

A detailed feeding algorithm improves delivery of nutrition support in an intensive care unit

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The evidence for early commencement of nutrition support in critically ill patients within 24–48 hours of admission is well documented and is linked to positive outcomes with respect to infection and postoperative complications.^{1–7} Some studies have also linked early nutrition support to reductions in length of stay (LOS) and mortality, although these data are less consistent.^{1–4,8}

The recommendation for commencement of nutrition support within 24–48 hours of admission is consistent across three clinical practice guidelines published to date, all of which have used an evidence-based approach in their development.^{1,9,10}

In addition to the timing of nutrition support, there is emerging evidence that total nutrition delivered during a stay in the intensive care unit is an important determinant of patient outcomes. Several studies have found that cumulative energy deficit is linked with increased LOS and/or infective complications.^{6,11,12} Energy balance at the end of the first week of admission and cumulative energy balance at end of the ICU stay have also been found to be strong predictors of overall LOS in the ICU.¹¹

The best way to achieve these nutritional goals of early and adequate nutrition is yet to be established, but the use of feeding algorithms is receiving increasing attention. Typically, these algorithms can be used by any staff who have been instructed in the initiation and goal for nutrition support as well as management of intolerance.^{6–8,10,13–16}

Our aim was to determine whether implementing a detailed feeding algorithm would achieve earlier commencement of nutrition support and more adequate provision of nutrition over the ICU stay compared with the standard feeding protocol. Secondary outcomes were to determine applicability of the detailed feeding algorithm to critically ill patients and reasons for deviation from the algorithm.

Methods

Our study was conducted in the ICU of the Royal Brisbane & Women's Hospital, a tertiary facility with 27 ICU beds at the time of data collection. Data were collected on two separate cohorts of patients: those admitted to the ICU before the introduction of the detailed feeding algorithm (February to April 2005, inclusive), and those admitted 6 months after algorithm implementation (June to August 2007, inclusive).

ABSTRACT

Objective: To determine whether a detailed feeding algorithm improved nutrition support of critically ill patients compared with a standard feeding protocol.

Design, setting and participants: Pre- and post-intervention comparison of nutrition commencement and nutritional adequacy in intensive care unit patients receiving enteral or parenteral nutrition until length of stay (LOS) exceeded 30 days, oral intake resumed, the patient was discharged from the ICU or the patient died. The study was conducted at the Royal Brisbane & Women's Hospital, a tertiary hospital with 27 ICU beds, in 2005 (pre-intervention) and 2007 (post-intervention).

Intervention: A detailed feeding algorithm that included commencement of nutrition support, progression to goal nutrition rates and management of gastric residual volumes.

Main outcome measures: Time to commencement of nutrition support; time to reach goal nutrition rate; nutritional adequacy over ICU stay.

Results: No demographic differences between pre- ($n=42$) and post-implementation ($n=41$) patient groups were observed. Implementation of the detailed feeding algorithm reduced the mean time to commence nutrition support from 28 hours to 16 hours ($P=0.035$). Time to reach goal nutrition rate fell from 22 hours to 13 hours, although the difference was not statistically significant. There was no significant difference between pre- and post-implementation groups in the number of patients reaching goal volume during ICU admission. Interruptions were a major obstacle to goal volumes of enteral feeds being reached.

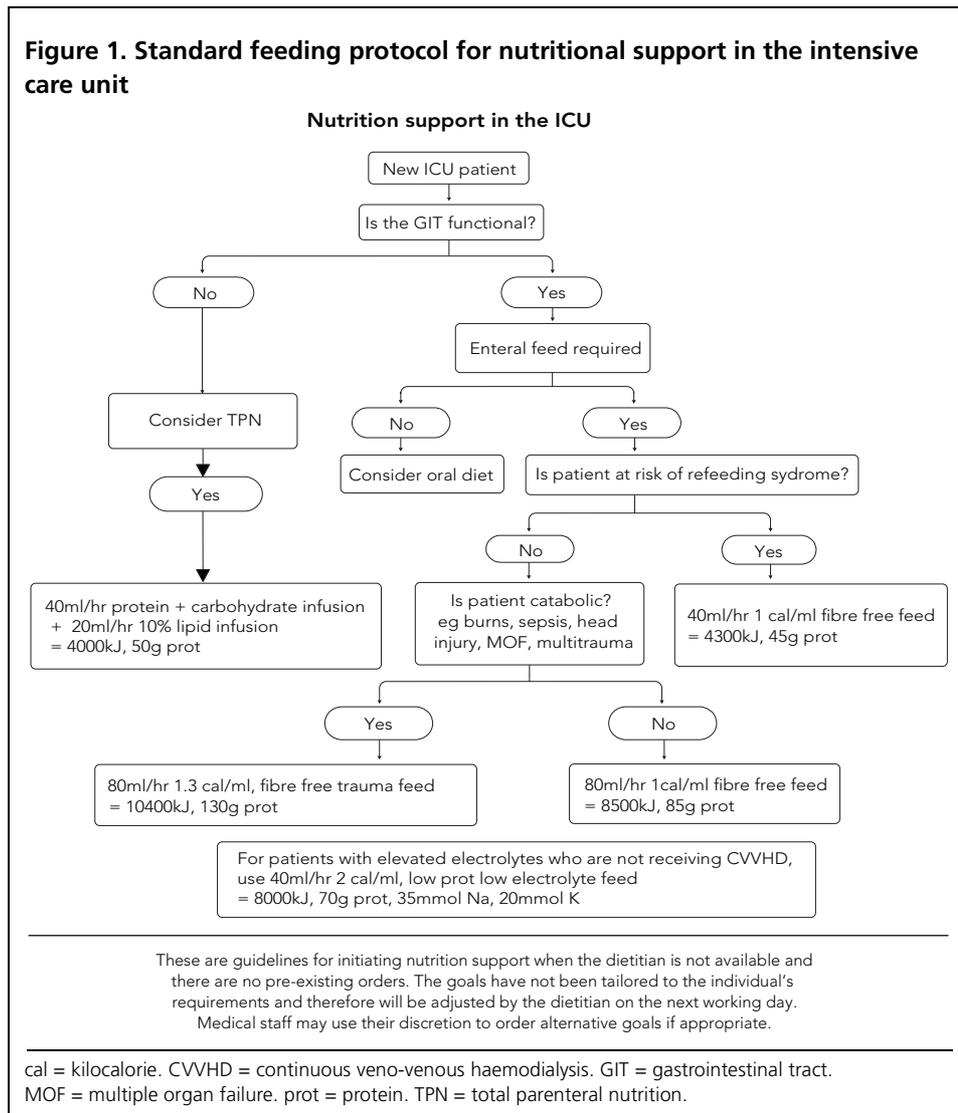
Conclusions: Introduction of a detailed feeding algorithm resulted in earlier commencement of nutrition support and increased numbers of patients reaching goal rates in less time. To improve nutritional adequacy, the algorithm needs to be modified to account for unavoidable interruptions during ICU stay.

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Subjects

Patients were included in our study if they were admitted to the ICU for ≥ 72 hours and received enteral or parenteral

Figure 1. Standard feeding protocol for nutritional support in the intensive care unit



Development and implementation of a detailed feeding algorithm for ICU patients

A working party comprised of ICU consultants, nursing staff and dietitians developed the detailed feeding algorithm (Figure 2) from expert consensus and a literature review. The literature review was conducted using Medline and Cochrane databases and keywords: early enteral nutrition, energy requirements, practice guidelines, motility agents, gastric residual management, postpyloric feeding, parenteral nutrition, and feeding algorithms in adult populations. Only English studies were reviewed. Articles were reviewed using National Health and Medical Research Council (NHMRC) levels of evidence.¹⁷

The overarching goal of the detailed feeding algorithm was for patients to commence nutrition support within 24 hours of ICU admission and to be receiving goal nutrition within 72 hours of ICU admission. Using the algorithm, the standard enteral nutrition formula provides about 125 kJ/kg and 1.3 g protein/kg/day and contains

fibre. Indications and instructions for use of a fibre-free and a fluid- or electrolyte-restricted enteral nutrition formula were also provided as part of the algorithm. All nursing and medical staff were educated on the new algorithm via bedside tutorials and group education sessions.

Data collection

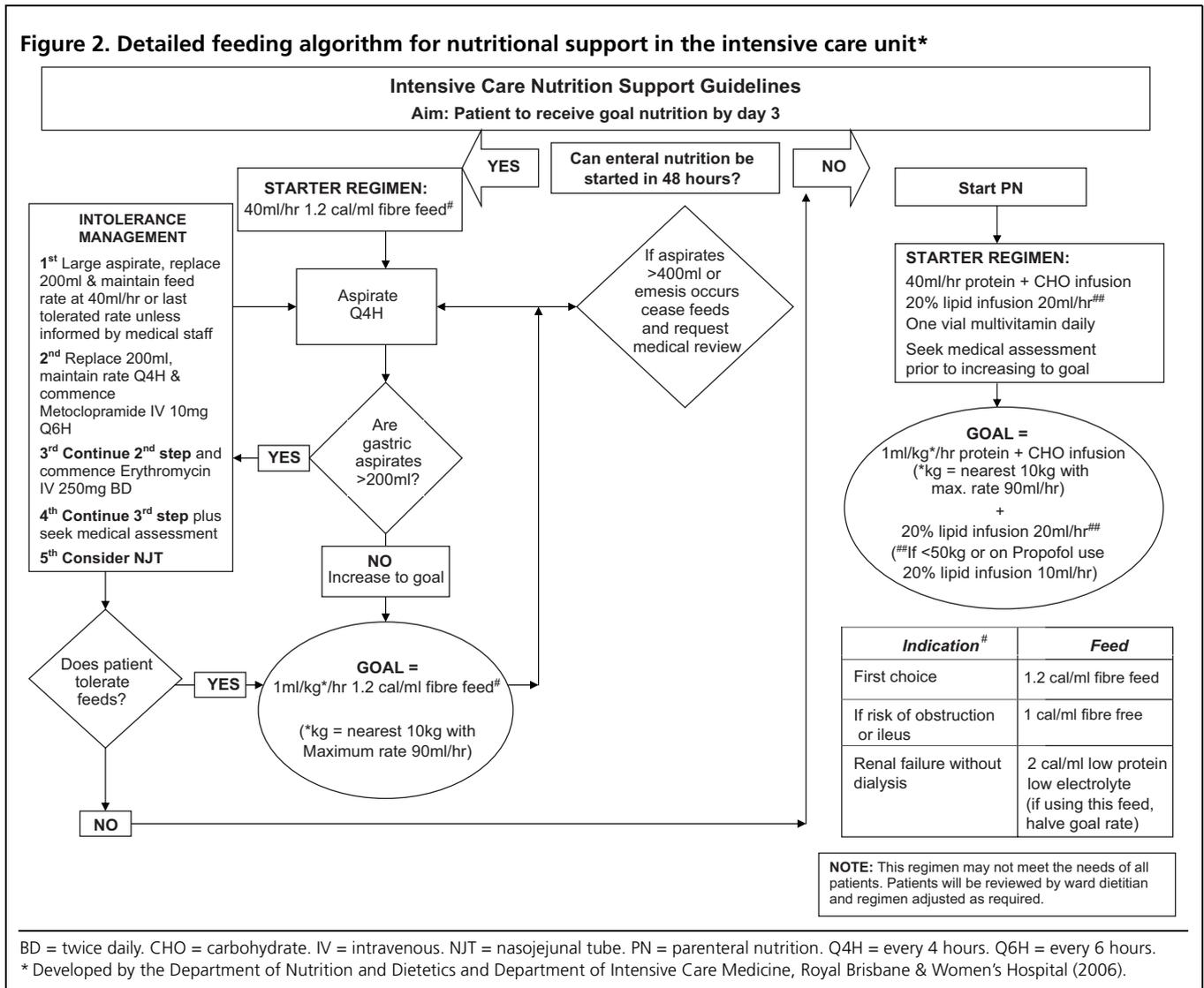
Demographic data, LOS and nutrition data (applicability of the algorithm, time to commence nutrition support, time to reach goal rate, and nutritional adequacy over ICU LOS) were collected prospectively using computerised medical records for the pre- and post-implementation groups. Data were collected until oral intake was commenced, LOS exceeded 30 days, the patient was discharged from ICU or the patient died. Data were collected during each of the data collection periods by the dietitian working in the ICU

nutrition during their ICU stay. Those who stayed in the ICU less than 3 days or were able to be fed orally were excluded.

Standard feeding protocol

Before the implementation of the detailed algorithm, a standard feeding protocol had been used when the dietitian was not available to document individual nutrition support targets using local dietetic practice (Figure 1). It provided instructions on how to initiate nutrition support and what formula to use. If fourth-hourly gastric residual volumes (GRVs) exceeded 200 mL, feeds were either reduced from the goal nutrition rate to 40 mL/hour, or turned off if the feeds had only progressed to 40 mL/hour. Although instructions were provided to ICU staff on when to consider the use of prokinetic agents and postpyloric tubes, there was no information on dosage or when to initiate.

Figure 2. Detailed feeding algorithm for nutritional support in the intensive care unit*



at the time, with all other staff blinded to the data collection.

Additional data were collected on feed interruption and management of GRVs during the post-implementation period to allow assessment of the detailed feeding algorithm.

Data analysis

Comparisons of pre- and post-implementation groups were made using SPSS statistical software, version 16 for Windows (SPSS Inc, Chicago, Ill, USA). Data were available on sex, age and admitting team.

Subjects were classified according to the following categories: medical (including mental health, cardiology, infectious disease, liver, renal and gastroenterology), surgical (including gastrointestinal, vascular, gynaecological, orthopaedic, ear nose and throat, and urological cases), neuro-

surgical, burns, neurological/stroke, respiratory, or oncological/haematological admissions.

Kolmogorov–Smirnov and Shapiro–Wilk tests were used to assess normality. Data not normally distributed were analysed using non-parametric tests (independent Mann–Whitney *U* test). Frequency distributions were cross-tabulated and assessed using Pearson χ^2 tests. Significance was determined at $P < 0.05$.

Our project was conducted as a quality assurance activity and received verbal approval by the Chair of the Royal Brisbane & Women's Hospital Human Research Ethics Committee for exemption from full ethical review.

Results

Characteristic data on 42 patients from the pre-implementation period and 41 from the post-implementation period

are presented in Table 1. The two groups were similar with respect to admitting unit, APACHE (Acute Physiology and Chronic Health Evaluation) status, ICU LOS and discharge destination, and both groups contained more men than women, reaching statistical significance in the post-implementation group ($P=0.03$).

Applicability of the algorithm

During the pre-implementation period, the standard feeding protocol was used in 14/42 study patients (33%). The protocol was not applicable for seven patients in this group because they had transferred to the ICU already on feeds and, therefore, were not counted in the analysis. In the post-implementation group, the detailed algorithm was used in 34/41 study patients (83%).

There was a significant 24-percentage-point improvement in the proportion of patients being given the appropriate formula for indication, from 27/39 (69%) in the pre-implementation group to 38/41 (93%) in the post-implementation group ($P=0.006$). Use of appropriate nutrition

support (ie, enteral v parenteral) was similar between pre-implementation (40/42 [96%]) and post-implementation (40/41 [98%]) groups.

Time to commencement of nutrition support

The time to start nutrition support also improved significantly, from a mean of 28.19 (SD, 25.74) hours before implementation ($n=42$) to 16.06 (SD, 18.35) hours after implementation ($n=39$), with a mean difference of 12.13 hours (SE of difference, 5.00 hours [95% CI of difference, 2.18 to 22.09 hours]; $P=0.031$ using Mann-Whitney U test). Also observed were a reduction in median time to commencement (from 22 hours before implementation to 12 hours after implementation) and reduced variability in practice (Figure 3).

Frequency distributions indicated that significantly fewer patients were started at 40 mL/hour in the pre-implementation group (23/42 [55%]) compared with the post-implementation group (32/41 [78%]) ($P=0.025$).

Time to reach goal nutrition rate

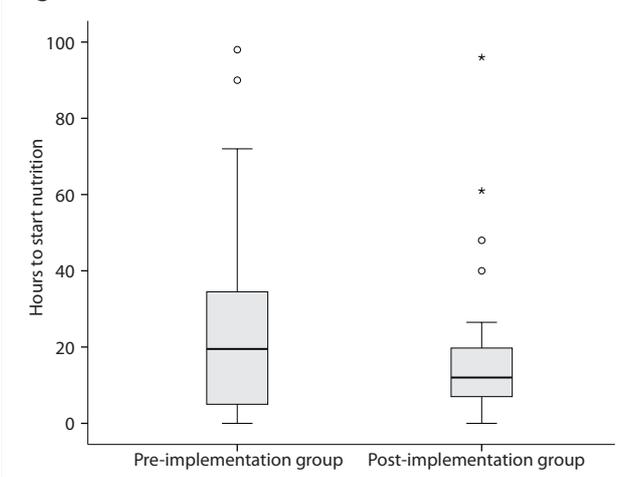
Goal nutrition rates were reached in an average of 22.25 (SD, 29.42) hours ($n=36$) in the pre-implementation group (median, 12 hours) compared with 13.11 (SD, 20.69) hours

Table 1. Demographic comparisons between pre- and post-implementation groups

Characteristic	Pre-implementation ($n=42$)	Post-implementation ($n=41$)
Sex, n (%)		
Male	27 (64%)	30 (73%)*
Female	15 (36%)	11 (27%)
Admitting/consulting unit, n		
Medical†	13	8
Neurosurgical	10	5
Burns	3	2
Oncological/haematological	3	7
Neurological/stroke	3	2
Surgical‡	10	13
Respiratory	0	4
Mean age in years (SD)	46.8 (18.8)	54.7 (18.3)
Mean LOS in days (SD)	10.6 (8.3)	10.9 (8.3)
Mean APACHE score (SD)	24.0 (8.0)	22.6 (8.6)
Status at ICU discharge, n		
To ward	37	40
Died	4	1
Discharged home	1	0

APACHE = Acute Physiology and Chronic Health Evaluation. ICU = intensive care unit. LOS = length of stay. * $P<0.03$ for within-group difference. † Includes mental health, cardiology, infectious disease, liver, renal and gastroenterology. ‡ Includes gastrointestinal, vascular, gynaecological, orthopaedic, ear nose and throat, and urological.

Figure 3. Distribution about the mean of number of hours to commence nutrition support, before and after implementation of the detailed feeding algorithm*



* The box plots summarise the distribution of scores. The bar through the middle of the boxes is the median (a normal distribution would have median in centre of box). The lower and upper boundaries of the boxes are the 25th and 75th percentiles, respectively. The smallest and largest observed values are represented by the horizontal lines ("whiskers") at either end. Extreme scores (outliers) (≥ 3 box lengths from upper or lower edge) are shown with a circle or asterisk. The length of the box indicates spread or variability: there is much more variability in the pre-implementation group than the post-implementation group.

($n=38$) in the post-implementation group (median, 4.5 hours). This indicated a trend towards reduction in time to goal rate, but the mean difference (9.15 hours; SE of difference, 5.89 hours [95% CI of difference, -2.59 to 20.88 hours]) did not reach significance using the Mann-Whitney U test (Figure 4).

Frequency distributions indicated that feeds were increased to goal rate 4 hours after commencing nutrition support in 7/35 patients (20%) in the pre-implementation group compared with 21/41 patients (51%) in the post-implementation group ($P=0.05$).

Nutritional adequacy over ICU LOS

There was no significant improvement between pre- and post-implementation groups in mean goal volume reached (mean difference, 4.38 L; SE of difference, 5.50 L [95% CI of difference, 6.66 to 15.22 L]; $P=0.439$) (Table 2).

Feed management in the post-implementation group

In the post-implementation group, pending decisions about intubation/extubation and fasting for theatre were the main barriers to feed commencement within the first 24 hours after admission. As patients' LOS increased, extubation trials, tracheostomy insertion, scans, theatre requirements, or GRVs of over 200 mL led to further feed interruptions. When interrupted, feeds were restarted at the last tolerated feed rate in two-thirds of cases.

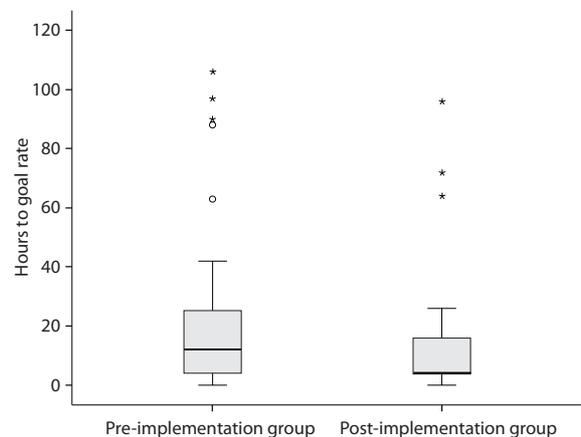
Using the criteria in the algorithm, 20 patients in the post-implementation group had GRVs of over 200 mL on consecutive occasions. Nine of the 20 patients (45%) had their GRVs managed in accordance with the algorithm. Deviation from the algorithm included the use of metoclopramide with the first "high" GRV (as opposed to the second consecutive large aspirate, as specified in the algorithm) or the use of combined therapy (metoclopramide and erythromycin concurrently) at the first high GRV. In five patients, nutrition support was ceased instead of using the algorithm. This affected the average daily volume of feed delivered.

Discussion

The use of nutrition support algorithms in the ICU has been linked with increased numbers of patients receiving enteral nutrition and more efficient and adequate delivery of nutrition support. The use of such algorithms has the potential to improve clinical outcomes in critically ill patients.^{8,10,14}

We demonstrated that a detailed feeding algorithm is applicable to patients admitted to a tertiary ICU. The significant reduction in the time to commence nutrition support and the trend towards faster progression to goal

Figure 4. Distribution about the mean of patients' time to goal nutrition rate, before and after implementation of the detailed feeding algorithm*



* For interpretation of graph elements, see footnote to Figure 3.

Table 2. Adequacy of nutrition support over length of stay in ICU in pre- and post-implementation groups

Condition	Pre-implementation (n=41)	Post-implementation (n=39)
Mean percentage of goal volume received over length of stay (Day 1 excluded)	72% (SD, 27%; range, 0–102%)	68% (SD, 22%; range, 8–92%)
Proportion of patients who reached $\geq 80\%$ of their goal volume during ICU admission	51%	41%

ICU = intensive care unit.

rate after introduction of a detailed feeding algorithm are consistent with the results of other published studies.^{6,18,19}

The median time to goal nutrition rate also improved by 7.5 hours after implementing the algorithm, but the difference did not reach statistical significance because of small numbers. However, compared with other protocols reviewed, our detailed feeding algorithm allowed a faster "one-step" progression to goal rate that was well tolerated by patients, with significantly more patients in the post-implementation group having their feeds progress using this process. We felt that the reduction in both time and variability in practice was of clinical significance.^{2,6-8,14,20,21}

In our study, pre- and post-implementation groups received 70% and 68% of prescribed nutrition volumes, respectively. Results from studies comparing nutrition pre-

scribed versus nutrition delivered have varied from 49% to 95% of prescribed volume being achieved.^{6,7,11,14,20-24} Both our results are at the upper end of the range reported in published data, and may be explained by the algorithm specifying starter and target rates for parenteral nutrition if the gut cannot be used. They may also reflect the advantage of faster introduction of nutrition support, as many of the other protocols had a longer progression to goal rate. Although no significant improvement was observed in mean goal volume received over LOS, it was found that interruptions from fasting for theatre/procedures, extubation trials, and possible re-intubations were the biggest obstacle to goal volumes being reached. These factors are often unavoidable in the ICU and appear to be universal.

Similar studies comparing nutrition adequacy and delivery before and after implementing a feeding algorithm have reported improvement in nutrition delivery, with one study showing a 40% increase in the number of patients receiving the prescribed nutrition volume.¹⁴ In many of these studies there were no previous feeding protocols in use, so the reported difference may be greater than that found in our study, which was conducted in an environment with a feeding protocol already in place.

In a meta-analysis investigating the optimum amount for feeding critically ill patients, Stapleton and colleagues concluded that early and aggressive nutrition support is linked with improved clinical outcomes, but as nutrition delivery is generally inadequate in practice, strategies should aim to optimise delivery.¹⁶ Data collection for our study did not include clinical outcomes. However, as it is well documented that early nutrition support in ICU patients is linked with reduced infection and postoperative complications,¹⁻⁷ our results highlight the importance of using algorithms to align practice with current clinical guidelines.

An additional benefit of our detailed algorithm is that it did not rely solely on the dietitian for setting of goal rate, ensuring accountability and shared responsibility by all members of the ICU team. Sinuff and colleagues evaluated barriers to and facilitators of guideline adherence in three Canadian ICUs.¹⁵ Enablers were endorsement of guidelines as a primary tool for knowledge, a cohesive and cooperative team, and open communication. We consider that these enablers were all present in our study and may have helped implement the algorithm.

By delaying data collection until 6 months after the implementation process and blinding staff to the data collection, we hope that the potential for bias from the Hawthorne effect was minimised in our study and that the observed improvements reflect a true change in practice.

Although our detailed algorithm has improved nutrition delivery in the ICU, there is room for further improvement. Adherence to protocol varied — for example, some patients

were not commenced at the starter rate because of inadequate documentation. We also found differences in the management of patients with high GRVs, with most patients being given prokinetic agents after the first high GRV reading. Although this is consistent with recent studies as an effective way of improving tolerance to enteral nutrition, this practice was inconsistent with the algorithm, and has therefore prompted review of the algorithm to reflect what has been published.²⁵⁻³⁹

Conclusion

Compared with our standard feeding protocol in the ICU (Figure 1), a detailed feeding algorithm (Figure 2) resulted in earlier commencement of nutrition support and more patients reaching goal nutrition rates earlier in their ICU stay. This is in line with current evidence-based clinical practice guidelines. To further improve nutritional adequacy for ICU patients over the period of their stay, we need to review our algorithm to assess the need for procedure-related feed interruptions and take into account unavoidable interruptions. Nutrition staff also need to be proactive in promoting education programs to ensure the ongoing success of such algorithms.

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