. APACHE II and supine knee height were measured by the researcher at enrollment. Nutritional intake data were collected daily for four consecutive days from the patient's medical record, including the type of enteral formula, energy and protein prescribed by the physician, energy and protein received in the previous 24 hours. Gastric residual volumes (GRVs), the number and volume of diarrhea, and the number of episodes of vomiting were recorded daily for four days from the medical record. Medications that can influence the motility of the GI tract (prokinetics and antibiotics) were also recorded daily (Pachorek & Chan, 2002). The reason for each cessation of enteral feeding recorded by nurses was categorized into one of the seven options described previously in the method section. The duration of each interruption was calculated and recorded in minutes.

Data analysis

All data were analyzed in SPSS version 15.0 for Windows. A two-tailed, *p* value of less than .05 was set as the level of significance, except for the post-hoc test where alpha was preset at $p \leq .01$. Descriptive statistics were used to examine the characteristics of patients.

Aim 1: To determine whether prescribed energy for enteral nutrition met energy requirements on each day. A two-way repeated measures ANOVA was used to determine the difference between prescribed and required amounts of energy on each day of the 4 days. If the difference significantly interacted with time, post-hoc tests were conducted to identify which days significantly differed from each other.

Aim 2: To determine whether energy received by enteral nutrition met energy required on each day. A two-way repeated measures ANOVA was used to determine the difference between received and required amounts of energy on each day of the 4 days. If the difference significantly interacted with time, post-hoc tests were conducted to identify which days significantly differed from each other.

Aim 3: To determine whether prescribed protein for enteral nutrition met protein requirements on each day. A two-way repeated measures ANOVA was used to evaluate the differences between prescribed and required amount of protein on each day of 4 days. If the difference significantly interacted with time, post-hoc tests were conducted to identify which days significantly differed from each other.

Aim 4: To determine whether protein received by enteral nutrition met protein requirements on each day. A two-way repeated measures ANOVA was used to evaluate the differences between received and required amount of protein on each day of 4 days. If the difference significantly interacted with time, post-hoc tests were conducted to identify which days significantly differed from each other.

Aim 5: To determine the relationship between total interruption time of enteral nutrition and mean energy received by enteral nutrition for the entire 4 days. The amounts of interruption time for 4 days were calculated and summed. The percentages of prescribed energy received for 4 days were calculated using mean and SD. A Pearson product moment correlation was calculated to determine the relationship between total interruption time and the mean percentage of prescribed energy received over the 4 days.

Aim 6: To determine the relationship between interruption time of each reason for the interruptions and the energy received on the day feeding was interrupted. The interruption time for each reason was calculated. The percentage of prescribed energy received on the day enteral nutrition was withheld was calculated. A Pearson product moment correlation was used to examine the relationship between the interruption time by each reason for interruption and the percentage of prescribed energy received by enteral nutrition on the day feeding was interrupted.

Results

Sample Characteristics

Forty-five subjects were enrolled in the study. Eleven subjects (24%) were withdrawn because they stopped enteral feeding within 4 days. Reasons for stopping feeding were that patients were changed to parenteral nutrition (n=5), changed to oral feeding (n=3), transferred out of the unit (n=2), or died (n=1).

Thirty four subjects completed the entire study. The average of the subjects was 70.8 years; half of the subjects were men. Fifteen patients (44.1%) were mechanically ventilated. The mean APACHE II score was 13.0 (SD 6.1). All patients were fed through a nasogastric tube.

Data show the majority of subjects had a major diagnosis of neurological and respiratory disease (Table 1). The subjects' mean serum albumin was 3.3 (SD 0.8) g/dl and serum C-reactive protein (CRP) was 6.1 (SD 7.1) mg/dl. Body mass index showed the following weight categories for the patients: overweight/obese (*n*=18), normal weight (*n*=13), and underweight (*n*=3). Average time to enteral nutrition initiation was 5.3 (SD 6.8) days after admission to the ICU.

Findings by Study Aim

Aim 1 was to determine whether prescribed energy for enteral nutrition meets energy requirements on each day. Two-way repeated measures ANOVA showed that energy requirements and energy prescriptions were significantly different (F(1,33)=12.27

p=.001). Figure 1 showed that energy requirements were consistently greater than prescribed. There was a significant interaction between energy amounts (requirement and prescription) and time (days 1, 2, 3, 4) (F(3,99)=44.12, *p*<.001) indicating the difference in energy between required and prescribed differed across the days. Post hoc tests revealed that the difference between energy required and prescribed on day 1 differed significantly from those on day 2, 3, and 4, with the magnitude of the difference decreasing over time (-362 vs. -189, -95, -68 kcal; *p*<.001). The difference on day 2 was significantly larger those on day 3 and day 4 (-189 vs. -95, -68 kcal; *p*=.001). Energy required and prescribed on day 3 did not differ significantly from that on day 4 (-95 vs. -68 kcal; *p*=.059) (Figure 1).

Aim 2 was to determine whether energy received by enteral nutrition meets energy required on each day. Energy received by enteral feeding was significantly different than the energy requirement (F(1,33)=27.14, *p*<.001). Energy received was consistently less than required during the 4 study days (Figure 1). The difference in amounts of energy required and received was significantly different depending on time, F(3,99)=28.16, p<.001. In post hoc tests, the difference between required and received on day 1 was significantly larger than those on day 2, 3, and 4 (555vs. 287, 171, 174 kcal; *p*<.001). The difference on day 2 was significantly larger than that on day 3 (287 vs. 171; *p*=.003), but no different than on day 4 (287 vs. 174 kcal; *p*=.018). The difference on day 3 did not differ significantly from that on day 4 (171 vs. 174; *p*=.928) (Figure 1).

Aim 3 was to determine whether prescribed protein for enteral nutrition meets protein requirements on each day. The two-way repeated measures ANOVA showed that there was a significant interaction between protein required and protein prescribed, and time (day 1, 2, 3, 4), F(3, 99)=40.57, *p*<.001. Prescribed protein was lower than required on day 1 and day 2, but higher on day 3 and day 4 (Figure 2). Post hoc tests showed that the gap between protein requirement and prescription on day 1 was significantly different than those on day 2, 3, and 4 (-15.1 vs. -3.0, 4.3. 6.7 g; *p*<.001); the gap on day 2 was different than those on day 3 and 4 (-3.0 vs. 4.3, 6.7 g; p=.002, *p*<.001). The difference on day 3 was not significantly different from that on day 4 (4.3 vs. 6.7 g; *p*=.026). The negative gap (protein prescribed lower than required) on day 1 drastically decreased on day 2 and then, became positive (protein prescribed higher than required) on day 3 and day 4 (Figure 2).

Aim 4 was to determine whether protein received by enteral nutrition meets protein requirements on each day. Patients received significantly less protein than their requirement during the study period, F(1,33)=21.44, *p*<.001. The difference in amounts received and required was significantly different depending on time, F(3,99)=31.56, p<.001: the difference on day 1 was significantly larger than those on day 2, 3, and 4 (-25.4 vs. -12.1, -6.3, -6.8 g; *p*<.001); the difference on day 2 was larger than day 3 (-12.1 vs -6.3 g; *p*=.002); day 4 did not differ from day 2 and 3 (-6.8 vs. -12.1, -6.3 g; *p*=.012, *p*=.807)(Figure 2).

Aim 5 was to determine the relationship between total interruption time of enteral nutrition and mean energy received by enteral nutrition for the entire 4 days.

To investigate the reason for inadequate enteral intake, interruptions of enteral feeding were assessed. Enteral nutrition was withheld 54 times in 24 patients (79%) in the first 4 days after initiation of enteral nutrition. A total of 12 patients had only one interruption, whereas 12 patients had more than one. On the day of enteral feeding initiation, feeding interruptions occurred 10 times in all patients, but they increased to 17 times on day 2, and then leveled out at 14 times on day 3 and 13 times on day 4. The mean length of total interruption time that enteral nutrition were withheld for 4 days was 360 minutes (6 hours) per patient. Total interruption time was strongly negatively related to mean percentage of prescribed energy received for 4 days (r=-0.822, p<.01); patients who had more prolonged feeding interruption time received less prescribed energy.

Aim 6 was to determine the relationship between interruption time of each reason for the interruptions and the energy received on the day feeding was interrupted. The reasons for interruptions of enteral feeding are presented in Table 2. The most frequent and longest feeding interruptions were due to GI intolerance (high GRVs and vomiting), accounting for 28% of the incidence and 29.5% of the total time that enteral feeding was withheld (the total interruption time). The interruption time caused by GI intolerance was strongly negatively related to percent of prescribed energy received (r=-0.87, p<.01). GI problems including GI intolerance and bleeding accounted for almost 50% of the total interruption time.

The second frequent category of interruptions was routine nursing care with 22% of the incidence that feedings were withhold and it occurred in 35% of patients. However, routine nursing care accounted for only 1.4% of the total interruption time and was not related to energy intake.

The next most common reason that feedings were withheld (19% incidence) was related to procedures, and that accounted for 17.5% of the total interruption time (a mean interruption time of 216 minutes per procedure). There was a strong negative relationship between the interruption time caused by procedures and energy intake (*r*=-0.839, *p*<.001). Although interruptions for airway management accounted for 22.4% of the interruption time, they were less frequent and had no relationship with energy intake.

Problems related to enteral feeding tube led to the least and shortest feeding interruptions and this short interruption time was positively and significantly related to energy intake (*r*=0.968, *p*=.03). The other category including hemodynamic shock of a patient and lapse in nursing care also led to the low incidence of feeding interruptions.

Discussion

For critically ill patients who cannot tolerate an oral diet, enteral nutrition is a suitable alternative due to its more favorable effects when compared to fasting or parenteral nutrition (Dvir et al., 2006; Hill et al., 2002; Rayes, Hansen, & Seehofer, 2002). However, insufficient enteral nutrition intake has been reported as a weakness of enteral feeding in critically ill patients (Kim et al., 2010; O'Leary-Kelley et al., 2005; Reid, 2006). This study confirms that a large portion of Korean critically ill patients do not receive their required energy and protein with enteral nutrition. To our knowledge, this is the first study to demonstrate the trend in prescribed energy and protein amounts for enteral nutrition with that actually received by focusing on the interaction with time. Also, this study demonstrates the reasons for enteral feeding interruption that are associated with adequacy of enteral feeding.

In the present study, patients received less energy and protein intake than their requirements across 4 days after initiation of enteral nutrition. The insufficient enteral nutritional intake in critically ill patients that was observed in this study is consistent with the findings from previous studies (De Jonghe et al., 2001; Dvir et al., 2006; Kim et al., 2010; O'Leary-Kelley et al., 2005; O'Meara et al., 2008; Petros & Engelmann, 2006). This finding indicates that more aggressive nutritional interventions and monitoring are required for critically ill patients.

When the trend in prescription and delivery of nutrients is examined, Umali et al. (2006) demonstrated significant differences between requirements and actual intake of energy and protein over 3 days after admission to the ICU. Petros and Engelmann (2006), Singh et al. (2009), and Beaux et al. (2001) reported an increasing trend in daily intake during the early phase of the ICU stay (from day 1 to day 4 or 6). This is a usual trend in enteral feeding with a lower level of intake that increases over time. However, calculating the mean value for several days loses important data by collapsing the data across time. The acute starvation that occurs therefore cannot be recognized or addressed when mean values are presented. Therefore, attention to the difference across the days is important. This study adds new information that the difference between requirements and actual intake significantly interacts with time. The difference significantly decreased over time, but leveled out on the fourth day.

In the present study, comparison of requirements, prescription, and actual intake in terms of energy and protein suggests that the combination of under-prescription and under-delivery contributed to inadequate intake of energy and protein in enterally fed patients in the medical ICU. Although the amount of the daily prescription of energy and protein increased with time, the prescription for energy did not meet patient requirements during the study period. This trend is consistent with findings reported in previous studies (De Jonghe et al., 2001; O'Meara et al., 2008). The American Society of Parenteral and Enteral Nutrition (2002) recommends a gradual increase in bolus enteral feeding starting with a small amount of 120 ml, given 3-8 times per day, and increasing the amount by 60-120 ml every 8-12 hours as tolerated up to the goal volume until at least 48 hours after initiation. Although under-prescription may be beneficial for tolerability for early enteral feeding in critically ill patients, the prescription of energy failed to reach patient requirements even after 48 hours. Therefore, it is evident that under-prescription of required energy contributed significantly to insufficient intake.

A possible explanation for under-prescription is the complex process for prescription of nutritional support. Prescription requires healthcare providers to consider patients' nutritional requirements, physiological conditions, and anticipated potential problems with enteral nutrition, based on their awareness and knowledge of nutritional support (De Jonghe et al., 2001). Despite the importance of enteral nutritional support in critically ill patients, enteral nutrition is typically a lower priority compared to hemodynamic, neurologic, or respiratory support interventions in ICU settings. The "low technology" associated with this type of feeding may contribute to its low priority. Furthermore, although resident doctors provide medical care for ICU patients, there are no specialty trained critical care residents or fellows in Korean hospitals; there is no registered dietician who is responsible for ICU patients; thus contributing to the lack of awareness of the unique needs of these patients and the importance of enteral nutritional support for critically ill patients.

Nutritional support is challenging for healthcare providers in the ICU setting. It is difficult to determine nutrient requirements for patients, because they are calculated based on age, weight, height, sex, stress level, severity of disease, and/or metabolic needs in critically ill patients (ADA, 2000). The HBE with a stress factor and the ADA equation used in this study may be better assessments of energy and protein requirement, since they are relatively simple formulas and are used in many clinical institutions (Ishibashi et al., 1998; MacDonald & Hildebrandt, 2003; Scheinkestel et al., 2003). However, critical care patients are a special population with unique needs. Their energy requirements may be similar to those of healthy people because their hypermetabolism may be offset by inactivity in the ICU (Beaux et al., 2001). Furthermore, if the equations overestimate patients' needs, patients may not actually be underfed. This is not likely in this study because when requirements were calculated conservatively, using the lowest stress factors and adjusted body weight.

However, in Korean ICUs, many healthcare providers do not use a specific formula for prescribing enteral nutrition and this may contribute to the inadequate prescription of enteral nutrition. One strategy to raise healthcare providers' awareness and knowledge of enteral nutritional support in critically ill patients is to provide education. A standardized enteral feeding prescription including an accurate estimation of nutrient requirements and consideration of anticipated problems may guide appropriate prescription of enteral nutrition in critically ill patients.

On the other hand, protein prescription was variable with smaller amounts early on and larger amounts on day 3 and 4, although protein received was less than required across all four days. In addition, there were significant differences in energy and protein between prescription and actual intake during 4 days. These findings suggest that insufficient delivery of what was prescribed also contributed to insufficient intake of energy and protein required in our patients. Long interruptions of enteral feeding due to procedures or tests, GI intolerance of enteral feeding, problems with the feeding tube, airway management, GI hemorrhage, and nursing care activities were likely explanations for the insufficient delivery of enteral nutrition.

This study contributes significantly to the literature because it demonstrates the specific reasons that feeding interruption is significantly associated with adequacy of enteral intake. The percentage of prescribed energy received was significantly correlated with the total time that enteral feeding was withheld due to GI intolerance of enteral nutrition including high residual volume, diarrhea, and vomiting. GI intolerance was the most common reason for feeding interruption and resulted in the longest total interruption time. GI complications including GI bleeding accounted for about half of the total interruption time. Similarly, McClave et al. (1999) and Roberts et al. (2003) found that GI intolerance is the most frequent cause; affecting 45% of patients (McClave et al., 1999) and 66% of patients (Roberts et al., 2003). However, these results are somewhat different from those of previous studies, accounting for only 9% of total interruption events (Rice et al., 2005) and 13.3% of the total interruption time (O'Meara et al., 2008).

In this study, enteral nutrition was withheld for GRVs of more than 50 ml, which is consistent with previous studies using an intermittent feeding method with cutoff points for high GRVs defined as 60 to 100 ml (Chen, Chou, Lin, & Wu, 2006; Kim et al., 2010). This is in contrast to 200 to 300 ml cutoff points in other studies with a continuous feeding method (O'Meara et al., 2008; Rice et al., 2005). The discrepancy in the cutoff points may be explained by the findings that continuous feeding is associated with higher GRVs and lower intestine peristalsis than intermittent feeding (Chao, 1998; Steevens, Lipscomb, Pool, & Sacks, 2002). Despite, low cutoff point for GRVs of 50 ml in this study may contribute to frequent and unnecessary feeding interruptions by high GRVs. It suggests that the cutoff point in this ICU needs to be improved. There is a trend that the cut points for GRVs are moving up in some Korean hospitals. Although prokinetics that can reduce GRVs were administrated for 119 days (88.3%) out of a total of 136 feeding days in this study, GI intolerance was the most common reason for feeding interruptions. There was no statistically significant relationship between the number of prokinetics administrated and GRVs on each day. In addition, all our patients received enteral nutrition via a nasogastric tube which is associated with a higher incidence of GI intolerance than that of a transpyloric tube (Davies et al., 2002). Transpyloric feeding into the duodenum or jejunum may be a more appropriate way to improve the delivery of enteral nutrition to critically ill patients with GI intolerance. Several studies conducted in medical ICUs support this suggestion (Esparza et al., 2001; Hsu et al., 2009; Kearns et al., 2000).

However, GRV may be not useful for monitoring GI intolerance of enteral nutrition. Although there was no significant difference in APACHE II scores between patients with and without GI intolerance in this study, more critically ill patients may have more GI intolerance than patients with less severe disease (Roberts et al., 2003). Rather, the use of GRV as an indicator of GI intolerance may lead to unnecessary interruption of enteral feeding (O'Meara et al., 2008; Reid, 2006). Therefore, it is important to study reliable markers for intolerance of enteral nutrition in critically ill patients.

Adequacy of enteral intake was also negatively associated with the total time that feeding was withheld to prepare for diagnostic procedures or therapeutic procedures. This finding is consistent with other study results suggesting that procedures were the most common reason for feeding interruption. Interrupted time was reportedly 35% of total interruption time (Elpern et al., 2004; McClave et al., 1999) and affected 51.6% of patients (O'Leary-Kelley et al., 2005). In clinical settings, patients who are scheduled for procedures usually receive nothing by mouth after midnight, but clear liquid is allowed until 2 hours before a procedure (Maltby, Pytka, Watson, Cowan, & Fick, 2004). McClave et al. (1999) suggested that enteral nutrition can be provided up to 4 hours before a procedure without a risk of aspiration. These recommendations, however, have not been tested. Furthermore, if the procedure is rescheduled for the next day, fasting time is prolonged more than 24 hours. In this study, a tracheostomy was scheduled for airway management in four patients, which accounted for 22.4% of the total interruption time. Two out of four patients had the tracheostomy rescheduled for the next day, that is, they fasted unnecessarily due to delay of the procedure. Procedures should be scheduled and completed, not delayed, in order to prevent unnecessary withholding of enteral nutrition.

Routine nursing care also requires a supine position for preventing aspiration. This was the second most frequent reason for interruption of enteral nutrition, although it led to withholding of enteral nutrition for only a short time (range 1-30 minutes). Of interest, feeding interruptions for short times due to nursing care could be compensated for. Therefore, they did not significantly affect energy intake. Because enteral nutrition is provided as an intermittent bolus in the Korean ICU where this study was conducted, feeding time could be flexible to compensate for the delayed volume. Unlike other studies where bathing is a frequent reason for interruption (McClave et al., 1999; O'Meara et al., 2008), enteral feeding in this study was not withheld for bathing. This is because routine nursing care is usually scheduled to avoid disrupting the feeding schedule in the intermittent feeding method. Therefore, the intermittent feeding method with a flexible feeding schedule may be beneficial for adequate delivery of enteral nutrition., Although it has the drawback of high risk of aspiration, some interruptions can be compensated for (Singh et al., 2009). Furthermore, the intermittent method can avoid feeding overnight and meet the human physiology for nutrients intake (Chen et al., 2006).

Feeding tube problems such as absence, occlusion, or mal-position were a major reason for interruption in some studies (O'Leary-Kelley et al., 2005; O'Meara et al., 2008). In the present study, four patients who removed the feeding tube by themselves experienced withholding of feeding for a short time (range 10-50 minutes). The time required to re-insert the feeding tube was relatively short, because the reinserted tube was confirmed by auscultation rather than radiology, which may have contributed to the short interruption time. The delayed volumes caused by interruptions were completely compensated for and replaced after the feeding tubes were re-inserted.

Insufficient intake due to frequent interruptions in enteral nutrition may be avoided. Well-defined feeding protocols to prevent and compensate for unnecessary interruptions of enteral feeding may improve the delivery of enteral nutrition. Protocols need to address how to manage GI intolerance, decisions to withhold or advance enteral feeding, and adjustment of feeding rate for goal achievement.

This study has several limitations that should be considered when interpreting the data. First, this study assessed a small number of patients who received gastric feeding through large-bore feeding tubes in a single unit in a single university teaching hospital. Although our results may be not generalized to diverse ICU populations, our findings may be representative of the Korean ICU population, because this feeding method is commonly used in Korean ICUs. Second, energy and protein requirements might not have been considered on a day-to-day basis during the study period, because they were calculated once at enrollment. However, there might have been no significant change in the requirements during the study period, because parameters (age, gender, height, body weight, and stress factors) that are used to calculate the requirements do not significantly change for a short period of four-days. Another limitation is that the number and duration of enteral feeding interruptions might have been under-recorded, because the data relied upon the recording of bedside nurses. However, it is unlikely since the records were verified with bedside nurses who cared for the patients. Finally, this study evaluated enteral nutritional intake during the first four days after initiation of enteral feeding, thus the results may be different with those of chronically critically ill patients on prolonged enteral nutritional support.

Conclusion

This study is the first study to demonstrate the trend of enteral nutritional intake by considering the interaction with time in critically ill adults. The study findings underscore that critically ill patients receive inadequate enteral nutrition during their ICU hospitalizations. Insufficient prescription and incomplete delivery of enteral nutrition caused by frequent interruptions of enteral nutrition are the reasons for insufficient energy and protein intake. Prolonged feeding interruptions due to GI intolerance as well as diagnostic or therapeutic procedures contributed mainly to the amount of nutritional intake.

It is important to raise the awareness and knowledge of healthcare providers about nutritional therapy in critical care in order to improve nutritional support of critically ill patients. Continued education and training about nutritional support should be integrated into the mandatory critical care program for healthcare providers. The accuracy of methods used to estimate energy and protein requirements need more evaluation for use in diverse ICU populations to ensure adequate prescription of enteral nutrition. Uncertainties regarding the levels of GRVs triggering aspiration, reliable indicators of GI intolerance, acceptable lengths of time that patients can be in the supine position without aspiration during enteral feeding, minimal fasting time for preparation for procedures need to be investigated and incorporated into enteral feeding protocols for the critically ill. Therefore, future study is warranted to develop, implement and test standardized enteral feeding protocols that can prevent and compensate for unnecessary feeding interruptions to maximize nutritional intake in critically ill patients.

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Table 1

Demographic and Clinical Characteristics of the Subjects (n=34)

Characteristic	Value
Age, mean (SD), years	70.8 (14.8)
Gender (male/female), number	17/17
Primary Diagnosis, % (number)	
Neurological	47.1 (16)
Respiratory	29.4 (10)
Sepsis	14.7 (5)
Gastrointestinal	5.9 (2)
Renal	2.9 (1)
Mechanical ventilation, % (number)	44.1 (15)
APACHE II[†] score, mean (SD)	13.0 (6.1)
Albumin, mean (SD), g/dl	3.3 (0.8)
C-reactive protein, mean (SD), mg/dl	6.1 (7.1)
Body Mass Index Category, % (number)	
Underweight	8.8 (3)
Healthy weight	38.2 (13)
Overweight	20.6 (7)
Mild obese	32.4 (11)
Nasogastric feeding tube, % (number)	100 (34)
Nasogastic feeding tube size, %	
16 French/18 French	50/50
Time after ICU[‡] admission to initiation of enteral feeding, mean (SD), days	5.3 (6.8)

[†] APACHE II: acute physiology chronic health evaluation II

[‡] ICU: intensive care unit

Table 2

Reasons for and Duration of Interruptions in Enteral Feeding

Reasons	No. of patients affected	No. of interruption	% of total interruption time	Correlation [†](r)
GI[‡] intolerance	9	15	29.5	-0.874[**]
Routine nursing care	12	12	1.4	0.506
Procedure	9	10	17.5	-0.839[**]
Airway management	4	6	22.4	-0.006
GI[‡] bleeding	3	5	18.9	-0.252
Feeding tube problem	4	4	1.2	0.968[*]
Other	2	2	9.1	-

*, <.05; **<.01
†: relationship between the interruption time that feedings were withheld due to each reason and percent of prescribed energy received with enteral nutrition
[‡] GI: gastrointestinal

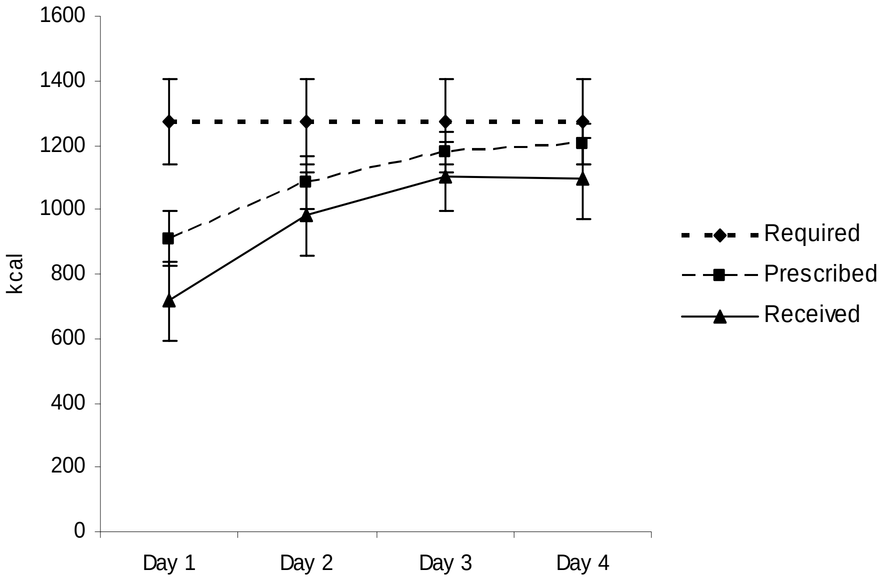

Figure 1

Mean Energy Required, Prescribed, and Received Enterally by Day (n=34)

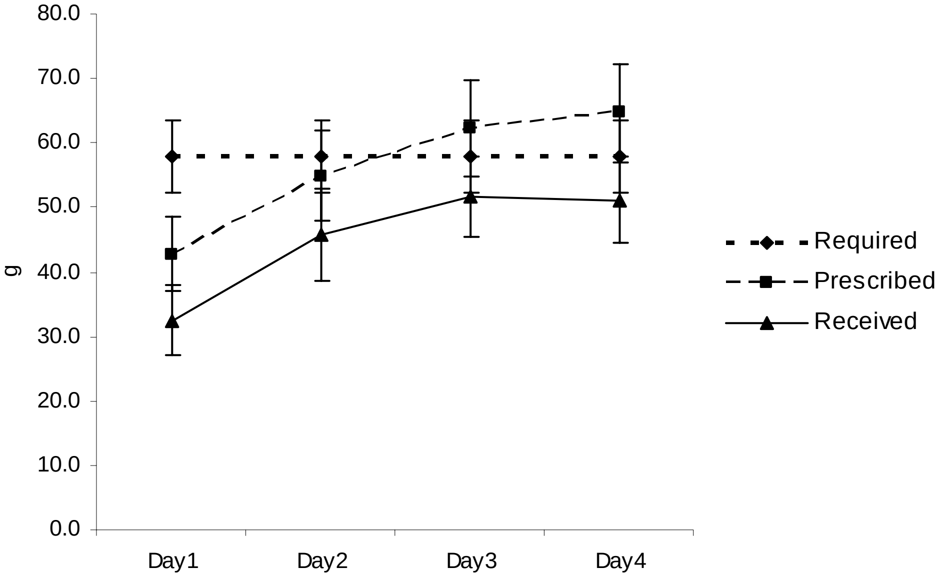

Figure 2

Mean Protein Required, Prescribed, and Received Enterally by Day (n=34)

CHAPTER 5

Conclusion and Implications

Nutritional support is essential therapy in the intensive care unit (ICU). Most critically ill patients who cannot be fed orally receive enteral nutrition during their ICU stay (ASPEN, 2002). However, underfeeding has been a major concern in the enteral feeding of critically ill patients, despite advancements in enteral formulas, materials, and techniques (Binnekade, Tepaske, Bruynzeel, Mathus-Vliegen, & de Haan, 2005). The findings from this dissertation confirm that enteral nutritional intake is insufficient in critically ill patients. The data provides a significant addition to knowledge of the factors that impact adequate enteral intake in critically ill Korean patients.

The literature review (Chapter 2) indicates that there are many barriers contributing to inadequate enteral nutrition in critically ill patients in United States (US). The barriers are categorized as patient factors, feeding method factors, feeding process factors, under-prescription, and frequent interruptions of enteral nutrition. Although patient factors were not associated with adequacy of enteral intake in this study, under-prescription of enteral nutrition was found to be a significant barrier to adequate enteral intake. Of the feeding method factors, nutrient-dense formulas and transpyloric feeding contributed to adequate intake. Among feeding process factors, early initiation of enteral nutrition and rapid progression to goal rates led to increased enteral intake. Frequent interruptions of enteral nutrition due to gastrointestinal (GI) intolerance, diagnostic procedures, surgeries, feeding tube problems, airway management, shock, or nursing care that required turning off the feeding infusion were also major barriers to enteral nutritional intake.

The dissertation research study (Chapter 3) investigated the adequacy of energy and protein intake in critically ill Korean patients receiving enteral nutrition. The focus of the study was on identifying the factors that contributed to adequacy of nutritional intake in this Korean population. This study confirmed that most critically ill patients hospitalized in a Korean ICU were underfed in terms of energy and protein. To our knowledge, this study is the first study that identified the factors associated with underfeeding in this Korean population. Under-prescription and early initiation of enteral nutrition, and prolonged interruptions of prescribed enteral nutrition had impacts on underfeeding in Korean ICU patients.

The second research paper (Chapter 4) provided detailed information about the amount of energy and protein prescribed and received across the four days after initiation of enteral feeding in Korean ICU patients. Patients received consistently less energy and protein than their requirements across all four days, although the difference between requirements and intake decreased across the days. The mean amount of energy prescribed was also less than energy requirements across all four days. The findings from this study are important because this study analyzed difference across the days. Also, this paper focused on the relationship between energy intake and interruption in enteral feeding, a major factor associated with underfeeding. Among many reasons for feeding interruptions, prolonged feeding interruptions due to GI intolerance and diagnostic or therapeutic procedures were the major contributors to inadequate nutritional intake in Korean critically ill patients.

In conclusion, this dissertation provided important knowledge about inadequate nutritional intake and its contributing factors in critically ill patients. The findings from this dissertation have clinical implications for providing adequate nutritional intake to the critically ill. Furthermore, the findings may be used as foundation for future research to develop interventions designed to improve enteral nutritional support.

Clinical Implications

There are several clinical implications resulting from this dissertation. First, this dissertation showed that enteral nutrition for critically ill patients was under-prescribed, one of the factors that impeded adequate nutritional intake and, clearly,adequate enteral nutrition prescription is basic to meeting the nutrient requirements of ICU patients. Healthcare providers' knowledge of enteral nutrition is an important foundation for accurate prescription. However, it is common for healthcare providers to under-prioritize enteral nutritional support for critically ill patients (De Jonghe et al., 2001). To raise awareness and improve knowledge, continuing education should be provided to healthcare providers who prescribe nutrition for the critically ill. Such education needs to include physicians, physician assistants, and nurse practitioners, all of whom have prescriptive authority in ICU.

Furthermore, adequate prescription is based on accurate measurement of nutrient requirements. The use of equations such as the Harris-Benedict equation (HBE) or the American Dietetic Association equation that do not require special equipment and complex procedures in the ICU can help providers accurately estimate energy and protein requirements (ASPEN, 2002). A standardized enteral feeding protocol describing accurate estimation of nutrient requirements using the equations may guide appropriate prescription of enteral nutrition in the ICU, especially in Korean ICUs where there are no standard protocols or equations used for enteral feeding prescription.

In addition to under-prescription, frequent and prolonged interruption of enteral feeding was identified as an important factor contributing to inadequacy of nutritional intake. Some interruptions of enteral nutrition are due to avoidable causes (McClave et al., 1999), suggesting such interruptions may be prevented with more careful clinical care. Also, the use of prokinetics may reduce the prevalence of GI intolerance, a major reason for interruption. As much as possible, diagnostic and surgical procedures should be scheduled, completed, and not delayed to avoid unnecessary prolonged interruptions in enteral feeding. Also, the procedure for replacement of a feeding tube needs to be simplified to reduce replacement time. Some short term interruptions may be compensated for by adjusting the feeding administration rate. Therefore, well-developed feeding protocols that prevent and/or compensate for interruptions of enteral feeding may improve the delivery of enteral nutrition. Finally, health care providers should follow existing feeding protocols. The protocol must include monitoring the adequacy of enteral intake in critically ill patients.

Future Research

Several recommendations for future research follow from this dissertation. This dissertation demonstrated that factors that impact adequate nutritional intake can be targeted in order to develop interventions for nutritional support in critically ill patients. Because little is known about the factors contributing to adequacy of nutritional intake in Korean ICU patients, further studies are warranted in this population.

Above all, healthcare provider awareness and knowledge of enteral nutrition provide a foundation for adequate nutritional support, including accurate prescription and complete delivery of enteral nutrition in the ICU. Future research is needed to assess the knowledge and attitudes of ICU healthcare providers about enteral nutritional support. Providers include physicians, nurses, and nutritionists. Based on the evaluation, interventions such as education need to be developed in order to raise their knowledge and awareness. Quality assurance studies need to be undertaken to evaluate the effectiveness of enteral feeding.

The findings from this dissertation suggest that the estimation of energy requirements using the HBE with a stress factor may help in the accurate prescription of enteral nutrition to meet patients' energy requirements. Although the HBE is used in many clinical institutions (MacDonald & Hildebrandt, 2003), it needs to be validated in Korean ICU patients. Research is also needed to test the validity of other equations as well as the HBE in the Korean population in order to determine the most accurate method for estimating energy requirements.

The dissertation data showed that delay in feeding initiation contributed to adequate enteral intake, possibly because delay in feeding minimized GI intolerance. This finding is in contrast to findings from previous studies that early initiation was associated with increased energy intake (Charvat, Kratochvil, Martinkova, Masopust, & Palova, 2008; Ibrahim et al., 2002). To validate whether later initiation of enteral nutrition results in adequate nutritional intake, the research presented in this dissertation needs to be replicated in diverse populations of critically ill patients. For interpretation of the contribution of later initiation on nutritional intake, the relationship between later initiation and GI intolerance needs to be a part of this future research.

This dissertation consistently demonstrated that frequent and prolonged interruptions of enteral feeding were major barriers to adequate nutritional intake in enterally fed critically ill patients. Future research is warranted to examine strategies to avoid unnecessary and prolonged interruptions of enteral nutrition. Research is needed to identify reliable indicators of GI intolerance, address ways of minimizing fasting time for preparation for diagnostic or surgical procedures, and identifying soon after feeding enterally fed patients can be in the supine position without increasing the risk of aspiration. Based on these strategies, the development of enteral feeding protocols addressing how to prevent or manage feeding interruptions is the ultimate goal of future studies.

Future research also needs to investigate the factors that were not evaluated in this dissertation research. The effects of many factors on the adequacy of enteral feeding in Korean ICU patients are not known, including gastric tube versus transpyloric tube, continuous versus intermittent feeding, and gradual increase in feeding rate versus immediate feeding at goal rate. Future research is warranted to examine the contribution of these uninvestigated factors in this population.

The prospective cohort study approach used in this research is not designed to demonstrate causal effects of factors on adequacy of nutritional intake. Future work using randomized experimental design is warranted. In addition, the research is limited by the small sample size. These study limitations suggest the need for future research on enteral nutrition in Korean ICU patients, ideally using an experimental study design with a larger sample.

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