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Original article

Implementing a physician-driven feeding protocol is not sufficient to achieve adequate caloric and protein delivery in a paediatric intensive care unit: A retrospective cohort study

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SUMMARY

Background and aims: Daily caloric and protein intake is crucial for the management of critically ill children. The benefit of feeding protocols in improving daily nutritional intake in children remains controversial. This study aimed to assess whether the introduction of an enteral feeding protocol in a paediatric intensive care unit (PICU) improves daily caloric and protein delivery on day 5 after admission and the accuracy of the medical prescription.
Methods: Children admitted to our PICU for a minimum of 5 days who received enteral feeding were included. Daily caloric and protein intake were recorded and retrospectively compared before and after the introduction of the feeding protocol.
Results: Caloric and protein intake was similar before and after introduction of the feeding protocol. The prescribed caloric target was significantly lower than the theoretical target. The children who received less than 50% of the caloric and protein targets were significantly heavier and taller than those who received more than 50%; the patients who received more than 100% of the caloric and protein aims on day 5 after admission had a decreased PICU length of stay and decreased duration of invasive ventilation.
Conclusion: The introduction of a physician-driven feeding protocol was not associated with an increase in the daily caloric or protein intake in our cohort. Other methods of improving nutritional delivery and patient outcomes need to be explored.

1. Introduction

Hospital-acquired malnutrition is a significant burden in the pediatric intensive care population with increased risk of mortality, length of stay, duration of mechanical ventilation, and infection [1,2]. Achieving adequate caloric and protein intake in critically ill children admitted to paediatric intensive care units (PICUs) is challenging. While enteral nutrition (EN) is the recommended feeding method [3], it is frequently associated with inadequate energy delivery in the PICU. It is often impaired because of barriers, such as fluid restriction, respiratory or haemodynamic instability, and gastrointestinal paresis due to medications, including opiates and benzodiazepines. Additionally, critical care procedures cause frequent feeding interruptions [4–7].

PICU patients are already at particular risk of malnutrition prior to hospital admission. As shown in previous studies, up to 40% of critically ill children present with malnutrition or obesity criteria at admission, which are both associated with increased mortality and morbidity [8–10]. During the acute phase of illness, adequate nutritional intake is not achievable most of the time because of the previously mentioned reasons. Consequently, children develop negative energy and protein balances, resulting in malnutrition or

Abbreviations: EN, enteral nutrition; IQR, interquartile range; PICU, paediatric intensive care unit; PN, parenteral nutrition; REE, resting energy expenditure.

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worsening underlying malnutrition [10]. They systematically accumulate protein and caloric debt during the first few days after admission to the PICU. This debt stops growing between the fifth and eighth day after admission to the PICU [11–13]. All of these taken together, critically ill children are at a major risk of developing nutritional deficiencies (macro- and micronutrients) after a few days of PICU stay.

Providing adequate nutritional support is part of quality standards of care. However, clinicians still do not consider feeding a priority among other intensive care treatments and procedures, owing to a lack of time, resources, interest, or specific knowledge on the topic and the consequences on outcomes [14]. In addition to managing resuscitation and urgent somatic issues, clinicians must also be aware and convinced that nutrition is essential and confront the difficult task of feeding critically ill children as appropriately as possible.

As suggested by several studies, early and adequate enteral provision of macro- and micronutrients could improve survival in adults and children in the intensive care unit [1,2,11–13,15]. Similarly, some studies showed improvements in survival in patients when a higher percentage of the prescribed dietary energy goal was provided [2,15–17].

The implementation of a feeding protocol may be an efficient strategy for standardizing and improving feeding practices in the PICU [18]. This approach was evaluated approximately 10 years ago in several studies with a variety of designs, yielding insufficiently robust findings in some cases; some studies included a control group retrospectively selected several years before the study group, while other studies did not [19–22]. Only Mehta et al. have shown that using a feeding protocol in a PICU allowed a better daily caloric and protein intake and was associated with fewer acquired infections and lower mortality [2]. Since then, knowledge on daily caloric and protein requirements in critically ill children has been more accurately defined [11]; however, as shown by the American Society for Parenteral and Enteral Nutrition in 2017, there is still a lack of evidence-based literature to justify the systematic use of feeding protocols [3].

In July 2018, we implemented a feeding protocol based on national and international up-to-date recommendations to improve feeding practices and decrease the negative caloric and protein balances accumulated during the first days after admission. The primary aim of this study was to evaluate the impact of a feeding protocol on caloric and protein intake in children hospitalised in our PICU for more than 5 days. The secondary aims were to evaluate the accuracy of the daily medical prescription of calories and proteins as recommended in the feeding protocol and identify the risk factors for decreased caloric and protein intake in our population. We also looked for any changes in the feeding practices regarding the feeding route and the use of prokinetics before and after the introduction of the feeding protocol.

2. Methods

2.1. Settings

Our hospital is a tertiary university hospital in Switzerland. Its 12-bed PICU is a mixed medical, cardiac, and surgical unit with approximately 450 admissions annually.

2.2. Participants and design

Children from birth to 16 years old admitted to the PICU of the University Hospital of Lausanne from January 2017 to December 2019 were considered eligible. The inclusion criteria were a PICU stay of more than 5 days, EN, and/or parenteral nutrition (PN). The exclusion criteria were a PICU stay fewer than 5 days, oral feeding, intestinal disease, gastrointestinal surgery as the main cause of PICU admission, and extracorporeal membrane oxygenation support during the first 5 days after admission. Our institutional research ethics committee approved the study and waived the requirement for informed consent (Swissethics 2020-00273). This retrospective study was reported following the STROBE guidelines [23].

Based on the previously described literature, the fifth day of ICU stay was chosen as the endpoint to assess any change in energy and protein delivery and feeding practices. Demographic and clinical data, such as PICU length of stay, invasive and non-invasive ventilation duration, nasogastric or nasoduodenal tube use, partial or total PN, prokinetic medication, and diagnostic category (postoperative cardiac, neurological, respiratory diseases and sepsis), were retrospectively collected from the intensive care unit database (MetaVision, iMDSoft, Tel Aviv, Israel) and computerised medical records (SOARIAN, Cerner, Berlin, Germany).

Prescribed and actual caloric and protein intake, as well as theoretical target, were recorded from admission until day 5 after admission. According to protocol recommendations, the physician in charge decides on the feeding monitoring, route, caloric, and protein intake goals on a daily basis.

2.3. Feeding protocol

The feeding protocol was developed by the medical team and nutritionists of the unit. Physicians were taught to apply it for their prescriptions. The protocol describes when and how to start EN, how to progressively increase enteral feeding, which nutritional solution to choose, and age-dependent minimal protein and caloric intake goals.

Resting energy expenditure (REE) can be measured via indirect calorimetry; however, no calorimeter was available in our unit at the time of assessment to allow accurate measurement of the REE. Therefore, we used the results of previous studies to estimate the energy requirements [11]. The minimal caloric requirements for the children in the PICU depend on their age, clinical condition (disease, mechanical ventilation, sedation, and muscle relaxation), and physical activity. Schofield's equation was used to predict the REE among mechanically ventilated patients older than 8 years. Table 1 shows the recommended daily caloric targets based on the protocol used in the unit. According to the patient's condition and physical activity, the requirements are increased by 20 up to 50% after extubation. Minimal protein intake was also estimated according to recent research in critically ill children (approximately 1.5 g/kg/d) [3,11].

Our protocol also includes the indications required to stop enteral feeding (intubation, extubation, radiological imaging, surgical procedure, or worsening abdominal status), as well as tricks and tips to speed up the introduction and the progression of enteral feeding, with the use of prokinetics and post-pyloric route. It also specifies which feeding solutions were available in the unit and the most appropriate for each patient, depending on age, weight, and condition. Recommendations for vitamins, trace elements, and laxatives are also included.

2.4. Data analysis

Our results were expressed as means ± standard deviations for normally distributed data and as medians (interquartile ranges [IQRs]) for non-normally distributed data. The baseline patient characteristics of each group were compared using the Mann–Whitney U test for numerical data and the Pearson chi-squared test for categorical data. Differences in the demographic

Table 1
Recommended caloric target based on protocol used in the unit and Schofield's equation.

	0–6 months	7–12 months	1–3 years	4–8 years	9–18 years
Daily caloric target (kcal/kg/d)	58	62	58	46	Schofield's equation ***Girls:*** 8.365*W + 4.65*H + 200 ***Boys:*** 16.25*W + 1.372*H + 515.5

W = Weight in kg; Height in cm; Results in kcal/kg/d.

data (age, weight, height, and length of stay in the PICU in days and hours on invasive and non-invasive ventilation) were tested using the Mann–Whitney U test for median comparison and variance (ANOVA). The t-test for independent samples was used to compare the means between the two samples. In addition, Levene's test was used to assess the homogeneity of the variance between the two groups, allowing the selection between the t-test and Welch's test as the appropriate test for our analysis.

Comparisons between the paired samples were performed using the Wilcoxon signed-rank test and t-test. For all comparisons, a p-value of <0.05 was considered statistically significant. Statistical analyses were performed using SPSS 26.0 and 27.0 (IBM SPSS software, NY, USA).

3. Results

3.1. Demographic data

After screening for eligibility of 1208 admissions in our PICU register, we retrospectively included 240 patients: 126 patients before and 114 patients after the implementation of our protocol. The study population is described in Table 2. Two hundred and forty patients (105 girls and 135 boys) were included in this study. The median age, weight, and size were 0.97 [IQR, 0.25–3.53] years, 8.00 [IQR, 5.00–14.00] kgs, and 0.74 [IQR, 58–99] meters, respectively. All our patients were fed through a nasogastric, nasoduodenal, or nasojejunal tube, and 32 of them (13.3%) received partial PN. Thirty percent of our patients were fed through a nasogastric tube and 70% through a post-pyloric tube. There were 126 (52.5%) patients admitted for respiratory diseases, 76 (31.70%) for cardiac diseases, including cardiac surgery, 12 (5.0%) for neurological diseases, 2 (0.8%) for sepsis, and 24 (10.0%) for other diagnoses. The median duration of invasive ventilation was 119.58 [IQR, 73.00–173.13] hours, and the median PICU length of stay was 9.97 [IQR, 7.07–14.41] days. Domperidone was administered to 94% (n = 225) of our patients, metoclopramide to 26.3% (n = 63), and erythromycin to 2% (n = 4). There were no significant differences in demographic data between pre and post protocol groups.

3.2. Theoretical caloric and protein target and amount delivered before and after feeding protocol implementation

Table 3 summarizes median theoretical targets and real intake for calories and proteins on day 5 of PICU stay. There was no significant difference in caloric intake before and after protocol implementation (p = 0.74). Figure 1 shows the median percentage of the caloric target received from admission (day 0) to day 5 after admission, before and after the implementation of the feeding protocol. Both groups received approximately 86% of their caloric target on day 5. The median cumulative caloric debt from day 0 to day 5 before and after the implementation of our protocol was 104 kcal/kg and 120 kcal/kg, respectively, as shown in Fig. 1, with no significant difference (p = 0.96).

There was no significant difference in the protein intake before and after protocol implementation (p = 0.80, Table 3) nor in the cumulative protein debt on day 5 (3.1 g/kg and 3.0 g/kg, respectively) (p = 0.79), as shown in Fig. 2.

3.3. Prescribed caloric and protein target compared with the caloric and protein recommendations of the feeding protocol on day 5

We compared the prescribed with the theoretical caloric and protein target on day 5 according to the recommendations of our feeding protocol as shown in Table 4. The prescribed caloric target was significantly lower than the theoretical goal recommended by our feeding protocol (62.8 [56.3–86.7] versus 80.0 [58.3–89.5] kcal/kg, p = 0.003).

There was no significant difference between the prescribed and theoretical recommended protein target (1.51 [1.47–1.57] versus 1.50 [1.48–1.55], p = 0.35).

3.4. Subgroup analyses

We analysed 2 subgroups of patients. First, we compared children who received less than 50% of caloric and protein targets, meaning those severely underfed, with those who received more than 50% of targets. Second, we compared children who received

Table 2
Demographic and clinical variables.

	Total (n = 240, 100%)		Pre-protocol (n = 126, 52.5%)		Post-protocol (n = 114, 47.5%)		
	n (%)	Median [IQR]	n (%)	Median [IQR]	n (%)	Median [IQR]	p-value
Female/male	105(43.7)/135(56.3)	–/–	56(55.6)/70(44.4)	–/–	49(57)/65(43)	–	0.82/0.82
Age (years)	240 (100.0)	0.97 [0.25–3.53]	126 (52.5)	0.83 [0.27–2.93]	114 (47.5)	1.16 [0.22–4.05]	0.961
Weight (kg)	240 (100.0)	8.00 [5.00–14.00]	126 (52.5)	7.90 [4.94–14.63]	114 (47.5)	8.45 [5.00–13.93]	0.870
Size (m)	238 (99.2)	0.74 [0.58–0.99]	125 (52.1)	0.71 [0.58–1.00]	113 (47.1)	0.76 [0.60–0.99]	0.926
BMI (kg/m^2)	238 (99.2)	14.49 [13.01–16.11]	125 (52.1)	14.72 [13.31–16.41]	113 (47.1)	14.36 [12.82–15.93]	0.070.
Length of Stay (days)	240 (100.0)	9.97 [7.07–14.41]	126 (52.5)	9.98 [7.09–14.93]	114 (47.5)	9.97 [7.00–14.01]	0.690
Invasive Ventilation (h)	163 (67.9)	119.58 [73.00–173.13]	79 (32.9)	121.90 [67.91–188.30]	84 (35.0)	117.34 [78.52–167.44]	0.201
Non-Invasive Ventilation (h)	194 (80.8)	104.00 [43.33–148.95]	97 (40.4)	117.15 [53.01–162.71]	97 (40.4)	95.08 [34.47–142.30]	0.768
Total Ventilation (h)	233 (97.1)	154.45 [112.94–234.50]	121 (50.4)	160.91 [114.21–238.76]	112 (46.7)	149.60 [112.09–233.09]	0.955

All values are expressed as numbers (n) and percent (%), and median and interquartile range [P25–P75].
Mann–Whitney U Test was used to compare the medians between the two populations.

Table 3
Theoretical caloric and protein target and real intake on day 5 of PICU stay.

	Total (n = 240, 100%)		Pre-protocol (n = 126, 52.5%)		Post-protocol (n = 114, 47.5%)		
	n (%)	Median [IQR]	n (%)	Median [IQR]	n (%)	Median [IQR]	p-value
Theoretical Caloric Target (kcal/kg/d)	240 (100.00)	86.58 [58.33–90.00]	126 (52.5%)	86.91 [58.43–90.00]	114 (47.5%)	80.00 [58.30–89.52]	0.645
Real Caloric intake (kcal/kg/d)	240 (100.00)	60.47 [42.64–86.72]	126 (52.5%)	63.43 [36.87–91.35]	114 (47.5%)	60.03 [48.46–77.81]	0.736
Theoretical Protein Target (g/kg/d)	240 (100.00)	1.50 [1.49–1.54]	126 (52.5%)	1.50 [1.50–1.52]	114 (47.5%)	1.50 [1.48–1.55]	0.257
Real Protein intake (g/kg/d)	240 (100.00)	1.40 [0.98–1.86]	126 (52.5%)	1.41 [0.97–1.85]	114 (47.5%)	1.38 [0.98–1.89]	0.800

All values are expressed as numbers (n) and percent (%), and median and interquartile range [P25–P75].
Mann–Whitney U Test was used to compare the medians proximity between the two samples.

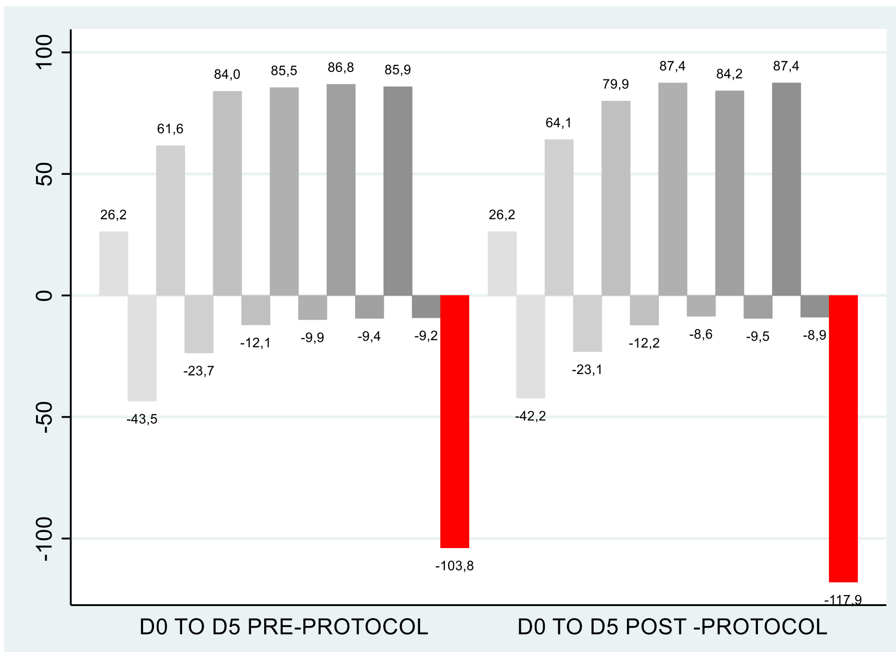

Fig. 1. Percent of real caloric intake (%) and caloric debt (kcal/kg) from day 0 to day 5 before and after implementation of the feeding protocol. Values are expressed as medians.

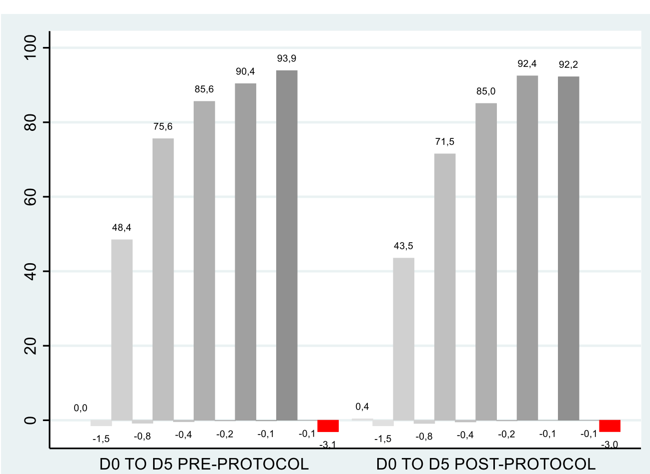

Fig. 2. Percent of real protein intake (%, above zero) and protein debt (kcal/kg, under zero) from day 0 to day 5 before and after implementation of the feeding protocol. Values are expressed as medians.

more than 100% of caloric and protein targets, meaning patients adequately or even overfed, with those than received less than 100% of targets.

Twenty children (8.3%) received less than 50% of the theoretical caloric and protein targets on day 5. Table 5 compares these 20 children with the 220 children who received more than 50% of the caloric and protein targets. There were no significant differences between the two groups except for weight and size.

Sixty children (25%) received more than 100% of the theoretical caloric and protein targets on day 5. Table 6 shows that these children were significantly younger, had a shorter duration of invasive ventilation but a higher duration of non-invasive ventilation, and had a shorter length of stay than the 180 children who received less than 100% of the caloric and protein targets.

3.5. Delivery route of feeding and prokinetics use

Table 7 shows that more than 70% of our patients receive post-pyloric feeding. Median time of invasive ventilation is longer in the post-pyloric group compared to the pre-pyloric group (134.75 [IQR, 92.50–187.70] hours versus 90.24 [IQR, 42.20–149.76] hours, p = 0.002), as well as total ventilation (165.25 [118.85–253.31] hours versus 132.10 [90.66–204.74] hours, p = 0.000). There was no other significant difference.

Prokinetic administration significantly decreased after the protocol: domperidone (98% before the protocol versus 88.6% after the protocol, p = 0.002) and metoclopramide (31.7% before the protocol versus 20.2% after the protocol, p = 0.042). However, erythromycin

Table 4
Theoretical caloric and protein target and prescribed target after implementation of the feeding protocol.

		Post Protocol Population (n = 114)	
		n (%)	Median [IQR]
Theoretical caloric target (kcal/kg/d)		114 (100.00)	80.00 [58.30–89.52]
Prescribed caloric target (kcal/kg/d)		114 (100.00)	62.83 [56.31–86.70]
Theoretical versus prescribed caloric target	**p-value**	–	0.003
Theoretical protein target (g/kg/d)		114 (100.00)	1.50 [1.48–1.55]
Prescribed protein target (g/kg/d)		114 (100.00)	1.51 [1.47–1.57]
Theoretical versus prescribed protein target	**p-value**		0.346

All values are expressed as numbers (n) and percent (%), and median and interquartile range [P25–P75].
Mann–Whitney U Test was used to compare the medians proximity between the two samples.

Table 5
Comparison between patients receiving <50% and >50% of theoretical caloric and protein target at day 5.

	Under 50% of Theoretical Caloric and Protein Intake Population (n = 20, 8.3%)		Over 50% of Theoretical Caloric and Protein Intake Population (n = 220, 91.6%)		
	n (%)	Median [IQR]	n (%)	Median [IQR]	p-value
Age (years)	20 (8.3)	2.73 [0.31–9.33]	220 (91.6)	0.91 [0.24–3.17]	0.066
Weight (kg)	20 (8.3)	13.25 [5.33–23.00]	220 (91.6)	7.90 [4.99–13.63]	0.042
Size (m)	20 (8.3)	0.95 [0.60–1.14]	220 (91.6)	0.72 [0.58–0.97]	0.048
BMI (kg/m^2)	20 (8.3)	15.91 [13.22–18.18]	220 (91.6)	14.45 [13.00–15.99]	0.113
Length of Stay (days)	20 (8.3)	11.61 [7.55–17.91]	220 (91.6)	9.94 [7.06–14.11]	0.288
Invasive Ventilation (h)	15 (6.2)	115.66 [65.17–229.50]	148 (61.6)	121.78 [74.15–172.60]	0.702
Non-Invasive Ventilation (h)	15 (6.2)	91.76 [30.60–132.80]	179 (74.5)	106.26 [44.37–150.00]	0.246
Total Ventilation (h)	19 (7.9)	136.33 [94.92–226.55]	214 (89.1)	157.13 [113.22–235.67]	0.563

All values are expressed as numbers (n) and percent (%), and median and interquartile range [P25–P75].
Mann–Whitney U Test was used to compare the medians proximity between the two samples.

Table 6
Comparison between children receiving <100% and >100% of theoretical caloric and protein target at day 5.

	Under 100% of Theoretical Caloric or Protein Intake Population (n = 180, 75%)		Over 100% of Theoretical Caloric and Protein Intake Population (n = 60, 25%)		
	n (%)	Median [IQR]	n (%)	Median [IQR]	p-value
Age (years)	180 (75)	1.47 [0.31–4.91]	60 [25]	0.41 [0.13–1.27]	0.00
Weight (kg)	180 (75)	9.60 [5.35–15.69]	60 [25]	5.45 [4.50–8.52]	0.00
Size (m)	180 (75)	0.80 [0.60–1.05]	60 [25]	0.62 [0.56–0.76]	0.00
BMI (kg/m^2)	180 (75)	14.69 [13.18–16.50]	60 [25]	13.97 [12.78–15.26]	0.015
Length of Stay (days)	180 (75)	10.19 [7.67–14.98]	60 [25]	8.02 [6.77–13.20]	0.006
Invasive Ventilation (h)	136 (56)	121.46 [77.06–172.60]	27 (11.2)	96.00 [45.80–181.67]	0.00
Non-Invasive Ventilation (h)	142 (59.1)	93.26 [31.36–147.29]	52 (21.6)	122.99 [92.31–156.92]	0.001
Total Ventilation (h)	173 (72)	161.50 [113.43–238.05]	60 [25]	142.81 [110.27–199.00]	0.56

All values are expressed as numbers (n) and percent (%), and median and interquartile range [P25–P75].
Mann–Whitney U Test was used to compare the medians proximity between the two samples.

Table 7
Comparison of pre-pyloric and post-pyloric feeding.

	Pre-pyloric feeding (n = 71, 30%)		Post-pyloric feeding (n = 169, 70%)		
	n (%)	Median [IQR]	n (%)	Median [IQR]	p-value
Age (years)	71 (29.5)	2.42 [0.19–7.11]	169 (70.4)	0.91 [0.26–2.60]	0.085
Weight (kg)	71 (29.5)	11.40 [4.98–21.00]	169 (70.4)	5.00 [8.00–12.00]	0.062
Size (m)	71 (29.5)	0.87 [0.57–1.12]	167 (69.5)	0.72 [0.59–0.90]	0.09
BMI (kg/m^2)	71 (29.5)	15.00 [13.20–17.08]	167 (69.5)	14.36 [13.01–15.97]	0.138
Length of Stay (days)	71 (29.5)	9.14 [7.07–13.85]	169 (70.4)	10.07 [7.08–15.00]	0.178
Invasive Ventilation (h)	44 (18.3)	90.24 [42.20–149.76]	119 (49.6)	134.75 [92.50–187.70]	0.002
Non-Invasive Ventilation (h)	54 (22.5)	107.00 [42.39–138.13]	140 (58.3)	103.44 [44.60–160.46]	0.257
Total Ventilation (h)	67 (28)	132.10 [90.66–204.74]	166 (69.1)	165.25 [118.85–253.31]	0.000

All values are expressed as numbers (n) and percent (%), and median and interquartile range [P25–P75].
Mann–Whitney U Test was used to compare the medians between the two populations.

administration slightly increased from 0.8% before the protocol to 2.6% after the protocol, without a significant difference ($p = 0.27$).

4. Discussion

This study failed to show that a feeding protocol improves either the daily caloric intake or the daily protein intake in critically ill patients on day 5 of hospitalization in our PICU.

Several paediatric studies have shown some benefits of feeding protocols in the PICU. Briassoulis et al. demonstrated the feasibility of introducing a protocol in the PICU in a prospective study without a control group [10]. Petrillo-Albarano et al. examined the effect of feeding protocol implementation in their PICU in 93 patients compared with 91 patients before protocol implementation [19]. They reached their nutrition goal 18.5 h after the protocol compared with 57.7 h before the protocol but did not clearly mention their caloric goal per patient per day. Similarly, Meyers et al. found an important improvement in feeding practices after the implementation of a feeding protocol in their PICU [21]. In 1994, after an audit of feeding practices, they implemented a feeding protocol in their units. The measures were repeated in 1997, 2001, and 2005, and the feeding practices were compared after each audit. They showed a significant decrease in the median time taken for nutrition to be started. On day 3 after admission in their cohorts, 15%, 26%, 58%, and 59% of their patients received at least 50% of the estimated average requirement in 1994–1995, 1997–1998, 2001, and 2005, respectively. For patients receiving at least 70% of the estimated average requirements, proportions were 6%, 10%, 35%, and then 21% in 2005.

In comparison, on day 3 in our study, the median caloric intake was 85.5% and 87.4% of the estimated needs before and after the implementation of the feeding protocol. Our results suggest a better performance of the nutritional management in our unit even before the implementation of the protocol, as it has been historically considered an important aspect of our global management of critically ill children. This may partly explain why the sole implementation of a protocol did not increase the caloric or protein intake as expected. Furthermore, in this study, we did not evaluate whether it shortened the delay between admission to the PICU and the introduction of EN or increased the rapidity of the feeding progression, both being potential positive impacts of a protocol.

Another explanation for the lack of difference in the daily caloric and protein intake before and after the implementation of our feeding protocol may be the clinical condition of the patients included in our cohort. Patients matching our inclusion criteria were among the sickest of our PICU. Critical conditions and fluid restrictions make nutrition a complex challenge. In the first days after admission, clinical decisions regarding fluid and nutrition management are especially difficult to handle for physicians because children are not weighted due to their unstable condition. This includes more than 30% of our patients who had postoperative cardiac diseases. These patients are commonly intubated and often present with haemodynamic instability requiring, on one hand, substantial and numerous intravenous treatments and, on the other hand, fluid restriction, which allows little space for EN or PN support and makes nutritional goals challenging to reach. Nutritional support is indeed constantly adapted and tailored to the patient's condition. Even if our feeding protocol is extensive, it allows physicians to adapt nutritional support to the context of the child. Choosing the fifth day after admission to achieve nutritional goal may have hidden its impact: the protocol implementation may have more impact over a longer period of time and especially during convalescence and until discharge of PICU. Also, fifty-two percent of our patients were admitted owing to upper or lower respiratory diseases; the vast majority received invasive or non-invasive respiratory support, which might have led to delayed or insufficient nutritional delivery.

As our feeding practices were quite efficient before the protocol implementation, it is conceivable that it is even more difficult to improve caloric intake. With the enteral feeding solutions available in our institution, the children's condition might preclude increased caloric and protein intake without putting them at risk of complications such as fluid overload or poor feeding tolerance, vomiting and aspiration. Hypercaloric solution (1.2–1.5 kcal/mL instead of 1 kcal/mL), could be considered, but with the risk of poor feeding tolerance, osmotic diarrhoea, or ischemic enterocolitis in unstable patients with potentially impaired mesenteric perfusion.

On day 5 of PICU stay, the prescribed caloric target was significantly lower than the theoretical caloric target recommended by the protocol. This suggests that the medical team does not yet consider nutritional support as important as the rest of the medical management. A possible explanation is raised by Tume et al. [14], describing that one of the three perceived barriers across all professional groups to delivering adequate nutrition was the lack of time dedicated to education and training on how to feed patients optimally. Caregivers may somehow be unaware of the importance of nutrition in outcomes [20], despite recent scientific literature showing that increasing daily caloric and protein delivery to critically ill children improves clinical outcomes, such as mortality, and decreases nosocomial infections [1,2]. Intensive care physicians often focus on urgent medical care of the patient and may neglect the precise calculation of the caloric target. This is highlighted in two other studies, where nurse-driven feeding protocols and nutritional support team showed clear improvement in achieving nutritional goals in their PICU, despite already being very efficient in their nutritional practices [24,25].

Our results emphasize that implementing a physician-driven protocol fails to improve caloric or protein intake in the PICU. Physicians are particularly engaged in managing critically ill children, technical equipment, haemodynamic or respiratory management. Nutrition may be considered of minor importance compared to other medical procedures. Although our results are rather good, the implication of bedside nurses and a nutritional team may further improve nutritional management.

Unlike caloric targets, that were not accurately prescribed, and did not follow the recommendations, protein intake was accurately prescribed. We assume that the relatively easy method of calculating the daily protein goal, where the multiplicative number is constant and does not depend on age or clinical state, explains this.

Our study also aimed to identify patients at risk of caloric or protein deficits during the first 5 days after admission. The patients who received less than 50% of the theoretical caloric intake were older, although not significant, but were significantly heavier than their counterparts were. This difference may be explained by the subjective appreciation of the team, that older or heavier children have a larger energy reserve than neonates or infants and that nutritional support is therefore less crucial. This perception may contribute to neglecting nutritional support in older children. Furthermore, with the caloric aim being higher in these children, physicians and nurses may be reluctant to increase enteral feeding because of the fear of feeding intolerance or fluid overload, especially in patients with cardiac diseases, where fluid restrictions are seen as a major barrier to EN by medical staff [14]. Children weighing more than around 10 kg may be especially at risk.

Children who received more than 100% of the theoretically calculated intake had better outcomes. They had a shorter duration of invasive ventilation and PICU length of stay. This supports previous data on the benefits of appropriate caloric delivery to children and adults requiring critical care [2,15–17,26]. However, we also can hypothesize that, in our cohort, achieving nutritional goals may have been easier for these children because they were less critically ill and thus needed less intensive care support.

In our unit, nurses are used to inserting post-pyloric tubes, routinely, in mechanically ventilated patients, in order to decrease the time between admission and initiation of enteral feeding, even in unstable patients. Patients with post-pyloric feeding have longer invasive and total ventilation times. This may be explained by the fact that, in the sickest patients, with a long respiratory support expected, nurses are prone to insert immediately a postpyloric tube in order to feed the patient as soon and as efficiently as possible.

Similarly, the automatic administration of prokinetics was usual in our unit. These two habits are highly questionable and are not supported by evidence-based literature. Both of them decreased after the introduction of the protocol without measurable consequences for the patients.

Feeding practices in PICU and their impact on outcomes such as ventilation duration or length of stay, infectious complications or mortality need further evidence. Our study wasn't designed to define the benefit of enteral feeding in terms of outcomes. First, it has a retrospective design. Secondly, mortality incidence is less than 2% in our PICU, which implies to include a huge number of patients in order to achieve adequate power of the study. After this retrospective analysis, a prospective study is needed in order to evaluate these outcomes.

This study has some limitations. It has a retrospective, monocentric study design, which implied several potential methodological biases. As the design is relatively simple, we could not address all the potential reasons that explain the lack of improvement in our nutritional practices. Using a before/after design with aggregate data may have hidden some temporal fluctuations in nutritional management during the study period. In addition, the sample size was relatively small, and the cohort included only patients who needed more than 5 days of PICU stay. Thus, this addresses a very specific part of the PICU population—the sickest patients. However, the strengths of our study reside in the strict selection of our patients to make the two groups similar and the close distance in time, which excluded the possibility that other interventions in our PICU could have influenced our results.

5. Conclusion

While hospital-induced malnutrition is well recognized in the PICU, our study showed the limit of a physician-driven feeding protocol to address this issue in a unit with already quite efficient caloric and protein delivery. The nutritional management was not improved after the protocol implementation, nor did the physicians' nutritional prescription adequacy with recommended targets. Older and heavier patients may be at higher risk of underfeeding and require particular attention. Our protocol allowed us to question if the systematic use of post-pyloric tubes and prokinetics was necessary. Other methods of improving nutritional delivery and patient outcomes should be considered, involving other PICU healthcare workers. Nurse-driven protocols may be more efficient in enhancing nutritional management and require further evidence.

Author contributions (contributor roles taxonomy)

Ismael Touré: Conceptualization, Investigation, Writing - Original Draft, Methodology. **Maria-Helena Perez:** Conceptualization, Methodology, Software, Formal analysis, Investigation, Visualization, Resources, Supervision. **David Longchamp:** Analysis**,** Writing - Review & Editing. **Julia Natterer:** Writing - Review & Editing, **Vivianne Amiet:** Writing - Review & Editing **Thomas Ferry:** Writing - Review & Editing. **Laurence Boillat**: Writing - Review & Editing. **Guillaume Maitre**: Analysis - Writing - Review & Editing.

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Declaration of competing interest

None of the authors declares a conflict of interest.

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