

Use of body composition and phase angle analysis for the assessment of nutritional status and clinical outcomes in critically ill children

Zi-Hong Xiong

Chengdu Women's and Children's Central Hospital, University of Electronic Science and Technology of China

Xue-Mei Zheng

University of Electronic Science and Technology of China

Guo-Ying Zhang (✉ zhangguoying412@126.com)

Chengdu Women's and Children's Central Hospital, University of Electronic Science and Technology of China

Meng-Jun Wu

Chengdu Women's and Children's Central Hospital, University of Electronic Science and Technology of China

Yi Qu

Sichuan University

Research Article

Keywords: bioimpedance analysis, phase angle, critical illness, nutritional assessment, prognosis, children

Posted Date: October 13th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-923773/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background

Malnutrition is highly prevalent in critically ill children in the pediatric intensive care unit. We aimed to investigate the efficiency of bioelectrical impedance analysis (BIA) measurements and phase angle (PhA) analysis for the assessment of nutritional risk and clinical outcomes in critically ill children.

Methods

This single-center observational study included patients admitted to the Pediatric Intensive Care Unit (PICU) of Chengdu Women's and Children's Central Hospital. All patients underwent anthropometric measurement in the first 24 h of admission and underwent BIA measurements within 3 days after the admission. The patients were classified into different groups based on body mass index (BMI) for age. Electronic hospital medical records were reviewed to collect clinical data for each patient. All the obtained data were analyzed by the statistics method.

Results

There were 204 patients enrolled in our study, of which 32.4% were diagnosed with malnutrition. We found that BMI, arm muscle circumference, fat mass, and %body fat were lower in the group with poorer nutritional status ($P < 0.05$). Evident differences in the score of the Pediatric Risk of Mortality and the duration of mechanical ventilation (MV) among the three groups with different nutritional statuses were observed ($P < 0.05$). Patients in the severely malnourished group had the longest duration of MV. In the MV groups, there were significant differences ($P < 0.05$) in albumin level, PhA, and extracellular water/total body water (ECW/TBW ratio). The ECW/TBW ratio and the time for PICU stay had a weak degree of correlation (Pearson correlation coefficient = 0.375). PhA showed a weak degree of correlation with the duration time of medical ventilation (coefficient of correlation = 0.398).

Conclusion

BIA can be considered an alternative way to assess nutritional status in critically ill children. ECW/TBW ratio and PhA were correlated with PICU stay and duration time of medical ventilation, respectively.

Introduction

Malnutrition is highly prevalent in critically ill children in the pediatric intensive care unit (PICU). Critically ill children usually experience total body water redistribution, systemic metabolic status changes, and rapid lean body mass loss, thereby leading to their body composition changes dramatically. However, weight loss, body mass index (BMI), and biochemical indicators do not accurately reflect the nutritional status of critically ill children. Nutritional therapy for critically ill children must be based on a precise assessment of the changes in body composition and fluid status. Thus, adopting proper nutritional assessment is significantly important.

Bioelectrical impedance analysis (BIA) has been used to assess body composition by measuring the amount of water in and out of cells and fat and muscle mass. Previous studies have shown that BIA can be useful for assessing the prognosis of critically ill patients [1–3]. Moreover, BIA is a portable, easy-to-use, non-invasive, and low-cost method. For this reason, coupled with children’s comfort and cooperation, BIA is significantly appropriate for children in daily clinical practice.

BIA estimates body composition by measuring the impedance to an applied current while passing through the body. Impedance consists of two components: resistance and reactance. Tissues have different contents of fluid and conducting electrolytes; thus, the resistance of tissues is different. Cell membrane and tissue interfaces can affect capacitive reactance. BIA measurement of fat mass (FM) and fat-free mass (FFM) can reliably reflect body composition and is associated with patient’s nutritional statuses. BIA-derived phase angle (PhA) is calculated using the following equation: . PhA can be used when assessing the integrity of the cellular membrane and when evaluating cell mass and hydration status. In addition, PhA has been a good predictor of morbidity and mortality in different clinical situations. The European Society for Clinical Nutrition and Metabolism recommends PhA as a screening tool to identify patients at risk of deteriorating nutritional status and functionality [4,5], but studies assessing PhA among critically ill children are scarce.

This study aimed to explore the efficiency of BIA measurements for the assessment of nutritional risk and clinical outcomes in critically ill children and demonstrate whether PhA or other BIA-derived indexes were associated with adverse clinical outcomes.

Materials & Methods

Study Population

This study comprised patients admitted to the PICU of Chengdu Women’s and Children’s Central Hospital. This study was conducted between March 2019 and February 2021 and recruited patients aged 1–14 years. The participants underwent BIA within 3 days after admission. The exclusion criteria were as follows: patients with any amputation, with skin injury on the area where the electrodes of the BIA instrument would be placed, those who underwent dialysis 2 h before BIA, those with congenital chromosomal abnormalities and hereditary metabolic diseases, and those with serious errors in their BIA results. The children’s legal guardians provided written informed consent for their children’s participation in the study.

Anthropometric measurement and classification of nutritional status

Anthropometric measurement was performed in the first 24 h of admission. To reduce the possibility of errors, all measurements were performed by a trained PICU physician. Weight was measured using a scale that was calibrated for accuracy before each use. Infants were weighed using a scale accurate to 5 g. Children who could not be weighed standing were held by an adult. The child’s weight was obtained by

subtracting the weight of the adult from the total weight of the child and adult. Children aged 3 years or younger assumed the supine position for the measurement. Length was measured using a pediatric anthropometer with an accuracy of 0.1 cm. In children aged older than 3 years, height was measured using a stadiometer with an accuracy of 0.1 cm. In children whose condition prevented the use of conventional measuring techniques (e.g. patients who were mechanically ventilated or taking vasoactive drugs and above 1 m), the ulna length was measured using a pediatric anthropometer. Height and length prediction was extrapolated by Gauld et al. [6]. Arm muscle circumference (AMC) was measured using a metric tape marked in 0.5-cm increments. Measurements were taken at the midpoint of the distance between the acromion and olecranon with the arm extended along the body.

BMI was calculated using the following equation: $BMI/A = W \text{ (kg)}/H^2 \text{ (m)}$. Nutritional status was classified based on BMI for age using the World Health Organization (WHO) growth charts as the reference. Patients were categorized as the non-malnourished group, moderately malnourished group, and severely malnourished group, defined by weight for age 0 to - 2 standard deviation (SD), -2 to - 3 SD, and less than - 3 SD of the WHO growth charts, respectively.

Demographic, clinical, and biochemical data

Electronic hospital medical records were reviewed to collect data for each patient,

including age, diagnosis, height, weight, Pediatric Critical Illness Score, Pediatric Risk of Mortality (PRISM) score, length of hospital stay, length of PICU stay, duration of mechanical ventilation (MV), and other notable characteristics. Blood was drawn within 24 h of admission. Serum albumin level, total lymphocyte count (TLC), and hemoglobin level were also collected from the electronic medical records.

Bioelectrical impedance analysis data

InBodyS10 (Biospace, Seoul, South Korea) was used for the measurements of medical purpose. Body composition was measured using BIA with the patient in the supine position. The patients' arms were separated from the trunk, and both legs were separated from each other. Subsequently, surface electrodes were placed on the patient's thumbs and middle fingers and two sides of the ankles. The BIA data gathered included intracellular water, extracellular water (ECW) and total body water (TBW), ECM/TBW, body cell mass, bone mineral content, skeletal muscle mass, FM, %body fat (%BF), TBW/FFM, proteins, and minerals. Upon resistance and reactance results, the PhA score was calculated.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences version 20.0 software. Variables are expressed as number (%), mean \pm SD, or median (interquartile range). Continuous variables were compared and analyzed based on the independent sample t-test and analysis of variance. Pearson's correlation analysis was used to evaluate the association between the BIA results and duration of MV, length of ICU stay, and length of hospital stay. *P* value < 0.05 was considered statistically significant.

Results

We enrolled 204 patients. All these patients were divided into three groups according to their BMI. Among them, 138 were non-malnourished, 27 were moderately malnourished, and 39 were severely malnourished. There were significant differences in ages and BMI among the three groups ($P < 0.05$). We also found significant differences in the score of PRISM and the duration of MV in each group ($P < 0.05$). In the severely malnourished group, patients had the longest duration of MV (Table 1). Table 2 provides a comparison of the biochemical, BIA data, and PhA among the three different nutritional statuses. There were no significant differences in all biochemical test results (including albumin, TLC, and hemoglobin), but BMI, AMC, FM, and BF% were lower in the group with poorer nutritional status ($P < 0.05$). PhA showed no significant difference among these three groups. The MV group had significantly lower albumin levels compared with the non-MV group. We also found significant differences ($P < 0.05$) of PhA and ECW/TBW ratio between the two groups (Table 3). Table 4 shows the correlations between the BIA results and duration of MV, length of PICU stay, and length of hospital stay. A weak positive correlation was found between the duration of MV and PhA, the length of PICU stay, and ECM/TBW. The length of hospital stay had no significant correlation with any BIA indicators. The analyses were adjusted for age.

Discussion

Malnutrition is common in critically ill children, with a prevalence rate of 32.4% (66/204) in our study. Compared with critically ill adults, critically ill children are at a higher risk of experiencing malnutrition due to their lower nutritional status when they are admitted in the PICU. Hypermetabolic states and enhanced catabolic processes easily lead to exacerbation of nutritional status during hospitalization [7]. Meanwhile, malnutrition is always associated with an increased morbidity and mortality [8,9]. Thus, early identification of the high risk of malnutrition and proper assessment of nutritional status are crucial to improve the patients' outcome.

Traditional anthropometric measurements might not accurately reflect body composition changes in life-threatening disease states. Overall weight loss or decreased BMI does not differentiate FM from muscle mass. Compared with dual-energy X-ray absorptiometry, BIA can be considered a reliable method for assessing body composition in children [10]. A recent systematic literature review [11] has confirmed that BIA predicted body composition and other body composition tools. Recently, sarcopenia has become an important concern when evaluating patients' nutritional status. Moreover, depleted muscle mass is associated with infectious complications, prolonged duration of MV, longer hospitalization, greater need for rehabilitation care after hospital discharge, and higher mortality [12]. In our study, the malnourished group had longer duration of MV than the normal nutritional status group ($P < 0.05$). As demonstrated by Jaitovich et al. [13] and Weijs et al. [14], low muscle mass is an independent risk factor for mortality in critically ill patients [15]. Thus, early identification of low muscle mass may lead to more timely nutritional support, which may benefit the prognosis of patients. Computed tomography (CT) scan is the gold standard tool used to evaluate sarcopenia. However, the routine use of CT images in detecting low muscle mass in clinical practice is limited by radiation hazard. Therefore, both BIA and mid-upper arm

circumference (MUAC) might be well suited for the routine assessment of muscle mass because they are widely available, non-expensive, and relatively easy to perform. In our study, we found that AMCs significantly changed different nutritional statuses ($P < 0.5$). Chiabi et al. [16] observed that the MUAC was a more sensitive mortality predictor compared with weight-for-length/height z-score in children with severe acute malnutrition. Notably, MUAC measurements are influenced by the variability of observers' measurement technique and cannot discriminate adipose from non-adipose tissue. BIA showed high specificity at detecting low muscle mass in patients [17]. A recent study by Looijaard et al. [18] also showed that BIA and CT identified the same critically ill population with low skeletal muscle area on CT scan. Significant correlations have been detected for different BIA-derived muscle mass equations and CT-derived measurements (correlations ranging between 0.64 and 0.834). However, BIA also has some limitations. BIA measurements may have underestimated the presence of low muscle mass due to abnormal fluid redistribution in critically ill patients [19]. Among younger infants (especially aged less than 6 months), BIA may provide little benefit over anthropometry-based prediction equations.

In this study, lower albumin level, lower PhA values, and high ECW/TBW ratios were observed among patients who needed MVs. Albumin is the most abundant protein in the serum. Leite et al.'s [20] study showed that hypoalbuminemia at PICU admission is associated with a higher 60-day mortality, longer duration of MV, and lower probability of ICU discharge. Our study was consistent to this finding: patients with medical ventilation had lower serum albumin level. Possible causes of decreased serum albumin levels include inflammation and illness, increased vascular permeability, and decreased hepatic synthesis, not necessarily from poor nutrition. We also found that there was no statistical significance among the different nutritional status group. Additionally, the half-life of albumin is approximately 20 days, suggesting that in some cases, even if the blood albumin level is normal, the total body protein reserves have begun to decrease, but the extent of this decline has not yet affected the maintenance of albumin. Consequently, measuring serum albumin may not provide clinicians an accurate picture of the patient's nutritional status [21].

Fluid overload and positive cumulative fluid balance are common in life-threatening disease states and are positively correlated with adverse clinical outcomes [22]. Volume status assessment is significantly important in clinical practice to avoid inappropriate fluid therapy. The current methods used to evaluate fluid status have limitations. Chung et al.'s [23] study showed that BIA and ECW/TBW ratios are useful and convenient tools used to assess the volume status of patients. According to the result of previous studies, the cut-off value for the assessment of edema was 0.39 [24–26]. However, in our study, we measured the ECW/TBW ratio in all patients, and the median ECW/TBW ratio was greater than or equal to 0.39 in the different nutritional status groups. In fact, most of our patients did not display any edema symptoms. We hypothesize that children having higher water content than adults may be associated with a higher ECW/TCW ratio. We also found that the ECW/TCW ratio was higher in the MV group than that in the non-MV group, and the ECW/TBW ratio and the length of PICU stay had a weak degree of correlation (Pearson's correlation coefficient = 0.375). Slobod et al.'s [27] study also showed that a higher ECW/TBW ratio within 24 h of admission was correlated with a longer duration of MV. Therefore, the ECW/TBW ratio can be a good prognostic factor for diseases or as a guide for fluid management in critically ill patients

[28,29]. BIA has intrinsic limitations in its ability to accurately distinguish between intravascular and interstitial volume in the extracellular compartment. Some recent studies have shown that bioelectrical impedance vector analysis, using the resistance and reactance values obtained directly from BIA, could be superior to any other parameter of the BIA for evaluating the hydration of critically ill patients in the ICU [30,31].

BIA-derived PhA reflects the integrity of cell membranes and hydration status and is influenced by acute illness and general health. A low PhA always indicates cell membrane breakdown and decreased ability to store energy and complete metabolic functions [32]. Thus, it has been considered a prognostic, health, functional, and nutrition indicator [33–35]. Some previous studies have shown that PhA is a relatively sensitive indicator for monitoring and evaluating the nutritional status of patients. Sometimes, it is better than anthropometry and blood biochemical analysis [36–40]. However, PhA showed no significant difference among different nutritional status groups in our study. A systematic review has concluded that PhA is not an independent indicator of malnutrition [40] because it is affected by factors, such as age, sex, level of physical activity, fluid status, and body composition [41]. To account for such confounders, the calculation of a standardized PhA (SPhA) was proposed to solve this problem. An SPhA can be calculated as a z-score, which may be based on established population reference values stratified by a combination of age, sex, BMI, or ethnicity [42–44]. This method of reducing bias in BIA parameters in critically ill children requires further validation. Some studies have suggested that PhA revealed a predictive power for mortality than severity scoring systems in an ICU [45]. In our study, we found that patients who received MV had lower PhA (mean, 2.5 [SD 0.3]). Moreover, it showed a weak degree of correlation with the duration of MV (coefficient of correlation = 0.398). Another study has reported similar findings. Zamberlan's study noted that [46] patients with $\text{PhA} > 2.8^\circ$ compared with patients with $\text{PhA} \leq 2.8^\circ$ ($P < .0001$) showed higher survival rate, and children with lower PhA values were more likely to remain in the PICU. Stapel's [47] study found that a $\text{PA} < 4.8^\circ$ at ICU admission was an independent predictor of 90-day mortality (adjusted odds ratio = 3.65, confidence interval: 1.34–9.93, $P = 0.011$). Compared with critically ill adults, critically ill children had lower PhA. More studies are needed to confirm this finding. Until now, there is no clear PhA reference cut-off values, and it is difficult to associate it with disease and nutritional therapy. All these factors could affect the utility of BIA technology for pediatric clinical use.

Conclusion

Overall, BIA can be considered an alternative way to assess the nutritional status of critically ill children. PhA has a limitation in predicting adverse clinical outcomes, but has a potential role in determining the severity of illness in the PICU. Thus, more high-quality studies are needed to obtain more integrated and clear conclusions.

Abbreviations

AMC: Arm muscle circumference

BIA: Bioelectrical impedance analysis

BF: Body fat

BMI: Body mass index

BCM: Body cell mass

BMC: Bone mineral content

ECW: Extracellular water

FM: Fat mass; BF: body fat;

FM: Fat mass

FFM: Fat-free mass

ICW: Intracellular water;

LOS: Length of stay

MV: Mechanical ventilation

PICU: Pediatric intensive care unit

PhA: Phase angle

PICS: Pediatric Critical Illness Score

PRISM: Pediatric Risk of Mortality

SMM: Skeletal muscle mass

TLC: Total [lymphocyte count](#)

TBW: Total body water

TBW/FFM: Total body water/fat free mass

WHO: World Health Organization

Declarations

Author Contribution

Guoying Zhang: conception and design of the research; **Zihong Xiong, Ke Chen, Guoying Zhang:** the acquisition of the data and the analysis of the data; **Zihong Xiong, Xue-Mei Zheng:** Writing–Original Draft; **Zihong Xiong, Yi Qu, Meng-Jun Wu:** Writing–Review and Editing.

Conflict of Interest

Conflict of Interest All authors declare that they have no conflict of interests.

Availability of data and materials

The datasets used and analyzed during the current study are not publicly available due to limitations of ethical approval involving the patient data and anonymity but are available from the corresponding author on reasonable request.

Funding

This work was supported by the National Natural Science Foundation of China (81771634, 81971428), Grants from Science and Technology Bureau of Sichuan Province (2021YJ0017), Fundamental Research Funds for the Central University (SCU2020D006).

Acknowledgements

None.

Ethics approval and consent to participate

This retrospective study is approved by the Ethics Committee of Chengdu Women’s and Children’s Central Hospital, School of Medicine, UESTC. All methods were performed in accordance with the relevant guidelines and regulations. All participants gave their written consent to participate.

Consent for Publication

Not applicable.

References

- 1.Lee YH, Lee JD, Kang DR, Hong J, Lee JM. Bioelectrical impedance analysis values as markers to predict severity in critically ill patients. *J Crit Care.* 2017;40:103-107. doi:[10.1016/j.jcrc.2017.03.013](https://doi.org/10.1016/j.jcrc.2017.03.013)
- 2.Basso F, Berdin G, Virzì GM, et al. Fluid management in the intensive care unit: bioelectrical impedance vector analysis as a tool to assess hydration status and optimal fluid balance in critically ill patients. *BloodPurif.* 2013;36(3-4):192-199. doi:[10.1159/000356366](https://doi.org/10.1159/000356366)
- 3.Basso F, Berdin G, Virzì GM, et al. Fluid management in the intensive care unit: bioelectrical impedance vector analysis as a tool to assess hydration status and optimal fluid balance in critically ill

patients. *Blood Purif*. 2013;36(3-4):192-199. doi:[10.1159/000356366](https://doi.org/10.1159/000356366)

4. Kyle UG, Bosaeus I, De Lorenzo AD, et al. Bioelectrical impedance analysis—part I: review of principles and methods. *Clin Nutr*. 2004;23(5):1226-1243. doi:[10.1016/j.clnu.2004.06.004](https://doi.org/10.1016/j.clnu.2004.06.004)

5. Kyle UG, Bosaeus I, De Lorenzo AD, et al. Bioelectrical impedance analysis-part II: utilization in clinical practice. *Clin Nutr*. 2004;23(6):1430-1453. doi:[10.1016/j.clnu.2004.09.012](https://doi.org/10.1016/j.clnu.2004.09.012)

6. Gauld LM, Kappers J, Carlin JB, Robertson CF. Height prediction from ulna length. *Dev Med Child Neurol*. 2004;46(7):475-480. doi:[10.1017/s0012162204000787](https://doi.org/10.1017/s0012162204000787)

7. Valla FV, Baudin F, Gaillard Le Roux B, et al. Nutritional Status Deterioration Occurs Frequently During Children's ICU Stay. *Pediatr Crit Care Med*. 2019 Aug;20(8):714-721. doi: [10.1097/PCC.0000000000001979](https://doi.org/10.1097/PCC.0000000000001979). PMID: [31162370](https://pubmed.ncbi.nlm.nih.gov/31162370/).

8. Bechard LJ, Duggan C, Touger-Decker R, et al: Nutritional status based on body mass index is associated with morbidity and mortality in mechanically ventilated critically ill children in the PICU. *Crit Care Med* 2016; 44:1530–1537

9. Ward SL, Gildengorin V, Valentine SL, et al: Impact of weight extremes on clinical outcomes in pediatric acute respiratory distress syndrome. *Crit Care Med* 2016; 44:2052–2059

10. Okasora K, Takaya R, Tokuda M, et al. Comparison of bioelectrical impedance analysis and dual energy X-ray absorptiometry for assessment of body composition in children. *Pediatr Int*. 1999;41(2):121-125. doi:[10.1046/j.1442-200x.1999.4121048.x](https://doi.org/10.1046/j.1442-200x.1999.4121048.x)

11. Lyons-Reid J, Derraik JGB, Ward LC, Tint MT, Kenealy T, Cutfield WS. Bioelectrical impedance analysis for assessment of body composition in infants and young children-A systematic literature review. *Clin Obes*. 2021;11(3):e12441. doi:[10.1111/cob.12441](https://doi.org/10.1111/cob.12441)

12. Peterson SJ, Braunschweig CA. Prevalence of Sarcopenia and Associated Outcomes in the Clinical Setting. *Nutr Clin Pract*. 2016;31(1):40-48. doi:[10.1177/0884533615622537](https://doi.org/10.1177/0884533615622537)

13. Jaitovich A, Khan MMHS, Itty R, Chieng HC, Dumas CL, Nadendla P, Fantauzzi JP, Yucel RM, Feustel PJ, Judson MA. ICU Admission Muscle and Fat Mass, Survival, and Disability at Discharge: A Prospective Cohort Study. *Chest*. 2019 Feb;155(2):322-330. doi: [10.1016/j.chest.2018.10.023](https://doi.org/10.1016/j.chest.2018.10.023). Epub 2018 Oct 28. PMID: [30392790](https://pubmed.ncbi.nlm.nih.gov/30392790/); PMCID: [PMC6363817](https://pubmed.ncbi.nlm.nih.gov/PMC6363817/).

14. Weijs PJ, Looijaard WG, Dekker IM, et al. Low skeletal muscle area is a risk factor for mortality in mechanically ventilated critically ill patients. *Crit Care*. 2014;18(2):R12. Published 2014 Jan 13. doi:[10.1186/cc13189](https://doi.org/10.1186/cc13189)

15. Zhang XM, Chen D, Xie XH, Zhang JE, Zeng Y, Cheng AS. Sarcopenia as a predictor of mortality among the critically ill in an intensive care unit: a systematic review and meta-analysis. *BMC Geriatr*.

2021;21(1):339. Published 2021 Jun 2. doi:[10.1186/s12877-021-02276-w](https://doi.org/10.1186/s12877-021-02276-w)

16. Chiabi A, Mbanga C, Mah E, et al. Weight-for-Height Z Score and Mid-Upper Arm Circumference as Predictors of Mortality in Children with Severe Acute Malnutrition. *J Trop Pediatr*. 2017;63(4):260-266. doi:[10.1093/tropej/fmw083](https://doi.org/10.1093/tropej/fmw083)

17. Gort-van Dijk D, Weerink LBM, Milovanovic M, et al. Bioelectrical Impedance Analysis and Mid-Upper Arm Muscle Circumference Can Be Used to Detect Low Muscle Mass in Clinical Practice. *Nutrients*. 2021;13(7):2350. Published 2021 Jul 9. doi:[10.3390/nu13072350](https://doi.org/10.3390/nu13072350)

18. Looijaard WGPM, Stapel SN, Dekker IM, et al. Identifying critically ill patients with low muscle mass: Agreement between bioelectrical impedance analysis and computed tomography. *Clin Nutr*. 2020;39(6):1809-1817. doi:[10.1016/j.clnu.2019.07.020](https://doi.org/10.1016/j.clnu.2019.07.020)

19. Mulasi U, Kuchnia AJ, Cole AJ, Earthman CP. Bioimpedance at the bedside: current applications, limitations, and opportunities [published correction appears in *Nutr Clin Pract*. 2015 Aug;30(4):589]. *Nutr Clin Pract*. 2015;30(2):180-193. doi:[10.1177/0884533614568155](https://doi.org/10.1177/0884533614568155)

20. Leite HP, Rodrigues da Silva AV, de Oliveira Iglesias SB, Koch Nogueira PC. Serum Albumin Is an Independent Predictor of Clinical Outcomes in Critically Ill Children. *Pediatr Crit Care Med*. 2016;17(2):e50-e57. doi:[10.1097/PCC.0000000000000596](https://doi.org/10.1097/PCC.0000000000000596)

21. Smith SH. Using albumin and prealbumin to assess nutritional status. *Nursing*. 2017;47(4):65-66. doi:[10.1097/01.NURSE.0000511805.83334.df](https://doi.org/10.1097/01.NURSE.0000511805.83334.df)

22. Messmer AS, Zingg C, Müller M, Gerber JL, Schefold JC, Pfortmueller CA. Fluid Overload and Mortality in Adult Critical Care Patients-A Systematic Review and Meta-Analysis of Observational Studies. *Crit Care Med*. 2020;48(12):1862-1870. doi:[10.1097/CCM.0000000000004617](https://doi.org/10.1097/CCM.0000000000004617)

23. Chung YJ, Kim EY. Usefulness of bioelectrical impedance analysis and ECW ratio as a guidance for fluid management in critically ill patients after operation. *Sci Rep*. 2021;11(1):12168. Published 2021 Jun 9. doi:[10.1038/s41598-021-91819-7](https://doi.org/10.1038/s41598-021-91819-7)

24. Noda Y, Suzuki H, Kanai T, et al. The Association Between Extracellular Water-to-Total Body Water Ratio and Therapeutic Durability for Advanced Lung Cancer. *Anticancer Res*. 2020;40(7):3931-3937. doi:[10.21873/anticancer.14384](https://doi.org/10.21873/anticancer.14384)

25. Nishikawa H, Yoh K, Enomoto H, et al. Extracellular Water to Total Body Water Ratio in Viral Liver Diseases: A Study Using Bioimpedance Analysis. *Nutrients*. 2018;10(8):1072. Published 2018 Aug 12. doi:[10.3390/nu10081072](https://doi.org/10.3390/nu10081072)

26. Park KH, Shin JH, Hwang JH, Kim SH. Utility of Volume Assessment Using Bioelectrical Impedance Analysis in Critically Ill Patients Receiving Continuous Renal Replacement Therapy: A Prospective Observational Study. *Korean J Crit Care Med*. 2017;32(3):256-264. doi:[10.4266/kjccm.2017.00136](https://doi.org/10.4266/kjccm.2017.00136)

- 27.Slobod D, Yao H, Mardini J, et al. Bioimpedance-measured volume overload predicts longer duration of mechanical ventilation in intensive care unit patients. Une surcharge volémique telle que mesurée par bioimpédance prédit une durée prolongée de la ventilation mécanique chez les patients à l'unité de soins intensifs. *CanJAnaesth*. 2019;66(12):1458-1463. doi:[10.1007/s12630-019-01450-4](https://doi.org/10.1007/s12630-019-01450-4)
- 28.Chung YJ, Kim EY. Usefulness of bioelectrical impedance analysis and ECW ratio as a guidance for fluid management in critically ill patients after operation. *Sci Rep*. 2021;11(1):12168. Published 2021 Jun 9. doi:[10.1038/s41598-021-91819-7](https://doi.org/10.1038/s41598-021-91819-7)
- 29.Razzera EL, Marcadenti A, Rovedder SW, Alves FD, Fink JDS, Silva FM. Parameters of Bioelectrical Impedance Are Good Predictors of Nutrition Risk, Length of Stay, and Mortality in Critically Ill Patients: A Prospective Cohort Study. *JPENJParenterEnteralNutr*. 2020;44(5):849-854. doi:[10.1002/jpen.1694](https://doi.org/10.1002/jpen.1694)
- 30.Kammar-García A, Castillo-Martínez L, Villanueva-Juárez JL, et al. Comparison of Bioelectrical Impedance Analysis Parameters for the Detection of Fluid Overload in the Prediction of Mortality in Patients Admitted at the Emergency Department. *JPENJParenterEnteralNutr*. 2021;45(2):414-422. doi:[10.1002/jpen.1848](https://doi.org/10.1002/jpen.1848)
- 31.Hise ACDR, Gonzalez MC. Assessment of hydration status using bioelectrical impedance vector analysis in critical patients with acute kidney injury. *ClinNutr*. 2018;37(2):695-700. doi:[10.1016/j.clnu.2017.02.016](https://doi.org/10.1016/j.clnu.2017.02.016)
- 32.Norman K, Stobäus N, Pirlich M, Bösby-Westphal A. Bioelectrical phase angle and impedance vector analysis—clinical relevance and applicability of impedance parameters. *ClinNutr*. 2012;31(6):854-861. doi:[10.1016/j.clnu.2012.05.008](https://doi.org/10.1016/j.clnu.2012.05.008)
- 33.Visser M, van Venrooij LM, Wanders DC, et al. The bioelectrical impedance phase angle as an indicator of undernutrition and adverse clinical outcome in cardiac surgical patients. *ClinNutr*. 2012;31(6):981-986. doi:[10.1016/j.clnu.2012.05.002](https://doi.org/10.1016/j.clnu.2012.05.002)
- 34.Kyle UG, Bosaeus I, De Lorenzo AD, et al. Bioelectrical impedance analysis-part II: utilization in clinical practice. *ClinNutr*. 2004;23(6):1430-1453. doi:[10.1016/j.clnu.2004.09.012](https://doi.org/10.1016/j.clnu.2004.09.012)
- 35.Lee YH, Lee JD, Kang DR, Hong J, Lee JM. Bioelectrical impedance analysis values as markers to predict severity in critically ill patients. *J Crit Care*. 2017 Aug;40:103-107. doi: [10.1016/j.jcrc.2017.03.013](https://doi.org/10.1016/j.jcrc.2017.03.013). Epub 2017 Mar 22. PMID: [28380407](https://pubmed.ncbi.nlm.nih.gov/28380407/).
- 36.Bonaccorsi G, Baggiani L, Bassetti A, et al. Body composition assessment in a sample of eight-year-old children. *Nutrition*. 2009;25(10):1020-1028. doi:[10.1016/j.nut.2009.01.016](https://doi.org/10.1016/j.nut.2009.01.016)
- 37.Norman K, Wirth R, Neubauer M, Eckardt R, Stobäus N. The bioimpedance phase angle predicts low muscle strength, impaired quality of life, and increased mortality in old patients with cancer. *JAmMedDirAssoc*. 2015;16(2):173.e17-173.e1.73E22. doi:[10.1016/j.jamda.2014.10.024](https://doi.org/10.1016/j.jamda.2014.10.024)

38. Beberashvili I, Azar A, Sinuani I, et al. Bioimpedance phase angle predicts muscle function, quality of life and clinical outcome in maintenance hemodialysis patients. *EurJClinNutr*. 2014;68(6):683-689. doi:[10.1038/ejcn.2014.67](https://doi.org/10.1038/ejcn.2014.67)
39. Hui D, Bansal S, Morgado M, Dev R, Chisholm G, Bruera E. Phase angle for prognostication of survival in patients with advanced cancer: preliminary findings. *Cancer*. 2014;120(14):2207-2214. doi:[10.1002/cncr.28624](https://doi.org/10.1002/cncr.28624)
40. Rinaldi S, Gilliland J, O'Connor C, Chesworth B, Madill J. Is phase angle an appropriate indicator of malnutrition in different disease states? A systematic review. *Clin Nutr ESPEN*. 2019;29:1-14. doi:[10.1016/j.clnesp.2018.10.010](https://doi.org/10.1016/j.clnesp.2018.10.010)
41. Norman K, Stobäus N, Pirlich M, Bosity-Westphal A. Bioelectrical phase angle and impedance vector analysis—clinical relevance and applicability of impedance parameters. *Clin Nutr*. 2012;31(6):854-861. doi:[10.1016/j.clnu.2012.05.008](https://doi.org/10.1016/j.clnu.2012.05.008)
42. Bosity-Westphal A, Danielzik S, Dörhöfer RP, Later W, Wiese S, Müller MJ. Phase angle from bioelectrical impedance analysis: population reference values by age, sex, and body mass index. *JPENJ Parenter Enteral Nutr*. 2006;30(4):309-316. doi:[10.1177/0148607106030004309](https://doi.org/10.1177/0148607106030004309)
43. Norman K, Stobäus N, Zocher D, et al. Cutoff percentiles of bioelectrical phase angle predict functionality, quality of life, and mortality in patients with cancer. *AmJClinNutr*. 2010;92(3):612-619. doi:[10.3945/ajcn.2010.29215](https://doi.org/10.3945/ajcn.2010.29215)
44. Barbosa-Silva MC, Barros AJ, Wang J, Heymsfield SB, Pierson RN Jr. Bioelectrical impedance analysis: population reference values for phase angle by age and sex. *AmJClinNutr*. 2005;82(1):49-52. doi:[10.1093/ajcn.82.1.49](https://doi.org/10.1093/ajcn.82.1.49)
45. Azevedo ZMA, Santos Junior BD, Ramos EG, et al. The importance of bioelectrical impedance in the critical pediatric patient. *Clin Nutr*. 2020;39(4):1188-1194. doi:[10.1016/j.clnu.2019.05.005](https://doi.org/10.1016/j.clnu.2019.05.005)
46. Zamberlan P, Feferbaum R Associate Professor of Pediatrics, Doria Filho U, Brunow de Carvalho W Full Professor of Pediatrics, Figueiredo Delgado A Associate Professor of Pediatrics. Bioelectrical Impedance Phase Angle and Morbidity and Mortality in Critically Ill Children [published correction appears in *Nutr Clin Pract*. 2020 Apr;35(2):366]. *Nutr Clin Pract*. 2019;34(1):163-171. doi:[10.1002/ncp.10201](https://doi.org/10.1002/ncp.10201)
47. Stapel SN, Looijaard WGPM, Dekker IM, Girbes ARJ, Weijs PJM, Oudemans-van Straaten HM. Bioelectrical impedance analysis-derived phase angle at admission as a predictor of 90-day mortality in intensive care patients. *EurJClinNutr*. 2018;72(7):1019-1025. doi:[10.1038/s41430-018-0167-1](https://doi.org/10.1038/s41430-018-0167-1)

Tables

Table 1. Comparison of general characteristics, clinical outcomes among the different nutrition status groups (n=204)

Variables	Non-malnourished (n=138)	Moderately malnourished (n=27)	Severely malnourished (n=39)	P value
Age [years]	1.90(1.10-4.38)	2.40(1.53-5.30)	4.90(1.70-10.00)	0.031*
Male Sex(%)	73.50%	71.40%	63.20%	0.677
Length or Height [cm]	87.50(78.00-107.00)	94.50(78.25-114.25)	115.00(82.00-132.00)	0.142
Weight [Kg]	12.50(10.30-16.00)	11.25(8.88-16.50)	14.00(8.50-22.50)	0.583
BMI [Kg/m ²]	16.52±2.09	13.76±1.42	12.61±1.62	<0.01*
PICS score	86.00(76.00-88.00)	86.00(82.00-89.00)	86.00(80.00-92.00)	0.514
PRISM []	8.48±3.94	10.54±4.74	11.43±8.70	0.476
MV [n(%)]	24(35.3)	4(28.6)	9(47.4)	0.500
Duration of MV, days	5.00(3.00-7.00)	5.00(4.00-14.00)	11.50(6.00-16.00)	0.015*
Mortality PICU, n(%)	1.50%	0	0	0.788
LOS in PICU, days	7.00(6.00-10.00)	8.00(3.00-11.75)	11.00(2.75-15.00)	0.856
LOS in hospital, days	13.00(9.00-27.75)	14.00(10.50-22.00)	14.00(10.00-22.00)	0.893

**P<0.05. Values shown are mean±SD (standard deviation) [number (percentage) or median [IQR].

BMI: body mass index; PICS: pediatric critical illness score; PRISM: pediatric risk of mortality; LOS: length of stay; MV: mechanical ventilation; PICU: pediatric intensive care unit.

Table 2 comparison of the biochemical, phase angle and BIA data among the three different nutritional statuses.

*P<0.05. Values shown are mean±SD(standard deviation) [number(percentage) or median [IQR].BMI: body mass index;AMC:arm muscle circumference;TLC:total lymphocyte count; BCM: Body cell mass; BMC: bone mineral content; SMM: skeletal muscle mass; FM: fat mass; BF: body fat; ICW: intracellular water; ECW: extracellular water; TBW: total body water; TBW/FFM:total body water/fat free mass

Variables	Non-malnourished (n=69)	Moderately malnourish (n=14)	Severely malnourished (n=19)	P value
BMI,kg/m ²	16.52±2.09	13.76±1.42	12.61±1.62	<0.05*
AMC,cm	15.10(14.60-15.95)	14.20(13.85-14.98)	13.80(13.10-15.70)	<0.05*
Albumin ,g/dL	40.70(34.35-44.18)	40.10(34.98-43.08)	34.70(31.10-40.20)	0.116
TLC,cell/mm ³	2.23(1.40-3.36)	2.13(1.07-4.41)	1.52(0.77-2.61)	0.286
Hemoglobin,g/dL	111.00(98.2-120.7)	120.50(92.0-127.5)	119.00(100.0-128.0)	0.249
PhA	3.12±0.4	2.65±0.2	2.38±0.2	0.415
BCM,kg	6.10(4.75-9.03)	6.80(4.90-9.63)	8.60(5.00-11.20)	0.637
BMC, kg	0.45(0.27-0.84)	0.63(0.39-1.28)	0.93(0.46-1.39)	0.035
SMM,kg	3.70(2.30-6.10)	3.40(2.43-6.83)	3.80(2.60-8.20)	0.735
FM, kg	2.50(1.70-4.00)	1.35(0.58-2.80)	0.70(0.30-1.50)	<0.05*
%BF	23.50(13.00-31.30)	15.05(5.63-20.70)	6.00(3.00-9.20)	<0.05*
Protein,kg	1.90(1.40-2.70)	1.90(1.48-2.93)	1.90(1.50-3.40)	0.786
Mineral,kg	0.60(0.38-1.03)	0.70(0.40-1.43)	1.17(0.57-1.59)	0.100
ICW	4.30(3.33-6.35)	4.75(3.43-6.73)	6.00(3.50-7.80)	0.648
ECW	2.90(2.33-4.08)	3.15(2.45-4.20)	3.90(2.50-5.80)	0.601
TBW	7.20(5.63-10.30)	7.90(5.88-10.75)	9.90(6.00-13.60)	0.592
ECW/TBW	0.39(0.38-0.41)	0.41(0.39-0.42)	0.40(0.37-0.42)	0.564
%TBW/FFM	74.74±1.56	73.54±1.53	73.45±1.88	0.002*

Table 3. Comparison of biochemical data, and BIA data between non-MV group and MV group

Variables	Non-MV(n=64)	MV(N=37)	p value
Albumin,g/dL	38.9±6.4	25.9±3.1	0.027*
TLC,cell/mm ³	2.10(1.27-3.23)	1.87(1.28-3.14)	0.097
Hemoglobin,g/dL	115.00(100.75-122.00)	111.00(94.00-121.50)	0.249
PhA	3.4±0.5	2.5±0.3	0.032*
BCM,kg	6.60(5.00-9.25)	6.00(4.70-9.85)	0.746
BMC,kg	0.55(0.35-1.08)	0.46(0.30-0.94)	0.476
SMM	4.00(2.53-6.05)	3.30(2.30-7.08)	0.841
FM	2.10(1.40-3.63)	2.10(0.60-3.08)	0.259
%BF	16.90(8.30-27.20)	15.95(3.00-27.60)	0.343
Protein,kg	2.00(1.50-2.68)	1.85(1.40-3.00)	0.877
Mineral,kg	0.63(0.40-1.17)	0.60(-0.38-1.08)	0.534
ICW	4.60(3.50-6.48)	4.20(3.30-6.90)	0.775
ECW	3.00(2.43-4.18)	2.90(2.25-4.30)	0.727
TBW	7.60(5.85-10.65)	7.10(5.55-11.20)	0.751
ECW/TBW	0.38(0.36-0.43)	0.45(0.38-0.47)	0.038*
%TBW/FFM	74.21±1.77	74.55±1.60	0.339

* $P < 0.05$. BMI: body mass index; AMC: arm muscle circumference; TLC: total lymphocyte

count; BCM: body cell mass; BMC: bone mineral content; SMM: skeletal muscle mass; FM: fat mass; BF: body fat; ICW: intracellular water; ECW: extracellular water; TBW: total body water; TBW/FFM: total body water/fat free mass; MV: medical ventilation

Table 4. Pearson's correlation coefficients between BIA data and clinical outcomes

Variables	Duration of MV	LOS in PICU	LOS in hospital
PhA	0.398*	0.155	0.118
BCM,kg	-0.064	-0.118	0.136
SMM	-0.075	-0.120	0.136
FM	0.117	-0.112	0.011
%BF	0.117	-0.054	-0.047
Protein,kg	-0.073	-0.120	0.139
Mineral,kg	0.073	-0.156	0.186
ICW	-0.068	-0.121	0.134
ECW	-0.066	-0.116	0.169
TBW	-0.067	-0.120	0.149
ECW/TBW	0.052	0.375*	0.140

* $P < 0.05$. BCM: body cell mass; BMC: bone mineral content; SMM: skeletal muscle mass; FM: fat mass; BF: Body fat; ICW: intracellular water; ECW: extracellular water; TBW: total body water; TBW/FFM:total body water/fat free mass;MV: medical ventilation; LOS: length of stay; PICU: paediatric intensive care unit.