

Smart Phone/Device Application to Improve Delivery of Enteral Nutrition in Adult Patients Admitted to the Medical Intensive Care Unit

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ABSTRACT

BACKGROUND: Resident physicians are frequently uncomfortable ordering enteral nutrition (EN) and are unaware of the variety of formulas and supplements available for different disease processes. Many depend on a clinical dietician to assist with recommending EN formulas and patient energy requirements that may not be readily available on patient admission. This creates a barrier to early initiation of EN and non-compliance with Society of Critical Care Medicine and American Society of Parenteral and Enteral Nutrition clinical guidelines.

OBJECTIVE: Internal medicine resident physicians were provided an iPod with a smart phone/device application (EN application) to assist them in choosing EN formulas for patients during their intensive care unit (ICU) rotation. The primary outcome was improved initiation of EN within 24 hours of admission. Secondary outcomes included the following: time to initiate EN, goal calories reached, infections rates, length of stay, mortality, and concordance with clinical guidelines.

DESIGN: The study is a quasi-experimental design to improve delivery of EN at an academic medical center in the medical ICU. Data were collected from a retrospective chart review to evaluate the impact of an EN application to assist resident physicians when ordering EN.

RESULTS: Use of the EN application reduced the percent of patients with delayed initiation of EN from 61.2% prior to 37.5% ($P < .01$). The mean time to initiate EN also improved 44.5 vs 31.9 hours ($P < .01$). Patients were also more likely to achieve their daily caloric goal ($P < .01$).

CONCLUSION: The use of an EN application to assist internal medicine residents when ordering EN reduced delays in initiation of EN and improved overall delivery of EN to medical ICU patients.

KEYWORDS: enteral nutrition, critical illness, nutrition support, smartphone application, clinical nutrition guidelines, tube feeding formulas

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Introduction

Although studies recently have shown the importance of early nutrition support, clinical nutrition is rarely emphasized in traditional medical school teaching, resident lectures, or didactic teaching during daily educational rounds.¹ Therefore, many resident physicians are uncomfortable ordering enteral nutrition (EN) as they are unsure how to calculate basic energy requirements for hospitalized patients, leading to delayed initiation of EN. A previously published survey of surgery resident physicians ($N = 404$) found that 85% were dependent on the clinical dietician's recommendations for choosing the type and rate of tube feeding for patients.² The delay in ordering nutritional intake is common in the intensive care unit (ICU)

as many patients cannot tolerate oral nutrition and require EN via an enteral access device.^{3,4} These patients are also at a higher risk for increased infection rates associated with a delay in nutrition initiation and ongoing caloric deficit.⁵

The Society of Critical Care Medicine and American Society of Parenteral and Enteral Nutrition (SCCM/ASPEN) have developed guidelines to aid physicians with EN timing, amounts, and formula selection.^{6,7} However, translating this into clinical practice can be difficult at bedside. Many physicians are concerned regarding providing inappropriate supplements that may cause harm or calculating incorrect protein and caloric provisions. They will therefore wait for a recommendation from a registered clinical dietician, which creates a barrier



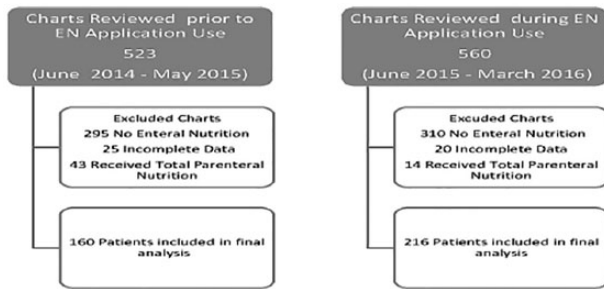


Figure 1. Flowchart outlining the patient chart selection prior to and after introduction of the EN application. EN indicates enteral nutrition.

to early initiation of nutrition support as the dietician recommendations can take between 48 and 72 hours.^{8,9}

Prior to developing the EN application, the authors surveyed the internal medicine resident physicians (N = 20) working in the critical care unit on the University of Oklahoma Health Sciences Center (OUHSC) and found 58% were not satisfied with their knowledge of EN formulas and 63% were not satisfied with their knowledge of current EN guidelines. Given this lack of knowledge and confidence, 85% would wait for the clinical dietician to enter their consult recommendations for EN prior to ordering nutrition. This data also showed a statistically significant relationship between delayed charted clinical dietician recommendations (which often takes >48 hours to be entered in the patients' chart) and delays in EN initiation. When asked whether they would use a smart device application, 90% agreed this may be helpful tool to assist with ordering EN timelier (S. Mahmood et al., Unpublished data, 2014).

Physician dependence on the clinical dietician seeing and charting nutrition requirements for patients prior to ordering and initiating EN prevents compliance with the recommendations of the SCCM/ASPEN guidelines of 24 to 48 hours. The goal of this study was to evaluate the effectiveness of an EN application to assist residents in determining appropriate nutritional support. We hypothesized that providing residents with the EN application would enable them to be less dependent on the charted recommendations of the hospital's clinical dietician and therefore initiate EN within 24 hours of admission. We also hypothesized the residents would have more confidence in ordering EN for medical ICU patients. This was evaluated via qualitative feedback as well as comparing the timing of the resident EN order and ability to document a reason for not initiating EN in patients with a contraindication. Finally, we hypothesized that patients treated during the EN application intervention would receive a higher percentage of goal calories and have improved clinical outcomes.

Materials and Methods

All data were evaluated via a retrospective chart review of patients admitted to the ICU at OUHSC both prior to and after residents were orientated to the availability of the EN

application during their ICU rotation. The study was approved by the OUHSC Institutional Review Board, and informed consent was waived. Control data were obtained from a review of 523 ICU patient charts. This patient information is part of an existing database previously developed by the pulmonary/critical care section on the OUHSC campus for research. Following use of the EN application for 10 months, 560 charts were reviewed. This review encompassed patients admitted to the medical intensive care unit (MICU) for the first 10-month period residents were provided the application (Figure 1).

The primary outcome was the number of patients with EN initiated within 24 hours of ICU admit. Secondary outcomes are (1) the mean time from admission to initiation of EN, (2) the percent of patients who received daily recommended goal calories during ICU admission, (3) the percent of patients with clear documentation of any reason for delay in initiation of EN, (4) infection rates, (5) ICU length of stay (LOS), and (6) mortality between the groups. Additional outcomes evaluating resident use of the application included (7) timing of resident signed EN order compared with dietician recommendation being charted, (8) the concordance rate of ordered EN based on the application's recommendation with the SCCM/ASPEN guidelines as documented by the clinical dietician, and (9) resident qualitative feedback regarding use of the EN application.

The following patient information was obtained from hospital records: patient demographics, admission diagnosis, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, body mass index (BMI), LOS, mortality, and comorbidities. Percent of goal calories, total calories fed, and time of initial EN order vs clinical dietician charted recommendation was abstracted from the electronic medical record. Documentation of delayed EN was assessed in the physician's progress notes. Concordance of resident EN orders and SCCM/ASPEN guidelines is based on the initial formula ordered by the resident. Qualitative evaluation of resident confidence levels was evaluated via EN application feedback at the end of the ICU rotation. ICU infection rates were defined as any new infection present 48 hours after admission.

The software component of the EN application was developed by physicians within the Department of Medicine at the OUHSC. Published guidelines as mentioned were used as the initial basis of the application's tube feeding algorithm. The EN application was initially based on the 2009 SCCM/ASPEN guidelines with some incorporation of updated literature. A faculty member in the Department of Nutritional Sciences assisted in making final decisions for the application's EN recommendations and patient energy requirements. Residents entered the patient's demographic information, admission diagnosis, comorbid diagnosis (if any), and any fluid restriction (Figure 2). The EN application followed a programmed algorithm based on this data to recommend two possible EN formulas for the patient.

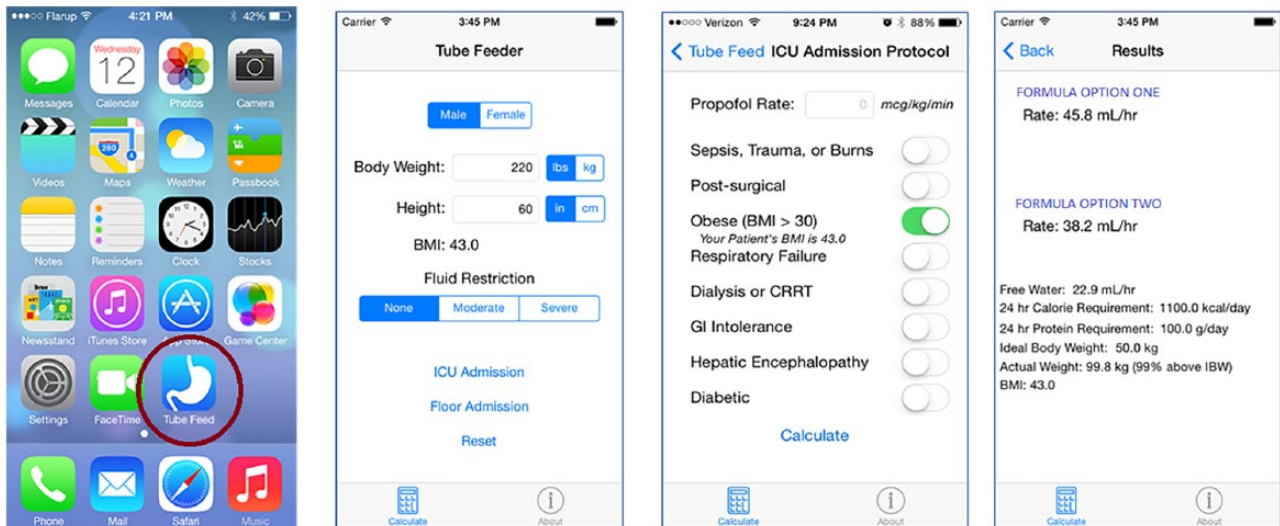


Figure 2. The four panels show the interface of the application with the user. Panels from left to right: (1) the initial screen showing the application icon (on the bottom right); (2) the initial screen to enter the sex, weight, height, any fluid restriction, and type of admission; (3) the screen for the user to input the current diagnosis, the rate of propofol (if any) and any co-morbid conditions; (4) the final screen with two options of enteral nutrition and rate per hour (the formulas offered by some vendors have changed since the study was conducted, the EN application is shown as used during the study).

The EN formulas recommended by the EN application are from the two largest EN suppliers in the United States by market share. The goal of the study was to produce an EN application without commercial bias; therefore, one commercial formula is not recommended over the other within the application. However, as there is no generic name for EN formulas, the EN application does reference-specific commercial formulas. The author's goal was for the EN application to be user friendly for physicians who are not familiar with diverse types of protein, immune-nutrition, or other specific nutrition jargon. Therefore, in an effort for the EN application to easily translate to the formula name used in the electronic medical record system, brand names were used within the EN application. The specific suppliers chosen for the EN application are the suppliers for all EN on the OUHSC campus.

The OUHSC Department of Medicine purchased an iPod to run the EN application for the study, which was placed in the medical ICU resident work area for residents to use when rotating through the ICU starting in June 2015. Residents were provided the EN application and orientated on how to use it when ordering EN. To minimize bias, the orientation did not suggest residents change their practice approach to EN only that they could use the EN application to assist them when they wanted to order EN. No additional information was provided regarding the SCCM/ASPEN guidelines or the study goals and objectives. No lectures pertaining to clinical nutrition were provided to the residents during the ICU rotation.

Specific resident demographic information was not tracked as part of the study; however, all residents rotating on the medical ICU service were offered use the EN application during their 1-month rotation on the ICU. Internal medicine

residents rotate in the ICU at OUHSC during all 3 years of their residency, the team consists of two interns and two upper level (either second or third year) residents, as well as a pulmonary and critical care fellow and attending. Feedback from the fellow and attending were not evaluated as part of this study. Demographics for the internal medicine residency program at OUHSC are as follows: the program accepts 16 categorical internal medicine residents per year and 8 preliminary interns, 59% male and 41% female residents, and 43% completed their undergraduate training at OUHSC. A total of 40 of 56 eligible residents rotated in the medical ICU during the study and were offered use of the EN application.

Data were evaluated with the SAS System (version 9.4 OUHSC) statistical package. Summary statistics expressed as mean or median were calculated for baseline demographic data with continuous responses, whereas frequencies and proportions were calculated for questions with categorical responses. One-way ANOVA was used to describe the difference between groups for continuous responses. Fisher exact test was used to evaluate delayed EN >24 hours. Logistical regression was used to determine any interaction between the groups. All $P < .05$ were considered statistically significant. Qualitative feedback was gathered via unstructured interviews following the residents' ICU rotation.

Results

The experimental group was older and more frequently had a diagnosis of cancer. In addition, the experimental group had less use of vasopressors compared with the control group. The two groups were otherwise similar (Table 1). The demographic variation (older age and more frequent diagnosis of cancer) although significant is unlikely to impact the provision of EN

Table 1. Demographic information for patients admitted pre- and post-EN application implementation.

VARIABLE	PREAPPLICATION (N=160)	POSTAPPLICATION (N=216)	P VALUE
Age, mean \pm SD	54.1 \pm 8.1	59.1 \pm 9.1	<.01
Male gender, n (%)	69 (45.1)	109 (50.5)	.31
BMI, mean \pm SD	30.8 \pm 4.1	29.4 \pm 5.1	.17
Diabetes, n (%)	37 (30.6)	57 (36.5)	.30
HTN, n (%)	66 (50.4)	100 (61.0)	.07
Chronic obstructive lung disease, n (%)	22 (19.8)	29 (20.3)	.93
Cancer, n (%)	29 (24.2)	57 (36.1)	.03
Congestive heart failure, n (%)	23 (19.5)	32 (21.3)	.71
APACHE II, mean \pm SD	21.2 \pm 4.1	18.5 \pm 6.1	.3
Delay in hours of Clinical Dietitian Recommendations placed in chart (from admit), mean hours \pm SD	52.8 \pm 14.9	63.3 \pm 11.3	.20
Patients high risk for malnutrition, n (%)	78 (61.9)	133 (62.1)	.96
Patients who received vasopressors (%)	61.9	45.0	<.01

Abbreviations: APACHE II, Acute Physiology and Chronic Health Evaluation II; BMI, body mass index; EN, enteral nutrition; HTN, hypertension.

Table 2. EN delivery and clinical outcomes pre- and post-EN application implementation.

VARIABLE	PRE-EN APPLICATION	POST-EN APPLICATION	P VALUE
Patients with delayed EN (>24 h) (%)	61.2	37.5	<.01
Average delay (h), mean \pm SD	44.5 \pm 4.9	31.9 \pm 5.3	<.01
Patients with EN goal achieved during ICU LOS (%)	52.5	59.5	<.01
Patients with no reason charted for delayed EN (%)	70.4	40.7	<.01
Average LOS	10.4 \pm 4.9	9.6 \pm 7.1	.20
Survival (%)	66.5	66.7	.93

Abbreviations: EN, enteral nutrition; ICU, intensive care unit; LOS, length of stay.

given other similar demographic information and disease severity. Additional analysis regarding vasopressor use and potential confounding effects is discussed below.

The experimental group showed a statistically significant improvement of patients started on EN within 24 hours of ICU admission. In addition, the total time from admission to initiation of EN was significantly less favoring the experimental group. The percent of patients who achieved their daily recommend EN goal calories was higher in the experimental group. Documentation of delayed EN was better in the experimental group compared with the control. There was no difference in ICU LOS or mortality between the two groups (Table 2).

There was a statistically significant difference between the two groups regarding vasopressor use (Table 1). As many clinicians consider this a contraindication to initiating EN, further analysis was done to evaluate the impact of this.^{7,10} Logistic

regression analysis showed there was a potential for interaction between the use of vasopressors and the impact of the EN application regarding decreased delay to initiate EN. Further analysis of initiation of EN within 24 hours of admit using a Fischer exact test showed that there continued to be a statistical significance favoring the experimental group for patients who did not receive vasopressors, but the same effect is not seen in patients receiving vasopressors (Table 3).

Logistical regression models showed that the odds ratio of having EN initiated within 24 hours of admission for the experimental group was 4.4 (95% confidence interval [CI]=2.18-8.99, P <.001) for patients who did not receive vasopressors. Although still improved, this relationship was not significant for patients receiving vasopressors (odds ratio [OR]=1.56, 95% CI=0.84-2.88, P =.157). The mean time to initiate EN also showed consistent results. In patients who did

Table 3. Fisher exact test comparing EN delay pre- and postapplication implementation in patients who did not and those who did receive vasopressors during ICU admission.

TIME TO EN INITIATION	PRE-EN APPLICATION	POST-EN APPLICATION	TOTAL, N	P VALUE
Patients with no vasopressors				
<24 h, n (%)	19 (33.3)	62 (68.8)	81	
>24 h, n (%)	38 (66.6)	28 (31.1)	66	
				<.0001
Patients who received vasopressors				
<24 h, n (%)	40 (43.0)	40 (54.0)	80	
>24 h, n (%)	53 (56.9)	34 (45.9)	87	
				.1644

Abbreviations: EN, enteral nutrition; ICU, intensive care unit.

not require vasopressors, there was significant decrease in mean time to initiate EN favoring the experimental group (29.0 vs 46.6 hours) ($P = .013$). Although patients on vasopressors had a reduced total time to initiate EN favoring the experimental group, this was not statistically significant (39.7 vs 43.1 hours) ($P = .616$). Additional analysis done when controlling for age, vasopressor use, and APACHE II score showed the odds of receiving EN within 24 hours of admit was 2.32 times more likely for patients in the experimental group compared with the control (95% CI = 1.43-3.74).

There was not a significant difference between the groups in overall infection rates ($P = .156$). There was however a statistically significant difference in rates of infection for all patients when comparing early vs delayed initiation of EN (>24 hours) regardless of EN application use ($P = .029$). This finding is consistent with other studies regarding early EN and decreased infection rates.¹¹

The study evaluated concordance between the EN formula ordered by the ICU resident and the SCCM/ASPEN guidelines during the experimental period. The concordance was found to be 81.5%. A total of 176 patients had an initial EN formula ordered by the ICU resident that was consistent with SCCM/ASPEN guidelines. This is attributed to the use of the EN application as opposed to a physician relying on a clinical dietician's recommendation in the chart. During the 10-month experimental period, 70.6% (141 of 201 patients with data available) had EN orders placed prior to the clinical dietician note being charted in the electronic medical record. A total of 59 patients did not have EN ordered prior to the clinical dietician recommendations. Within this group, 42% (25 patients) were receiving vasopressors at the time the clinical dietician note was charted which may have contributed to the delay in EN orders.

Finally, the investigators requested feedback from the residents rotating in the ICU who were offered use of the EN application. Resident comments noted the application was easy

to use and understand. The residents also felt more confident making a decision and ordering EN when using the EN application compared to without it. The residents did appreciate the EN application being based on published clinical guidelines, which several noted increased their willingness to use it. Overall, the resident's general opinion of the EN application was favorable.

Discussion

The perception of EN as adjunctive only for caloric support has begun to change; SCCM/ASPEN guidelines were initially published in 2009 and revised in 2016.^{6,7} Following the initial guidelines publication, evidence-based clinical trials have further outlined best practices for EN.^{11,12} However, previous surveys have shown many physicians feel under prepared and poorly trained to make confident decisions regarding nutritional therapy.^{1,2} This study is unique as it is the first trial to evaluate the use of an EN application to assist physicians with nutrition support. Although limited to a single center trial, the study does show improvement in the provision of EN with good overall compliance with published clinical guidelines. Furthermore, the EN application was well received by the internal medicine residents.

Medical school training hours dedicated to clinical nutrition and particularly EN have decreased over the past several years and some schools have stopped offering dedicated nutrition courses.¹ Yet with the increases in clinical trials for EN, there is growing evidence that EN can influence patient outcomes including hospital LOS, infection rates, days of mechanical ventilation, and in some studies decreased mortality.¹²⁻¹⁴ This disconnect between training and evolving medical evidence is seen in physician reluctance to order EN without a recommendation from a clinical dietician leading to delayed initiation of EN. The study did show improved nutrition support, which is attributed to the EN application providing physicians assistance in ordering EN.

Fewer patients in the experimental group received vasopressors compared with the control group. This is likely variation in admissions during the study influenced by the small sample size. This is, however, a complicating factor given that many patients on vasopressors are not given EN secondary to concern for ischemic gut.¹⁵ However, a subset analysis of patients who did not receive vasopressors showed a statistically significant difference favoring the experimental group. This is seen in both the initiation of EN within 24 hours and total mean time to begin EN. A trend is also seen in the subset patients who receive vasopressors, but the difference is not statistically significant. The impact of the EN application is not as robust in patients receiving vasopressors; however, these findings should be expected as there is not a clear practice guideline regarding providing EN to patients receiving vasopressors.

The SCCM/ASPEN guidelines recommend initiation of EN within 24 to 48 hours but also that patients be fully resuscitated prior to initiation of EN.^{6,7} Therefore, patients on vasopressors during ICU admission have a different standard of care for initiation of EN than patients who do not require vasopressors. Clinical practice varies depending on the physician's practice experience and comfort level. Generally, patients who receive vasopressors are not typically started on EN until the dose is either minimal or the vasopressors are stopped. This is reflected in our study as more patients on vasopressors experienced delayed initiation of EN past 24 hours with less impact of the EN application in this subset.

This study is in line with previously published evidence, as the results show for the entire study population, there is an increase in infection rates associated with delayed initiation of EN.¹⁶ However, there is no significant difference or reduction in infection rates attributable to use of the EN application. The lack of improvement in the clinical outcomes data for infection rates (as well as mortality and LOS) during EN application use may be influenced by the small sample size. Validation of improved clinical outcomes regarding use of the EN application would require a larger clinical trial.

The limitations of this study are that it is a single center trial with only one specialty of physicians participating as it was only used by the medical ICU teaching service. In addition, data were obtained via a retrospective chart review prior to and following use of the application. Finally, the study has a potential cofounder as the routine orientation to the EN application may possibly have made residents more likely to order EN sooner when admitting a patient to the ICU. To minimize this, the residents were not advised to the ongoing research plan in relation to the application. They were only told the EN application was in the team room to aid them as needed. They were also not required to use the EN application during their normal work routine.

Another weakness is possible commercial bias in the EN application. The brands chosen for the EN application are the two main suppliers to the OUHSC campus and are therefore

the brands available to the residents when ordering EN. As previously mentioned, the project goal was to be user friendly for physicians with little nutrition education or training. As many physicians are unfamiliar with nutrition jargon and terms, generic descriptions of EN formulas would not easily translate to an electronic medical order. Therefore, to make the EN application effective as a bedside tool, common brand names were used in the EN application.

The EN application was developed to be a tool for physicians to assist with the overall knowledge gap in this changing field of medical care. The overall high concordance rate of EN formula selected when using the EN application with the SCCM/ASPEN guidelines and improved provision of EN following use of the EN application are encouraging. The intent of the EN application, however, is not to replace medical education in clinical nutrition for current students or resident physicians in training. It is also not intended to replace the input and counsel of a registered dietician. Nutritional education for physicians and expert consultation remains essential components for developing a comprehensive patient care plan in the ICU setting. The EN application is meant to be used as a bedside tool to assist physicians and provide recommendations based on available evidence-based practice.

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Author Contributions

SM, LH, and KA all contributed to the design of the study and manuscript writing. SM and IAA preformed data collection and initial analysis. YDZ and AC preformed statistical analysis.

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