Malnutrition assessed by phase angle determines outcomes in low-risk cardiac surgery patients

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S U M M A R Y

Background & aims: Phase angle (PA), which is obtained from bioelectrical impedance analysis (BIA), is a non-invasive method for measuring altered electrical properties of biological tissues. It has been recognised as an objective prognostic marker of disease severity and frailty. The aim of this study is to determine whether PA is a marker of malnutrition and postoperative morbidity in low operative risk patients undergoing cardiac surgery.

Methods: A prospective study was conducted in a tertiary hospital. The nutritional state of the cardiac surgery patients was evaluated using BIA the day before the scheduled surgery. After applying selection criteria, 342 low operative risk patients were selected and classified into two groups in accordance with the PA value: a low PA group and a normal PA group. The correlation between low PA and low fat-free mass index (FFMI), a marker of malnutrition, was assessed. Associations between low PA and adverse postoperative outcomes, defined by the Society of Thoracic Surgeons postoperative risk evaluation model, were analysed. The impact of low PA on length of stay in an ICU and hospital was evaluated.

Results: Low PA was detected in 61 (17.8%) patients in the selected group, which consisted of low operative risk patients with a median Euroscore II value of 1.46 (IQR: 0.97–2.03) and was associated with FFMI with Pearson’s R of 0.515 (p < 0.001). Low PA was associated with higher rates (13 [21.3%] vs. 30 [10.7%], p = 0.023) and risk of postoperative morbidity in univariate regression analysis (OR = 2.27, CI 95% = 1.10–4.66, p = 0.026). Furthermore, low PA persisted as an independent factor in multivariate regression analysis (OR = 2.50, CI 95% 1.18–5.29, p = 0.016) adjusted for preoperative risk factors of malnourishment. Evaluation of hospitalisation length revealed a tendency of a prolonged hospitalisation (>14 days) rate (31 [50.8%] vs. 105 [37.8%], p = 0.063) in the group with low PA.

Conclusion: A low preoperative PA is an indicator of malnutrition and determines adverse outcomes after cardiac surgery. Further research is needed to evaluate clinical applications of the PA, such as a more accurate identification of malnourished cardiac surgery patients.

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1. Background

According to recent reports, nutritional deficiency is a common condition in cardiac surgery patients, with an incidence ranging from 1.2% to 46.4% [1–8]. The prevalence of malnutrition depends on the criteria used to determine it. Extensive research has been done in order to obtain diagnostic criteria of malnutrition. Weight loss, low body mass index (BMI), and reduced food intake are known screening markers of malnutrition [9]. However, it is obvious that in specific patient groups, these conventional methods of nutritional state evaluation might not be accurate enough in detecting malnutrition [1,10,11]. This poses a problem to diagnose malnourished patients using conventional methods, which are based on the decrease of body weight or use questions about unintended weight loss, which patients cannot always objectively answer [12,13]. Hence, malnutrition is often underdiagnosed and not treated accordingly. This results in a higher risk of postoperative infectious and non-infectious complications, as well as higher mortality rates, prolonged length of stay in the hospital and intensive care unit (ICU), and consequently poorer quality of life [2,8]. Therefore, an accurate detection of preoperative malnutrition is crucially important in predicting outcomes after cardiac surgery.

In this study, we used biochemical impedance analysis (BIA) to evaluate the nutritional status of the patients. BIA is a quick, easy-to-use, non-invasive, and easily applicable method of body composition and cell health evaluation [14]. Subtle alterations in the cellular membrane and fluid imbalance can be detected earlier using BIA than using anthropometric measurements. We hypothesise that, by using a phase angle (PA) value derived from the BIA, we can objectively differentiate malnourished patients from well-nourished patients [5,15,16]. Therefore, it is a way of detecting malnutrition at its first stages.

Moreover, PA value is associated with worse clinical outcomes in some chronic diseases: chronic obstructive pulmonary disease, liver failure, and haematology-oncology diseases [17–19]. However, only a couple of studies have been conducted with cardiac surgery patients [5,8], but none of them with low operative risk cardiac surgery patients. Thus, we aim to determine whether PA is a marker of malnutrition and postoperative morbidity in low operative risk patients undergoing cardiac surgery.

2. Materials and methods

2.1. Patients

A prospective cohort study was conducted in a tertiary referral university hospital between March 2013 and March 2014. Data of patients undergoing elective cardiac surgery were gathered. This study was approved by the research ethics committee of Vilnius University, and informed consent was obtained from the patients.

Selection of the patients was conducted using inclusion and exclusion criteria to design a low preoperative risk patient cohort. The inclusion criteria were as follows: elective pump cardiac surgery, type of surgery (coronary artery bypass grafting surgery [CABG]), valve surgery (aortic valve replacement, mitral valve replacement, mitral valve repair), combined surgery (CABG and valve surgery), age 20–79 years, and left ventricle ejection fraction (LVEF) more than 40%. The exclusion criteria were as follows: complicated intraoperative course; diagnosis of infectious endocarditis; severe pulmonary hypertension (>55 mmHg); use of preoperative intra-aortic balloon pump (IABP); and postoperative low cardiac output syndrome, defined as at least one of the following: failure to wean from cardiopulmonary bypass (CPB), intraoperative insertion of IABP, and infusion of two or more inotropic medications with a cumulative dose of 0.2 mcg/kg/min of two or more inotropic drugs. Standard anaesthesia and surgery techniques were applied to all study patients.

2.2. Evaluation of nutritional status

The nutritional status of the patients was evaluated one day prior to surgery using BIA, which was performed with the Inbody S10 device (Biospace, Seoul, Korea). Prior to analysis, the patients assumed a lying posture for 10 min. During the analysis, the patients were in a supine position with arms abducted 15° from the trunk and legs spread apart at shoulder width. The analysis was performed using eight electrodes placed on both hands (on thumb and middle finger) and between the patient’s anklebones and heels.

BIA provides resistance and reactance measured using different frequency currents, which provide estimations of the fat mass, fat-free mass, total body water, and intracellular body water of the patient [14]. The raw data of resistance and reactance are used to calculate the PA. This is done using the measurements of the 50 kHz current.

The cut-off value of the PA was determined using population reference values [20]. After stratifying the PA measurements by age and gender, the patients were classified into low and normal PA groups in accordance with the 15th percentile value (Fig. 1). The determination of the cut-off value is further described in the statistical analysis section. The relationship of PA and FFMI was evaluated. The rates of the low PA and low FFMI, well-established markers of malnutrition, were calculated. To do that, the cut-off points of low FFMI suggested by the European Society of Clinical Nutrition and Metabolism (ESPEN) diagnostic criteria for malnutrition (FFMI 15 kg/m² in women and 17 kg/m² in men) were used [12].

2.3. Postoperative outcome

The patients were followed for one month after surgery, focusing on short-term outcomes defined by the Society of Thoracic Surgeons (STS) risk evaluation model. This model includes nine endpoints, strictly objectifying the possible clinical outcome, and is primarily used to adjust for case mix when comparing outcomes across institutions with different patient populations [21,22].

Median postoperative hospitalisation and length of stay in an ICU were analysed. The data concerning these outcomes were collected prospectively.

2.4. Statistical analysis

Descriptive statistics were used to describe baseline characteristics.

The normality of the distribution was assessed using the Kolmogorov–Smirnov test. Student-t and Mann–Whitney U tests were used to evaluate the differences between the two independent normally and non-normally distributed data sets, respectively. The differences between the two independent qualitative data groups were evaluated by Chi-squared test.

To determine the PA cut-off value, which best discriminates the malnourished patients and postoperative morbidity groups, patients were split into subgroups by age and gender and categorised as being below the 45th through 5th percentiles using the reference values of a healthy population. These groups were further included in a univariate logistic regression model to determine their ability to predict STS morbidity. In this analysis, the patient group below the 15th percentile proved to be at a higher risk of postoperative STS morbidity and was classified as the low PA group.

Furthermore, univariate and multivariate logistic regression models were used to evaluate the potential risk factors for STS. Factors found to be significant in the univariate logistic regression
analysis were entered into a multivariate logistic regression model with a forward model selection process.

A Pearson correlation analysis was used to evaluate the FFMI–PA relationship.

A two-tailed p-value less than 0.05 was considered to be significant. Statistical analysis was performed using Statistical Analysis System (SAS) package version 9.2 and statistical tools package SPSS v21.

3. Results

3.1. Baseline characteristics

During the study period, 342 patients met the inclusion and exclusion criteria. The selected population consisted of low operative risk patients with a low value of Euroscore II.

The majority of the patients were men. The median age of the study group was 65 years. Two thirds of the patients had CABG surgery, and the rest had valve or combined surgery. The most common comorbidities in the study population were essential hypertension, peripheral artery disease, and diabetes. Baseline characteristics of these patients are presented in Table 1.

The low PA group consisted of 61 (17.8%) patients. There was a difference of low PA distribution within the genders, with a higher rate of low PA within women than within men (30 [25.6%] vs. 31 [13.8%] \( p = 0.011 \)), respectively. There were no other statistical differences between the low and normal PA groups regarding comorbidities and preoperative and operative characteristics.

3.2. Correlation between PA and FFMI

A positive correlation between values of PA and FFMI (R = 0.515, \( p < 0.001 \)) was determined (Fig. 2). After PA and FFMI categorisation, the rate of low PA was two times higher than the rate of low FFMI.

3.3. Low PA in relation to clinical outcomes

The rate of postoperative morbidity was 43 (12.6%) in the study cohort. The prevalence of postoperative morbidity was two times higher in the low PA group than in the normal PA group (13 [21.3%] vs. 30 [10.7%], \( p = 0.023 \), respectively). Low PA, CPB time, mitral valve repair, and combined type of surgery were found to be predictors of postoperative STS morbidity in the univariate analysis. Mitral valve repair, combined type of surgery, and low PA persisted as independent predictive factors for STS morbidity in the multivariate regression model (Table 2).

Evaluation of hospitalisation length showed a tendency of prolonged postoperative hospitalisation (>14 days) rate (31 [50.8%] vs. 105 [37.8%], \( p = 0.063 \)) in the group with low PA. Further analysis of hospitalisation lengths revealed statistically significant differences in total time spent in the hospital postoperatively (median [IQR]: 14 [11–15] vs. 12 [11–14], \( p = 0.036 \)) but no difference in the length of stay in the ICU (median [IQR]: 2 [2–4] vs. 2 [1–3], \( p = 0.106 \)).

4. Discussion

Our data confirm the hypothesis that a preoperative PA value derived from BIA can objectively distinguish malnourished patients from well-nourished patients undergoing cardiac surgery. Associations between low PA and low FFMI suggest that malnutrition and low PA are interrelated. A PA lower than the 15th percentile identified 17.8% of the patients as malnourished. As a result, those with a PA value lower than the 15th percentile had a higher risk of postoperative morbidity. Strict postoperative outcome definitions rendered by the STS were used to elude outcome variability and to objectify the evaluation. Low PA was associated with the overall postoperative morbidity but not with each STS-defined endpoint separately. This might be because the prevalence of each individual outcome was too low in our population.

The cardiac surgery population is very susceptible to malnutrition; however, it is rarely detected. Although it is relatively easy to suspect malnutrition in patients with severe heart failure and cardiac cachexia, the problematic groups of patients, in terms of malnutrition detection, are those with second and third New York Heart Association (NYHA) class heart failure, and as a result, retention of water and increased body weight. The median BMI of our study group was 28.39 kg/m², whereas ESPEN diagnostic criteria suggest a BMI lower than 18.5 kg/m² as one of the markers of malnutrition. Only 2 (0.6%) patients fit this criterion. Unintended weight loss (>10% indefinite amount of time, or >5% over the last three months), another suggested marker, is not accurate, because patients rarely recall how many kilograms of weight they have lost, and most of them do not keep track of their weight at all. In light of
these recommendations, FFMI is calculated only if unintended weight loss is reported. Overall, there were 11 (3.6%) patients who would be considered malnourished using the ESPEN malnutrition criteria, which is much less than the percent identified when using BIA. These patients are not yet in such an advanced stage of nutritional deterioration compared to the cachectic ones. However, they ought to be diagnosed and accounted for preoperatively. Therefore, we propose the usage of BIA PA to detect the first alterations of nutritional status.

There is no approved or recommended cut-off value of the PA for the diagnosis of malnutrition. However, it is pointed out that the classification value should be different in various chronic conditions. To determine whether the patient is in a good nutritional state, researchers have to make their own cut-off points [5,24]. Most of these cut-off points are the values with the highest predictive accuracy and specificity for adverse clinical outcomes. However, one size does not fit all. Age, gender, and BMI are the primary determinants of PA in healthy subjects [25], Stobäus et al. determined that disease malnutrition and elevated C-reactive protein are significant determinants of PA besides age, sex, and BMI [26]. Having this evidence in mind, the PA should be stratified in accordance with its determinants. In our study, PA was stratified by age and gender, because significant differences in PA values were detected only among these determinants. These results are consistent with the results of a study by Paiva et al. [27]. Healthy subjects’ age and gender reference values of PA were used to produce standardised measurements [20]. The standardised cut-off point of malnutrition used in different studies varies, ranging from the 5th to 20th percentile. In our study, patients who had a value lower than the 15th percentile or (−) 1 standard deviation of the subgroup in question were classified as malnourished and accounted for 61 (17.8%) of the patients.

The possible limitations of this study include the general limitations of BIA application. One of these is the equation used in the analysers, which is provided by a healthy Caucasian population and might not be accurate enough for an unhealthy cardiac surgery population. Furthermore, touch-type electrodes were used in this study, even though adhesive electrodes are recommended by ESPEN. Nevertheless, the manufacturers of the device recommend using adhesive electrodes only for amputee patients. Moreover, the specificity of the studied population also contributes to the limited application of the results. These results may only be applied to cardiac surgery patients and must be further evaluated in alternative settings.

We propose the use of the percentile method for PA standardisation. The standardisation process of the PA measurements allows accounting for different reference values of different patient subgroups. To perform the standardisation, one must use the following equation: standardised PA = observed PA − mean PA (reference)/standard deviation PA (reference) [28]. However, the calculations of this ratio require looking into reference values each time. We propose to have the reference values stratified by age and gender in a diagram (Fig. 1). This diagram would be composed of PA reference values plotted along the axis scaled for different age subgroups. To determine if the patient is malnourished and at risk of postoperative morbidity, a physician must use the diagram and determine if the patient is malnourished and at risk of postoperative morbidity. A patient whose PA value is below the 15th percentile in the age and gender reference group would be classified as malnourished (Fig. 1). In our study, we propose the usage of the percentile method for PA standardisation in cardiac surgery patients and must be further evaluated in alternative settings.

5. Conclusion

Preoperative low PA is an accurate marker of malnutrition and an independent predictor of adverse postoperative outcomes after cardiac surgery. Therefore, we propose the usage of the percentile method for PA standardisation in cardiac surgery patients and must be further evaluated in alternative settings.
low operative risk cardiac surgery. We recommend using it to detect malnutrition in the cardiac surgery population. Further research focused on preoperative PA would allow more accurate identification of malnourished cardiac surgery patients.

Statement of authorship

DR, DG, VV, and IN designed the study, collected and interpreted the data, and drafted the manuscript. TZ carried out the statistical analysis. AI, JI, and JS revised the manuscript. All authors read and approved the final manuscript.

Conflict of interest

The authors declare that they have no conflict of interest.

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References


Table 2

Regression analysis of STS morbidity predictors.

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n.s.: not significant with p value > 0.05.

Abbreviations: STS: Society of Thoracic Surgeons; CPB: cardiopulmonary bypass; CI: confidence interval; FFMI: fat-free mass index.