

The impact of body mass index on resource utilization and outcomes of children admitted to a pediatric intensive care unit

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Abstract

Introduction: Obesity is associated with poor health outcomes but may be protective in intensive care unit patients. The objective of this study is to describe the characteristics of underweight, normal weight, and obese children, and to compare their length of stay, resource utilization, and mortality.

Methods: The charts of 1447 patients who were admitted to a tertiary-level pediatric intensive care unit during 1 calendar year were reviewed. Patients were divided into three groups: underweight (<5th percentile), normal (5th–95th percentiles), and obese (>95th percentile). Body mass index for age percentile was used for children older than age 2 years, and weight-for-height percentile was used for children younger than age 2 years. Demographic data, Pediatric Index of Mortality 2 score, Pediatric Index of Mortality 2 risk of mortality, hospital mortality, hospital length of stay, the use and duration of ventilator support, hemodynamic support, and dialysis were determined.

Results: Fifteen percent of children were underweight, while 61.5% were normal weight and 23.5% were obese; 54.9% of the patients were male. The overall mortality was 1.87%, with no significant difference between the three weight groups. The racial distribution, prevalence, and duration of invasive and noninvasive ventilation, and the use of vasopressors, central venous lines, and dialysis were similar between three groups. Tube feeding and parenteral nutrition were used more often in the underweight group. Pediatric intensive care unit and hospital lengths of stays were higher in underweight children. Underweight children were younger when compared to normal or obese children. Pediatric Index of Mortality 2 scores and Pediatric Index of Mortality 2 risk of mortality scores were higher in underweight children.

Conclusion: There were no significant differences between the three weight groups in mortality. Underweight children were younger and sicker, and received tube feeding and parenteral nutrition more frequently.

Keywords

Child, critical illness, obesity, underweight

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Introduction/background

The incidence of health problems due to obesity is increasing at an alarming rate in the United States. The relationship between body mass index (BMI) and disease processes is complex. Although many studies of obesity and its comorbid conditions have been published, few of these studies targeted children, especially children admitted to a pediatric intensive care unit (PICU). Studies of obesity and its effects during intensive care unit (ICU) admission have shown conflicting results. Increased mortality was observed in adults with sepsis,¹ but a meta-analysis showed opposite results.² In adults

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with trauma, the presence of obesity was associated with prolonged hospital stay, longer duration of mechanical ventilation, more complications, and higher mortality.^{3–5} Obesity is an independent risk factor for infections after trauma and associated with increased resource utilization in adults.^{6,7} However, high BMI has a minimal or protective effect on mortality in critically ill adult patients.^{8–15} In contrast, low BMI was associated with increased mortality and worse discharge functional status.¹⁶

Despite similar admission characteristics and less severe head injuries, obese children and adolescents have more complications and require longer ICU stays than their lean counterparts.¹⁷ Obesity in children with trauma is associated with increased abdominal injuries, especially of the liver, without adversely affecting outcomes.¹⁸ In a single-institution study, incidence of deep vein thrombosis was greater in obese children.¹⁹ In a recent multisite study of ventilated children, both low and high BMI were associated with adverse outcomes, with higher mortality in underweight children.²⁰ Preoperative malnutrition (low BMI) was associated with worse outcomes in children after surgery for congenital heart disease, possibly due to poor myocardial function in malnourished children.²¹ In a multinational study of children with severe sepsis, undernutrition was associated with all-cause mortality, and overnutrition was associated with increased hospital length of stay (LOS) after adjusting for all risk factors.²² In a single center, multi-year study, Numa et al.²³ showed that the mortality rate was significantly affected by weight centile. The mortality rate had a U or reverse J shape with respect to weight centile, and the lowest mortality rate was around 75th weight-for-age centile.²³ In a multicenter study from Virtual PICU Systems database, the mortality rate was increased both in underweight and obese groups.²⁴

The purpose of this study was to evaluate the association between body weight and complications and outcomes during PICU stay, including PICU LOS and mortality. We evaluated characteristics of underweight, normal weight, and obese children admitted to a PICU and compared their PICU and hospital LOS, resource utilization, and mortality.

Study design/methodology

We included the charts of all patients, aged 1 month to 18 years, who were admitted to a tertiary care PICU during 1 calendar year and who survived for more than 4 h after being admitted. We excluded charts of patients older than age 18 years, charts with insufficient information such as height or weight, and unretrievable charts. After exclusions, 1447 of 1658 admissions were analyzed.

Chart reviews were completed after institutional review board approval. Hospital and local virtual pediatric systems (VPS) databases and electronic medical records were used to retrieve patient demographics and other variables. (The VPS is an international database of pediatric critical care

units that collect clinical data for the purpose of improving quality, benchmarking with peers, and establishing best practices.) Data were collected, including age, sex, Pediatric Index of Mortality 2 (PIM2) score, PIM2 risk of mortality (ROM)²⁵ (from the local VPS database), hospital mortality, PICU and hospital LOS, body weight, height, use and duration of ventilator support, antibiotic use, vasopressor and inotropic hemodynamic support, and dialysis. We calculated ventilator-free days (VFDs) as 28 minus duration of ventilation in days, and VFD was reported as zero for any negative value or for children who died during the PICU stay.

BMI was calculated using the formula—(weight in kilograms/(height in meters)²)—for patients aged 2 to 18 years. BMI percentile was calculated using the Centers for Disease Control and Prevention (CDC) BMI for age 2 to 18 years.²⁶ Weight for recumbent length percentiles was used to classify children aged <2 years using World Health Organization charts.²⁷ The BMI percentile for age (age, 2–18 years) and length percentile for weight (age, <2 years) were used to divide children into three groups: underweight, <5th percentile; normal (control subjects), 5th to 95th percentiles; and obese, >95th percentile.¹⁰ PIM2 score, risk-adjusted PICU stay, and hospital LOS were calculated. To visualize the relationship between BMI and mortality, we constructed a graph showing four BMI groups (underweight (z-score <−1.89, <3rd percentile), normal weight (z-score −1.89 to +1.04, 3rd–84th percentiles), overweight (z-score +1.05 to +1.65, 85th–95th percentiles), and obese (z-score ≥+1.65, >95th percentile)) and observed mortality rate and standardized mortality ratio (SMR; Figure 1). SMR was calculated by dividing the observed group mortality with mean PIM2 ROM.²⁸ A binary logistic regression was performed to assess the effects of ventilation, vasoactive medication, use of central venous line (CVL), dialysis, tube feeding and parenteral nutrition, PIM2 ROM, and BMI weight categories on mortality. Variables that were statistically significant at .1 or less on a univariate analysis were included in the model. Although BMI weight categories were not statistically significant with mortality at .1 or less, we still included in the model. Patients were grouped into five age groups according to the Eunice Kennedy Shriver National Institute of Child Health and Human Development in the United States.²⁹

Statistical software (SPSS, version 17, SPSS, Inc., Chicago, IL, USA) was used for data analysis. Descriptive data were reported as mean ± SD, median (interquartile range (IQR)), or number (%). Risk-adjusted ICU and hospital LOS were calculated using LOS as dependent variable and PIM2 score as predictive variable in a linear regression analysis. Kruskal–Wallis one-way analysis of variance was used to compare medians of continuous data, and chi-square test was applied to compare categorical data between the three groups.

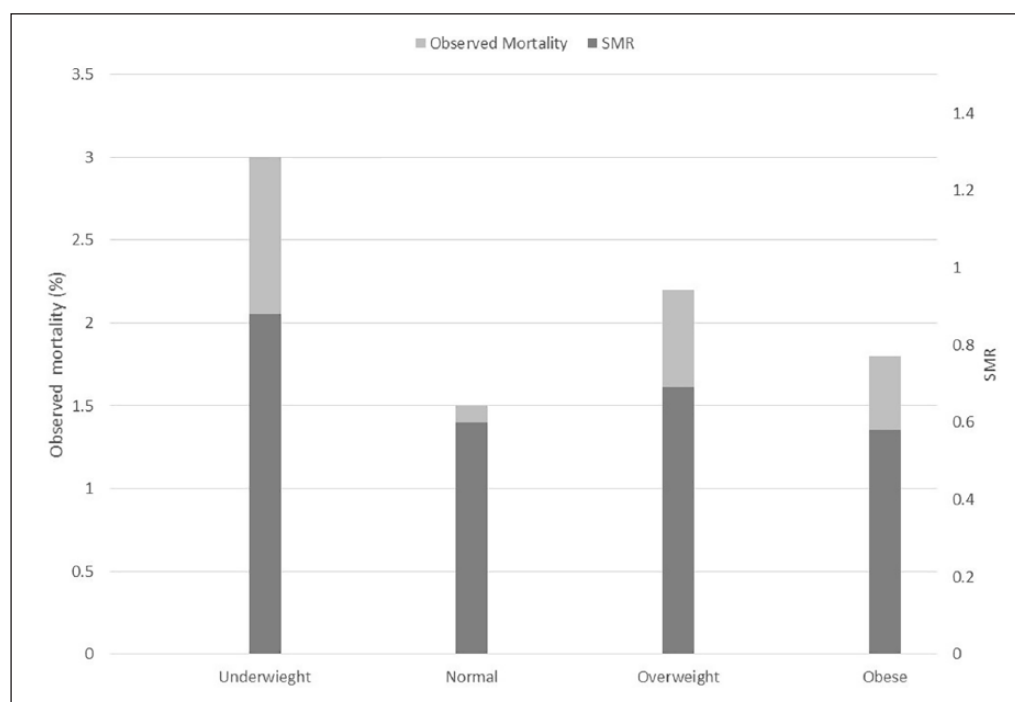


Figure 1. Observed mortality rate and SMR in underweight, normal weight, overweight, and obese children. SMR: standardized mortality ratio.

Results

A total of 1447 children were included in the analysis. Among the children admitted to the PICU, 15% were underweight, 61.5% were normal weight, and 23.5% were obese. Racial and ethnic distribution consisted of 57.15% Hispanics, 17.05% Whites, 12.35% Blacks, and 13.4% Others. Gender distribution was 54.94% male and 45.06% female. There were no significant differences in racial/ethnic and gender distribution between the three weight groups (Table 1). Underweight children were younger (3.0, IQR: 1–7.8 years) compared to obese children (4.3, IQR: 1–12.4 years) and children with normal weight (4.3, IQR: 1.2–10.6 years, $p=.043$; Table 2). In the underweight, normal weight, and obese categories, the percentage of children younger than 6 years of age was 64%, 52.5%, and 54.7%, respectively (Table 1; $p=.003$). However, the proportion of infants in underweight, normal weight, and obese groups was 24.4%, 26.1%, and 22.1%, respectively ($p>.05$).

PIM2 scores and PIM2 ROM were significantly different among the three weight groups, with a higher score in underweight children compared to normal or obese children ($p<.05$; Table 2). The risk-adjusted PICU and hospital lengths of stays were longer in underweight children ($p<.05$; Table 2). The median duration of noninvasive, invasive, or total ventilation was not significantly different among the three groups (Table 2).

The proportion of children in the three weight groups receiving noninvasive, invasive, or any positive pressure ventilation; vasopressor medications; dialysis; or insertion of

CVL was similar (Table 3). However, the use of enteral tube feeding and parenteral nutrition was more frequent in the underweight group compared to other groups ($p=.006$; Table 3). Enteral tube feeding was documented for 17.1% of underweight children compared to 10% of normal weight children and 9.3% of obese children ($p=.006$). Similarly, parenteral nutrition was used in 6.5% of underweight children compared to 2.5% of normal weight children and 2.3% of obese children ($p=.006$). The proportion of medical to surgical patients as well as the proportion of children with neurologic diagnoses were similar in the three groups. The overall mortality rate was 1.87% (95% confidence interval (CI)=1.17%–2.56%). Although there was no statistical significance, the mortality rate was 3.23% (95% CI=0.87%–5.58%) in the underweight group, compared to 1.57% (95% CI=0.76%–2.39%) in the normal weight group and 1.76% (95% CI=0.36%–3.17%) in the obese group ($p=.269$). The mortality rate was not statistically different even after adjusting for PIM2 ROM. Compared to normal weight group, the odds ratio (OR) of mortality in underweight group was 2.71 (95% CI=0.76–9.99) and in obese group was 1.17 (95% CI=0.29–4.7). The use of mechanical ventilation (OR: 17.13, 95% CI=2.0–146.8, $p=.01$), vasoactive medications (OR: 8.18, 95% CI=1.9–35.27, $p=.005$), and PIM2 ROM (OR: 1.05, 95% CI=1.02–1.07, $p<.001$) were significantly associated with mortality. The SMR was lower in normal (0.59; 95% CI=0.36–0.76) and in obese (0.58; 95% CI=0.18–0.76) groups compared to underweight group (0.98; 95% CI=0.40–1.26) but was not statistically different (χ^2 with

Table 1. Demographic and clinical characteristics of children who were admitted to the pediatric intensive care unit.

Variable	Underweight	Normal weight	Obese	Total	$p \leq^a$
Number of children	217 (15)	890 (62)	340 (23)	1447 (100)	
Age (years)					.003
<1	53 (15)	232 (64)	75 (21)	360	
1 to 2	42 ^b (22)	111 (57)	42 (22)	195	
3 to 5	30 (20)	77 ^b (51)	45 (30)	152	
6 to 11	25 (12)	135 (62)	58 (27)	218	
12 to 18	67 (13)	335 (64)	120 (23)	522	
Sex					NS
Male	116 (15)	478 (60)	201 (25)	795	
Female	101 (16)	412 (63)	139 (21)	652	
Race or ethnicity					NS
Hispanic	108 (13)	518 (63)	201 (24)	827	
White	43 (17)	152 (62)	52 (21)	247	
Black	29 (16)	112 (63)	38 (21)	179	
Other	37 (19)	108 (56)	49 (25)	194	

$N = 1447$ children. Data reported as number (%). Body weight groups were based on body mass index percentile (age, 2–18 years) and weight-for-length percentile (age, <2 years): underweight, <5th percentile; normal weight, 5th to 95th percentiles; and obese, >95th percentile.

^aNS, not significant ($p > .05$).

^bSignificantly different from others in multiple comparison tests with adjusted significant value.

observed versus expected mortality). The mortality rate among CDC weight groups (underweight, normal, overweight, and obese) shows the highest mortality rate in the underweight. However, the mortality rates (observed as well as risk-adjusted) were not statistically significant. Observed mortality rate and SMR in CDC weight groups are presented in Figure 1.

Discussion

In this study of children admitted to a PICU, nearly a quarter of the patients were obese and 15% were underweight. Underweight children were younger and required, in general, more resource utilization; furthermore, there was a trend toward a higher mortality in this group. Overall, in our study, obesity had no effect on resource utilization or outcomes but tended to be associated with a decreased LOS.

Nationally, the prevalence of obesity in 2- to 19-year-old children is 17%.³⁰ On the other hand, malnutrition is also a very serious problem in children, especially in developing nations, causing an estimated 540,000 deaths each year.³¹ A meta-analysis of pediatric inpatient admissions in Sub-Saharan Africa, with severe malnutrition but without human immunodeficiency virus infection, showed overall case fatality of 15%.³² The prevalence of underweight status and obesity in our study was similar to that reported in a multicenter study of ventilated pediatric patients.²⁰

Unlike in adults, the interpretation of BMI in children is age and gender dependent. The BMI for age chart is a J-shaped curve with the lowest BMI observed in children

aged 4 to 6 years.²⁶ Therefore, we used BMI for age percentile to classify obesity or underweight status rather than BMI used for adults. In children aged <2 years, we used a weight-for-length percentile chart to classify obesity and underweight status because BMI in this age group is a poor predictor of future obesity.²⁷

The relationship between body weight and its health effects is complex and variable. The shape of the curve relating weight to all-cause mortality in adults has been variously described as linear, J-shaped, and U-shaped.^{33,34} Despite an increase in overall mortality with obesity in adults, obesity may be protective during critical illness.³⁵ In studies of critically ill adults, obesity may have protective,^{8,9,12,14,36} harmful,³ or no effect.^{10,37–39} In contrast, in critically ill adults, underweight status or low BMI has been associated with a higher mortality and other adverse outcomes.^{8,10,16,36,40,41} A low fat-free mass was associated with higher 28-day mortality in critically ill adults.⁴²

In severely injured children and adolescents, the presence of obesity was associated with increased complications and LOS.¹⁷ Obese children with status asthmaticus tend to recover more slowly.⁴³ Obesity has also been associated with an increased risk of deep vein thrombosis.¹⁹ In thermally injured obese children, the LOS and respiratory interventions were increased but not the mortality rate.⁴⁴ Obesity has been associated with an increased risk of abdominal injuries, especially of the liver, but without an increase in the requirement for operative management.¹⁸ In children with acute lung injury, obesity had a protective effect on mortality in the subgroup of patients with indirect lung injury but had a prolonged LOS and mechanical ventilation.⁴⁵ In our study, mortality was not affected by a patient's weight group status.

Table 2. Treatment and outcomes of children who were admitted to the PICU.

Variable	Underweight	Normal weight	Obese	<i>p</i> ≤ ^a
Total number of children (%)	217 (15)	890 (62)	340 (23)	
Age (years)	3 ^b (1 to 7.8)	4.3 ^b (1.0 to 12.4)	4.3 (1.2 to 10.6)	.05
Number of children aged <6 years (%)	146 ^b (68)	491 ^b (58)	202 (59)	.003
PIM2 score	−4.7 ^c (−5.6 to −3.3)	−4.7 (−6.0 to −4.1)	−4.7 (−6.1 to −4.3)	.02
PIM2 ROM	0.95 ^c (0.39 to 3.6)	0.86 (0.24 to 1.6)	0.86 (0.22 to 1.3)	.02
Risk-adjusted LOS (days)				
PICU	4.1 ^c (2.6 to 6.4)	4.0 (1.9 to 5.0)	4.0 (1.7 to 4.7)	.021
Hospital	11.1 ^c (8.0 to 15.7)	10.7 (6.4 to 12.9)	10.8 (6.0 to 12.3)	.021
Duration of ventilation (days)				
Noninvasive	2 (1 to 5)	2 (1.8 to 3)	2 (1 to 4)	NS
Invasive	2 (2 to 13)	3 (2 to 8)	4 (2 to 13)	NS
Any positive pressure	2.5 (2 to 9)	3 (2 to 6)	3 (2 to 7)	NS
Ventilator-free days	25 (11 to 26)	25 (19 to 26)	25 (15 to 26)	NS
Ventilation, number of children (%) ^d				
Noninvasive	23 (11)	130 (65)	48 (24)	NS
Invasive	51 (19)	161 (61)	50 (19)	NS
Any positive pressure	64 (16)	248 (63)	81 (21)	NS
Other treatment, number of children (%)				
Vasopressor drugs	13 (6)	46 (5)	15 (5)	NS
Dialysis performed	3 (1.4)	5 (0.6)	3 (0.9)	NS
CVL insertion	49 (23)	157 (18)	52 (15)	NS
Nutritional support				
Enteral tube feeding	37 (17)	89 (10)	31 (9)	.006
Parenteral nutrition	15 (7)	22 (3)	8 (2)	.006
Service				
Medical	171 (79)	669 (75)	254 (75)	NS
Surgical	46 (21)	221 (25)	86 (25)	NS

PIM2: Pediatric Index of Mortality 2; PICU: pediatric intensive care unit; ROM: risk of mortality; CVL: central venous line; LOS: length of stay. N = 1447 children. Data reported as median (interquartile range) or number (%). Body weight groups were based on body mass index percentile (age, 2–18 years) and weight-for-length percentile (age, <2 years): underweight, <5th percentile; normal weight, 5th to 95th percentiles; and obese, >95th percentile.

^aNS, not significant; *p* > .05.

^bSignificantly different from each other in multiple comparison tests with adjusted significant value.

^cSignificantly different from normal and obese groups.

^dTotal number of children treated with ventilation: noninvasive, 201 children; invasive, 262 children; any positive pressure, 393 children.

However, we noted a trend toward higher mortality in children with a low BMI. In a single center, multi-year study, Numa et al.²³ showed that the mortality rate was significantly affected by weight centile. The mortality rate had a U or reverse J shape with respect to weight centile, and the lowest mortality rate was around 75th weight-for-age centile.²³ In a multinational study of children with severe sepsis, undernutrition was associated with increased all-cause mortality and overnutrition was associated with increased length of ICU stay.²² In a large multicenter study from Virtual PICU Systems database, the mortality rate was increased both in underweight and obese groups.²⁴ In our study, the sample size was not large enough to divide the sample into 9 to 10 groups as in the other two studies. In contrast to the study by Numa et al., we have used BMI z-scores for classification. The observed mortality rate and SMR were not statistically significant in any of the BMI groups (Figure 1). Failure in

our study to demonstrate an association of weight group categories on outcomes and resource utilization may be due to an insufficient sample size and confounded by reasons for admission.

In critically ill populations, underweight status is known to be associated with worse outcomes.^{26,46} Malnutrition is common in critically ill children.²⁰ In a study of mechanically ventilated children, underweight status was present in 17.9% of patients compared with 15% in our study; in the previous study, underweight status was associated with higher hospital mortality and fewer VFDs.²⁰ In postoperative children with congenital heart disease, underweight status was associated with worse clinical outcomes and decreased myocardial function.²¹ In our study, mortality was similar between groups, but underweight children required more nutritional support with enteral tube feeding and parenteral nutrition (Table 3).

Table 3. Resource use and complications in children who were admitted to the pediatric intensive care unit.

Variable	Underweight	Normal weight	Obese	Total	$p \leq^a$
Number of children	217 (15)	890 (62)	340 (23)	1447 (100)	
Any ventilation	62 (29)	250 (28)	81 (24)	393 (27)	NS
Noninvasive ventilation	23 (11)	130 (15)	48 (15)	201 (14)	NS
Invasive ventilation	51 (23)	161 (18)	50 (15)	262 (18)	NS
Medical patients	171 (79)	669 (75)	254 (75)	1094 (76)	NS
CVL	49 (23)	157 (18)	52 (15)	258 (18)	NS
Vasopressor	12 (6)	46 (5)	15 (4)	73 (5)	NS
DVT ^b	4 (1.8)	11 (1.2)	1 (0.3)	16 (1.1)	NS
Dialysis	3 (1.4)	5 (0.6)	3 (0.9)	11 (0.8)	NS
Tube feeding	37 ^c (17)	89 (10)	31 (9)	157 (11)	.006
Total parenteral nutrition	14 ^c (6)	22 (2)	8 (2)	44 (3)	.006
Death	7 (3)	14 (2)	6 (2)	27 (2)	NS

CVL: Central venous line.

N = 1447 children. Data reported as number (%). Body weight groups were based on body mass index percentile (age, 2–18 years) and weight-for-length percentile (age, <2 years): underweight, <5th percentile; normal weight, 5th to 95th percentiles; and obese, >95th percentile.

^aNS, not significant ($p > .05$).

^bDVT, deep venous thrombosis related to central venous line.

^cSignificantly different from other two groups in multiple comparison tests with adjusted significant value.

Although there is concern about the growing epidemic of obesity and its impact on the health of children, it is the underweight status that may be a significant health care risk to critically ill children. The presence of obesity may be protective in patients who are in a catabolic state due to an acute illness, whereas the opposite may apply to underweight patients.³⁵ However, there is no clear explanation for this obesity paradox in critically ill patients, especially adults.³⁵ In obese patients, leptins may act as anti-inflammatory agents.⁴⁷ Therefore, obesity may be preferable than underweight status during an acute illness. More research is needed on premorbid nutritional status and ICU outcomes of pediatric patients and their nutritional management during hospitalization.

An admission underweight status could be a sign of premorbid disease conditions that may predispose to worse outcomes. Malnutrition is associated with abnormal immune function that may lead to an increased risk of developing infections. Underweight children also may be more sensitive to the catabolic effects of an acute illness and less tolerant of poor nutritional intake during hospitalization.²⁰

There are several limitations to our study. This is a single center study and our patients have a racial/ethnic distribution different from the rest of the US population (our patients have a higher proportion of Hispanic patients). The retrospective nature of the study lends to potential inaccuracies of anthropometric measurements because standardization of anthropometric measurement methods was not present. In addition, weight measurements could be inaccurate due to fluid accumulation in critically ill patients. It is possible that, in some instances, weight and height values obtained from parents' recall of recent anthropometric measurements of their children may have been used instead of accurately measured values. In addition, information about prematurity or birth weight was not available which might influence the outcomes.

Conclusion

Our single center study demonstrates that there were no significant differences in mortality, demographics, and utilization of most resources between underweight, normal weight, and obese children. Underweight children were younger and sicker, and received tube feeding and parenteral nutrition more frequently; furthermore, there was a trend toward a higher mortality in this group.

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Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

The requirement for consent was waived by the Western Institutional Review Board (WIRB) (WIRB Application No. 307040).

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Informed consent

The requirement for consent was waived by the Western Institutional Review Board (WIRB). It is a retrospective medical chart review, and patient identifiers were excluded during data collection.

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