ORIGINAL ARTICLE

Computer-aided support improves early and adequate delivery of nutrients in the ICU

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ABSTRACT

Background: In 2007 a national guideline on perioperative nutrition was issued in the Netherlands. As external indicator for adequacy of nutritional therapy, the percentage of malnourished patients who reach at least 1.2 grams of protein on day 4 after admission was chosen by the Netherlands Health Care Inspectorate.
Methods: We developed an algorithm that allows users to ask for advice on which artificial nutritional formula to prescribe and at which rate, assuring provision of adequate amounts of both protein and energy. Feedback on nutritional therapy is given to the users on a daily basis, and to the management per quarter. Both the advice and the feedback have been integrated in our data management system. The advice module is also available on-line.
Results: In the baseline situation over the first four quarters (2006) an average of 30.2% of patients who had a full day 4 in our unit reached the protein indicator. In the last six quarters post-implementation, the average percentage reached was 56.5% with values consistently over 50%. Changes were statistically significant at third quarter of 2007 ($p<0.05$) and thereafter ($p<0.001$). Results for day 7 of admission were unaffected, which indicates that targets were reached earlier during hospital stay.
Conclusion: Our study shows that integration of nutritional advice and automatically generated feedback to users in a data management system consistently improves delivery of (early) nutrition.

KEYWORDS

Balanced protein/energy provision, decision support, optimal nutrition, patient data management system, quality indicator

INTRODUCTION

In 2007 a national guideline on perioperative nutrition was issued in the Netherlands. The guideline defines optimal nutrition in terms of energy and protein for hospitalised patients as provision of energy as calculated with the Harris and Benedict 1984 formula + 30%. For long-term acute patients in the intensive care unit the guideline advocates tailoring energy provision towards the total energy expenditure determined by indirect calorimetry (resting energy expenditure + 10%). For protein the guideline aims to provide an amount of 1.2 to 1.5 grams/kg pre-admission weight. The evidence supporting optimal nutrition is based on surrogate outcomes that have not been validated against patient-oriented, clinically meaningful outcomes.[1]
The aims of nutritional support have been defined as 1) to preserve or restore lean body mass, 2) to maintain immune function and 3) to avert metabolic complications. Provision of nutritional support is aimed at reduction of disease severity, diminishment of complications, decreased length of stay in the ICU and a more favourable patient outcome.[2]
To preserve lean body mass, historic studies in healthy volunteers have shown that when individuals keep meeting their increasing energetic needs by increasing exercise, protein provision based on body weight suffices when 1.0 gram per kg is provided.[3,4] Also in disease state, a fixed amount of protein (1.2 to 1.5 gram) per kg body weight has proven to be valid to minimise catabolism.[1]
So, optimal nutrition requires both an energy target and a minimal amount of protein provision per kg bodyweight.
For practical registration reasons, the Netherlands Health Care Inspectorate has proclaimed the provision of at least 1.2 grams of protein/kg pre-admission body weight an external quality indicator for adequate nutritional therapy for all malnourished perioperative patients in

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Dutch hospitals. The indicator should be reached on day 4 of admission; the day of admission is day 1. Choosing a minimum amount of protein on day 4 as indicator for adequacy of nutritional therapy implicitly presumes that provision of such an amount of protein will also guarantee provision of enough energy and that reaching the nutritional goal at an early moment after admission will be followed by a sustained intake during admission from day 4 on. In this article we aim to share our implementation strategies and results to optimise nutritional therapy by integrating knowledge in a patient data management system. We provide a review of the recent literature supporting evidence that reaching the surrogate endpoints is clinically relevant in terms of mortality.

MATERIALS AND METHODS

Our department is a 28-bed level 3 intensive care unit in an academic hospital. It is a mixed medical-surgical unit. The protocol for nutritional therapy in the unit aims at early feeding, preferably by the enteral route. Enteral nutrition is started as soon as the patient's condition allows it. The feeding rate is increased every 12 hours depending on retention until the target volume is reached. Post-pyloric feeding is initiated early if gastric retention (>250 ml every 6 hours) prohibits reaching the intended volume of nutrition. Parenteral nutrition is only prescribed if severe intestinal dysfunction does not allow enteral nutrition. The hospital's nutritional support team visits the ICU twice a week on a consultation basis.

Calculations based upon the guideline

In 2006 our local protocol already aimed at reaching the goals as defined in the national guideline that was published in 2007: for calculation of the resting energetic needs, the Harris and Benedict formula (1984) is used with a 20% supplementation.[5] An extra 10% is added to compensate for activity and thus to meet the total energy expenditure,[6] or is later determined by indirect calorimetry according to the AARC guidelines.[7] The value for measured energy expenditure is entered in the system and from that moment on this value is used as a target for energy provision. In terms of adequacy of energy supply, McClave *et al.* have proposed three categories: underfed (<90% of expenditure), provision of energy according to the metabolic needs (>90 to 110%) and overfed (>110%).[8]

Taking caloric content of standard commercially available nutritional formulas as a starting point, and calculating the dose according to energetic needs, we found that if the caloric goal is met, protein per kg usually falls short due to the limited amount of protein in these standard formulas (23% of patients adequately fed calorically also reached a minimum provision of protein). To overcome this mismatch and achieve both caloric needs and a provision of protein in the range of 1.2 to 1.5 gram/kg, we developed a mathematical algorithm that guarantees provision of energy and protein with three different commercially available enteral formulas, based on the patient characteristics energy expenditure/body weight and the ratio of energy/protein content of these three different formulas. To include the protein goal of 1.2 to 1.5 grams/kg body weight we multiply the energy/protein ratio of the nutritional formula by 1.2 and 1.5 for protein/body weight to calculate the cut-off points for adequate energy/protein provision. This results in another energy/weight ratio. The cut-off points for energy/body weight ratios are: 19.0 to 23.8 for a normal energy/high protein formula; 23.8 to 29.8 for a high energy/high protein formula and 30 to 37.5 for the normal energy/normal protein formula. As the cut-off points are adjacent, the algorithm covers energy/body weight ratios from 19.0 to 37.5. The choice for which nutritional formula to use depends upon the energy/body weight ratio of the patient. After having chosen the formula that guarantees an adequate ratio of energy and protein, further calculations start from energy requirements per 24 hours.[9]

As the protein goal is set for people with a BMI in the normal range and the body composition in higher BMI groups shows excess fat to lean body mass, the body weight for calculation of protein provision is corrected for patients with a BMI over 30 kg/m^2 and is, according to the guideline, recalculated to a weight corresponding with a BMI of 27.5 kg/m^2. Of note, the recent literature offers different recommendations for protein provision in different patient groups (e.g. adapted for low/high BMI, burns, trauma, age, and patients on renal replacement therapy),[2] but for practical reasons the Dutch guideline lacks recommendations on protein provision for specific patient groups apart for the high BMI groups.

Patient data management system

The unit is equipped with a patient data management system (Metavision, *i*MD-*soft*®, Israel). This system can be configured towards the needs that the users specify. Two fulltime ICT technicians with a nursing background are responsible for development and maintenance of the system and its applications.

In order to facilitate the users and to provide optimal nutrition for our patients, the following steps were taken: for every nutritional formula available in the unit, the ingredients (amount of kcal/l, protein in gram/l) were entered in the system, using calculations based on the volume delivered. Energy and protein contents from other sources (propofol, glucose, albumin) are entered in the same way. A nutritional section was added to the forms in the data management system, providing a quick insight into nutritional parameters and balances.

Height, weight, gender and age are entered in the patient data management system upon admission of the patient and the estimated energy expenditure is automatically calculated and used by the system. After indirect calorimetric measurement the calculated value is replaced by the most recent result of measured resting energy expenditure + 10%. For patients with a BMI >30 kg/m^2, body weight is automatically recalculated to a body weight corresponding with a BMI of 27.5 kg/m^2, and the latter value is used to compute the amount of protein to be prescribed.

Access to the algorithm is available to all users of the patient data management system through an advice button in the nutritional section of the system. Clicking the button provides the user with advice on which nutritional formula to use and on the amount of millilitres per hour. Furthermore, the user is given insight into the amount of energy and protein per 24 hours and the amount of protein/kg bodyweight that will be delivered if the advice is followed.

Feedback to users, nutritional support team, management

On a daily basis, at seven o'clock in the morning, an automated query is performed on all 28 beds in the unit. The query compares the amount of energy and protein provided in the last 24 hours with the results of the algorithm calculation per patient. The actual nutritional therapy given at the time of query is compared with what should have been prescribed. The results of the query are sent by e-mail to medical staff members and to the nutritional support team and are available before the early morning rounds start.

In the automatically generated daily doctors notes the attending physician is confronted with deviations from the intended nutritional therapy, and a suggestion to prescribe therapy as indicated by the algorithm is made.

Every three months, a query is run to determine the percentage of patients reaching at least 1.2 grams of protein/kg on day 4. The day of admission is day 1. Irrespective of the admission time, day 2 is defined as the next 24 hours from 00.00 hours on. The results of this query are communicated to the medical and nursing staff and are part of the monthly staff meetings. For the present study also the percentage of patients reaching the same protein target at day 7 of hospital stay is added for comparison. Also the mean length of stay on the ICU is added for the same quarterly periods of 2006 to third quarter of 2009.

Implementation strategy

The abovementioned steps were developed over time. The main intervention for users of the patient data management system was the availability of the advice button. All the workers in the unit were given background information on the rationale of optimal nutritional therapy and on the use of the advice button. The training lasted 20 minutes and was given by members of the nutritional support team. For new co-workers the use of the nutritional part of the data management system is an integral part of their initial training.

Statistical analysis

Percentages of patients reaching protein intake by day 4 have been compared within quarters between years (i.e. quarter 4 of 2007 with quarter 4 of 2006), using a χ^2 test (SPSS 17, SPSS Inc., Chicago, USA).

RESULTS

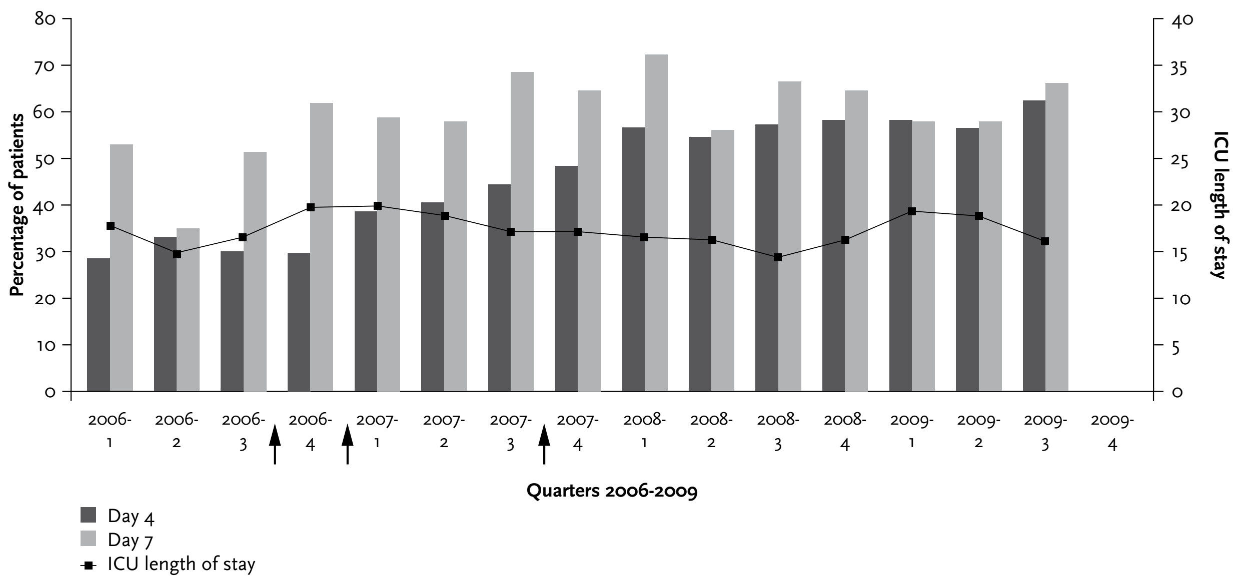
The results are shown graphically in *figure 1*. In the baseline situation over the first four quarters (2006) an average of 30.2% of patients who had a full day 4 in our unit reached the protein indicator. In the last six quarters post-implementation, the average percentage was 56.5% with values consistently over 50%. Changes were statistically significant at third quarter of 2007 ($p<0.05$) and thereafter ($p<0.001$). During the steady increase in the percentage of patients reaching the protein target at day 4 (2007 and 2008), also a steady decrease in length of stay on the ICU (LOS ICU) is observed. However, there is no continuous trend in LOS ICU across 2006 up to the third quarter of 2009. Furthermore, during the post-intervention period, the percentage protein target reached at day 4 approaches and finally equals the percentage protein target reached at day 7. This indicates that nutritional targets have been reached earlier, which is in accordance with current ICU guidelines.

Reaching 90% of the energy goal over the same periods rose from 46 and 66.9% respectively (data not shown).

DISCUSSION

In the present study, the percentage of patients reaching the indicator for early and adequate nutritional support as defined by the Netherlands Health Care Inspectorate rose from 30.2% in the pre-implementation phase to 56.5% in the post-implementation phase. This effect shows sustainability over the period of 18 months. By comparison with the same results on day 7 it can be shown that protein targets were met at an earlier stage of ICU stay, which is in accordance with ICU guidelines. Although the indicator measures only protein provision, the underlying algorithm that we use ensures provision of adequate amounts of energy. Defining optimal nutrition in quantifiable terms enables the development of decision support in a patient data management system and for assurance of nutritional

Figure 1. *Trend of percentage of patients who reach the protein indicator in time*



Arrows show at which point in time interventions were implemented: in 3rd quarter of 2006: daily report by e-mail; 1st quarter 2007: advice button; 4th quarter 2007: implementation of advice in medical notes.

therapy. Key points in reaching this goal are availability to the users of the advice button, allowing them to choose the right sort and amount of nutrition as a target from the moment of admission onwards; daily automatic feedback by e-mail on nutritional therapy to staff members and nutritional support team and integration of deviances of what should be provided in the daily medical notes. On a higher level, insight is given by three-monthly reports on the percentage of patients who reach the indicator.

Theoretically and practically, a 100% score of reaching the indicator seems impossible. As optimal nutritional therapy is volume dependent and retention is a main problem, patients who need large volumes will take longer to reach their goal. Furthermore, early in the course of admission patients will frequently undergo diagnostic or therapeutic procedures or surgery, which leads to interruption of nutrition.[10] Haemodynamic instability or limited treatment options hamper a further attempt to optimise nutritional therapy. In the present study no analysis of these and other factors that may explain the fact that the goal was not always reached, was performed.

An earlier study on the effects on nutritional therapy by the introduction of a patient data management system showed positive effects. Configuration of a nutritional page in the patient data management system made it possible to compute and display the daily energy target, the amount of nutrition actually delivered and to compute energy balances, which led to enhanced compliance with the feeding protocol. Provision of energy improved significantly in the groups that were supported by structured information from the data management system compared with the pre-implementation groups. No data on protein provision are given in this study.[11]

Negative effects of undernutrition have been reported in earlier studies: In the earliest study on cumulative energy balances in surgical intensive care patients, excess mortality was shown (although no statistical analysis was performed in that study) when the energetic deficit, as determined by the cumulative difference between energy expenditure measured by indirect calorimetry and the actual provision of energy exceeded 10,000 kcal during the ICU admission period.[12] A cumulative deficit of the supply of energy during the ICU stay has been shown to correlate with more complications and a prolonged length of stay.[13,14]

Despite the introduction of protocols aimed at the delivery of adequate amounts of energy and protein to intensive care patients, several studies have shown that implementation of evidence-based protocols does not result in a significant increase in nutrients delivered per day.[15-17] In these studies, emphasis was put on early initiation of nutrition, choice of the route of administration, stepwise increasing of the feeding rate, dealing with intolerance of enteral nutrition, gastric residues and management of diarrhoea. Although nutrition was initiated earlier in time the mean amounts of energy and protein provided per day were not significantly different; in the intervention group values for energy and protein were 1241 kcals and 50.1 grams, whilst in the control group 1065 kcals and 44.2 grams, respectively, were given.[15] Likewise, more days on enteral nutrition were reached in the ACCEPT trial but the amount of energy and protein provision per day did not increase.[16] Barr did not achieve statistically earlier nutrition and the percentage of patients who reached the caloric target on day 4 of nutritional support did not increase despite the adherence to evidence-based guidelines. The likelihood that patients would receive enteral nutrition increased by adhering to the protocol and for this group a reduced risk of in-hospital death of 56% was found.[17] In all three studies impediments for reaching adequate nutrition were the focus of attention, rather than a well-defined target for the amount of nutrition to be delivered. Nurses or doctors were not supported by a patient data management system to provide bedside advice for goals of nutritional therapy in either of the studies.

Recently, Anbar *et al.* provided preliminary evidence in a group of 50 patients with an expected ICU stay of >3 days that provision of energy according to indirect calorimetry led to cumulative positive energy balances whereas the control group (targeted at 25 kcal/kg) had negative cumulative energy balances; hospital morbidity and hospital mortality decreased in the intervention group.[18]

Pichard *et al.* demonstrated that provision of >1500 kcal/day, besides parenteral glucose, in the first three days of admission reduces ICU mortality and hospital mortality. Early provision of energy diminishes the cumulative caloric deficit.[19]

To the best of our knowledge, only two studies where both effects of energy supply and protein provision were studied showed beneficial effects of providing energy and protein closer to nutritional goals on mortality. Positive effects on 60-day mortality were demonstrated in a group of 2772 mechanically ventilated patients from 167 intensive care units and 37 countries. For a maximum of 12 days, the type and amount of nutrition was recorded. An increase of 1000 kcal/day was associated with reduced mortality (odds ration (OR) 0.76, confidence interval (CI) 0.61 to 0.95; p=0.014) and a similar trend was seen for an additional intake of 30 g of protein associated with an adjusted OR of 0.84 (CI 0.74 to 0.96; p=0.008). These effects were largely found in the BMI groups ≤25 kg/m^2 and in BMI group ≥35 kg/m^2.[20] The average provision of energy and protein were 1034 kcal/day and 47 g/day, respectively. Overall, patients received 59.2% of the energy and 56% of the protein prescribed. The second study was performed in 243 sequential mixed medical-surgical patients where the caloric goal was guided by the result of indirect calorimetry and aimed to provide at least 1.2 grams of protein/kg/day. Cumulative balances were calculated for the period of mechanical ventilation. Outcome parameters were ICU, 28-day and hospital mortality. In this study, female patients who reached their nutritional goals compared with those who did not showed a hazard ratio (HR) of 0.199 for ICU mortality (CI 0.048 to 0.831; p=0.027), a HR of 0.079 for 28-day mortality (CI 0.013 to 0.467; p=0.005) and a HR of 0.328 for hospital mortality (CI 0.113 to 0.952; p=0.04). Achievement of energy goals whilst not reaching protein goals did not affect ICU mortality; the HR for 28-day mortality was 0.120 (CI 0.027 to 0.528; p=0.005) and 0.318 for hospital mortality (CI 0.107 to 0.945; p=0.039). No difference in outcome related to optimal feeding was found for men.[21]

CONCLUSION

Our study shows that support by a patient data management system can almost double the percentage of patients who are adequately fed on day 4. Recent literature supports the view that surrogate endpoints for optimal nutrition as formulated in the Dutch guideline affect clinically important endpoints in terms of decreased mortality. Providing the users with an advice button that returns advice for one of three enteral nutritional formulas together with the desired pump setting in ml/hour, and guaranteeing adequate energy provision in combination with the desired 1.2 to 1.5 grams of protein/kg/day led to improved nutrition. Furthermore, making use of the possibilities of the patient data management system enabled threefold automated feedback on nutritional therapy on different levels: a daily dataset of all patients for staff members and the nutritional support team, a report for individual feedback to the attending physician in the medical notes, and a quarterly report of the percentage of patients who reached the indicator as feedback to all the workers in the ICU.

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NOTES

Part of the results were presented at the Intensivistendagen, Ede, the Netherlands on 11 February 2009.

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The first author, R.J.M. Strack van Schijndel, died on 12 September 2009. This manuscript has been written by him in his last days.

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ERRATUM

Unfortunately in the article ‘Internal medicine residents’ knowledge about sepsis: effects of a teaching intervention’, which was published in the October issue of the Netherlands Journal of Medicine on pages 312-315, the name of one of the authors was spelled incorrectly. The correct spelling should be T. van Achterberg. We apologise for any inconvenience caused.