Original paper

The association of body composition assessment with hospital length of stay in off-pump coronary artery bypass patients

Radosław Wilimski[1], Mikołaj Marszałek[1], Bartosz Walkowski[1], Wojciech Michalski[1], Ceren Eyileten[2], Zuzanna Przekop[3], Aleksandra Małachowska[3], Anita Grochowska[3], Maja Sosnowska[4], Mariusz Kuśmierczyk[1]

[1]Department of Cardio-Thoracic Surgery and Transplantology, Medical University of Warsaw, Warsaw, Poland

[2]Department of Clinical and Experimental Pharmacology, Medical University of Warsaw, Warsaw, Poland

[3]Department of Clinical Dietetics, Faculty of Health and Science, Medical University of Warsaw, Warsaw, Poland

[4]Department of Diabetology and Internal Diseases, Medical University of Warsaw, Warsaw, Poland

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Abstract

Introduction: Bioelectrical impedance analysis is a widely available, non-invasive method for body composition assessment.

Aim: To elucidate the perioperative body composition alterations and their prognostic utility for hospital length of stay (LOS) in low risk, off-pump coronary artery bypass (OPCAB) patients.

Material and methods: Fifty patients undergoing elective OPCAB were included in the study. Body composition assessments were performed 1 day before the scheduled surgery and on the 6th postoperative day. Patients were grouped into < 9 days (n = 29, 58%) and ≥ 9 days (n = 21, 42%). Multivariate logistic regression analysis was performed to create a body composition-based screening panel for prolonged hospital stay.

Results: No significant differences in anthropometric measurements, clinical characteristics or occurrence of postoperative complications were detected between the study groups. Patients with longer hospitalization had significantly higher content of fat mass (FM%) and fat mass index (FMI), and significantly lower content of fat free mass (FFM%) baseline parameters (p = 0.011, p = 0.04 and p = 0.012, respectively). High FM% values had 15-fold, low FFM% values had 13-fold and high FMI values had 7-fold higher risk of experiencing longer stay in the hospital (p = 0.001, p = 0.001 and p = 0.005, respectively). The combined panel of three variables (higher FM%, lower FFM% and higher FMI) had 16-fold higher risk of longer hospitalization (adjusted OR = 16.40; 95% CI: 3.52–76.34; p = 0.0004).

Conclusions: Preoperative high FM and low FFM content are independent predictors of prolonged hospital length of stay in normal- and increased-BMI patients after OPCAB.

Key words: bioelectrical impedance analysis, coronary artery bypass grafting, body composition, hospital length of stay.

Summary

This study aimed to elucidate the perioperative body composition alterations and their prognostic utility for hospital length of stay in low risk, normal- and increased-body mass index, off-pump coronary artery bypass grafting (OPCAB) patients. All body composition parameters assessed by bioelectrical impedance analysis (BIA) were altered in a time-dependent fashion. Patients with longer hospitalization had significantly higher baseline content of fat mass (FM%) and the fat mass index (FMI), and significantly lower content of fat free mass (FFM%) (p = 0.011, p = 0.04 and p = 0.012, respectively). High FM% values had 15-fold, low FFM% values had 13-fold and high FMI values had 7-fold higher risk for longer stay in the hospital (p = 0.001, p = 0.001 and p = 0.005, respectively). The combined panel of three variables (higher FM%, lower FFM% and higher FMI) had 16-fold higher risk of longer hospitalization (adjusted OR = 16.40, 95% CI: 3.52–76.34; p = 0.0004). A higher preoperative FM and lower FFM content might be potential indicators of prolonged hospitalization in normal weight or overweight patients subjected to OPCAB.

Corresponding author:
Radosław Wilimski, Department of Cardio-Thoracic Surgery and Transplantology, Medical University of Warsaw, Warsaw, Poland,
e-mail: rwilimski@gmail.com
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Introduction

Nutritional status assessment is mainly aimed at identifying malnourishment. However, in patients referred for coronary artery bypass grafting (CABG), the percentage of overweight and obese patients systematically increases [1]. Higher indices of central adiposity are associated with an increased risk of coronary artery disease (CAD) and cardiovascular mortality, irrespectively of the body mass index (BMI) measures, even among those with normal weight [2, 3].

The CABG procedure triggers a systemic inflammatory response that is far more intense if extracorporeal circulation is employed [4]. Contrary to the classic surgery, off-pump CABG (OPCABG) results in a lesser extent of endothelial activation and increased microvascular permeability. In effect, less plasma proteins leak, and less fluid accumulates in the interstitial space [5].

Bioelectrical impedance analysis (BIA) allows for non-invasive, functional and cheap estimation of body compartments. It has been widely studied for assessment of body composition and hydration status in patients undergoing cardiac surgery [6–12]. Compartmental differentiation with BIA allows for superior detection of subtle membrane dependent fluid imbalances, over the classic anthropometric measurements.

Cardiopulmonary bypass employment during CABG and the patient's initial state of malnutrition significantly affect body composition assessment results. Therefore, this pilot study was carried out on a group of OPCAB patients without clinical signs of malnutrition. Very few BIA reports link the postoperative BIA values to the clinical outcome after OPCAB, while most relevant reports focus on the effects of preoperative malnutrition on morbidity and mortality [13–17]. This study aimed to elucidate the utility of body composition parameters, namely fat mass (FM), fat free mass (FFM) and body water content, in refining in-hospital prognostic accuracy of OPCAB patients.

Aim

We hypothesize that BIA might be a potential indicator of prolonged hospitalization in normal- and increased-BMI patients subjected to OPCAB.

Material and methods

Study population

Fifty patients (40 men, 80%; 10 women, 20%) were consecutively recruited from all patients scheduled for elective OPCAB at the Department of Cardiac Surgery at the Medical University of Warsaw between October 2018 and July 2019. The study protocol was approved by the Institutional Review Board (KB/144/2018). All provided written informed consent.

The inclusion criteria were as follows: (i) elective OPCAB, (ii) age 18-80 years, (iii) left ventricle ejection fraction (LVEF) more than 40%, (iv) bioimpedance testing performed preoperatively and postoperatively, (v) BMI ≥ 22 kg/m^2, (vi) Mini Nutritional Assessment questionnaire (MNA) total score ≥ 17, (vii) serum albumin levels > 3.5 g/dl, (viii) provided written informed consent.

Exclusion criteria were as follows: (i) cardiovascular implantable electronic device (contraindication to bioimpedance testing), (ii) clinical instability requiring emergent surgery, (iii) complicated intraoperative course, (iv) intraoperative insertion of intra-aortic balloon pump (IABP), (v) history of congenital heart abnormality or previous cardiac surgery, (vi) cognitive impairment hindering cooperation.

The MNA is a simple screening tool for classifying subjects into three groups: well-nourished (≥ 23 points), at risk of undernutrition (≥ 17 points) and undernutrition (< 17 points).

The median postoperative hospital length of stay (LOS) was 8.79 days. Therefore, we grouped the cohort accordingly: < 9 days of hospitalization (*n* = 29, 58%) and ≥ 9 days of hospitalization (*n* = 21, 42%). The demographics and baseline clinical characteristics are presented in Table I.

Data collection

Upon admission, anthropometric measurements (age, gender, body weight and height), laboratory tests, LVEF and clinical status data were registered. Patients were stratified with MNA and EuroSCORE II.

Body composition assessment

Body composition assessment was conducted at two time points: 1 day before surgery (D0) and on the sixth

Table I. Demographic and clinical characteristics of patients

Variable	Overall (*n* = 50; 100%)	Hospital LOS < 9 days (*n* = 29; 58%)	Hospital LOS ≥ 9 days (*n* = 21; 42%)	*P*-value
Age, median (IQR) [years]	69 (61–72.25)	70 (61.50–72.50)	68 (60.5–72.5)	0.708
Female sex, *n* (%)	10 (20%)	4 (13.8%)	6 (28.6%)	0.197
Baseline characteristics:				
BMI, mean ±SD [kg/m^2]	29 ±0.54	28.93 ±4.05	29.42 ±3.52	0.659
Normal weight (BMI 18.5–25 kg/m^2), *n* (%)	10 (20)	7 (24)	3 (14.3)	0.390
Overweight (BMI ≥ 25 and < 30 kg/m^2), *n* (%)	19 (38)	10 (34.5)	9 (42.9)	0.547

Table I. Cont.

Variable	Overall (*n* = 50; 100%)	Hospital LOS < 9 days (*n* = 29; 58%)	Hospital LOS ≥ 9 days (*n* = 21; 42%)	*P*-value
Obese (BMI ≥ 30 kg/m^2), *n* (%)	21 (42)	12 (41.4)	9 (42.9)	0.917
CCS 1, *n* (%)	2 (4)	–	2 (9.5)	–
CCS 2, *n* (%)	28 (56)	18 (62)	10 (47.6)	0.310
CCS 3, *n* (%)	20 (40)	11 (37.9)	9 (42.9)	0.726
LVEF, median (IQR) (%)	55.00 (50.75–60.00)	60.00 (54.50–61.50)	55.00 (45.50–60.00)	0.080
EuroSCORE II, median (IQR) (%)	1.21 (0.80–1.85)	1.2 (0.78–1.80)	1.3 (0.80–2.04)	0.467
Diabetes mellitus, *n* (%)	20 (40)	14 (48.3)	6 (28.6)	0.160
COPD, *n* (%)	4 (8)	1 (3.4)	3 (14.3)	0.163
CKD STAGE > 3, *n* (%)	18 (36)	9 (31)	9 (42.9)	0.390
Hypertension, *n* (%)	44 (88)	26 (89.7)	18 (85.7)	0.672
AF, *n* (%)	5 (10)	4 (13.8)	1 (4.8)	0.293
Hyperlipidemia*, *n* (%)	29 (58)	18 (62.1)	11 (52.4)	0.493
Previous MI, *n* (%)	24 (48)	14 (48.3)	10 (47.6)	0.963
Previous PCI, *n* (%)	15 (30)	8 (27.6)	7 (33.3)	0.662
MNA, mean ± SD [total points]	24.24 ±2.94	24.52 ±2.91	23.86 ±3.00	0.439
β-blockers, *n* (%)	45 (90)	24 (82.8)	21 (100)	0.056
ACEI, *n* (%)	35 (70)	20 (69)	15 (71.4)	0.851
Sartans, *n* (%)	7 (14)	4 (13.8)	3 (14.3)	0.960
CCB, *n* (%)	21 (42)	14 (48.3)	7 (33.3)	0.291
Statins, *n* (%)	44 (88)	24 (82.8)	20 (95.2)	0.180
HbA_{1c}, median (IQR) (%)	6.9 (6.5–7.63)	6.9 (6.45–7.45)	6.6 (6.5–9.75)	0.672
Hemoglobin, mean ± SD [g/dl]	13.7 ±0.22	13.53 ±1.43	14.01 ±1.78	0.303
Hematocrit, mean ± SD (%)	40.56 ±0.66	39.83 ±3.98	41.57 ±5.37	0.194
Platelets, median (IQR) [× 10^3/µl]	224 (193–268)	221 (180.5–248.5)	243 (205.5–294.5)	0.371
Creatinine, median (IQR) [mg/dl]	1.01 (0.85–1.24)	1.01 (0.90–1.22)	1.01 (0.76–1.126)	0.623
eGFR baseline**, mean ± SD [ml/ min/1.73m^2]	71.13 ±20.88	69.75 ±19.50	73.04 ±23.00	0.588
Postoperative parameters:				
Number of coronary grafts, median (IQR)	2.00 (2.00–4.00)	2.00 (2.00–3.00)	2.00 (2.00–3.00)	0.875
ICU, median (IQR) [h]	47.50 (43.5–51.25)	46.00 (29.00–48.00)	50.00 (47.50–70.50)	0.001
Mechanical ventilation, median (IQR) [h]	6.50 (5–9)	6.00 (4.00–8.00)	8.0 (6.00–13.00)	0.006
Troponin 6h after OPCAB, median (IQR) [ng/ml]	1.14 (0.56–2.06)	0.98 (0.38–2.11)	1.42 (0.90–2.44)	0.160
Troponin 18 h after OPCAB, median (IQR) [ng/ml]	0.94 (0.32–2.13)	0.78 (0.25–1.81)	1.14 (0.61–4.36)	0.079
CK-MB 6 h after OPCAB, median (IQR) [ng/ml]	5.15 (3.38–8.40)	5.1 (2.55–8.30)	5.2 (4.6–12.6)	0.169
CK-MB 18h after OPCAB, median (IQR) [ng/ml]	5.65 (3.40–12.45)	4.7 (2.65–7.85)	6.30 (4.75–29.00)	0.046
MI, *n* (%)	5 (10)	2 (6.9)	3 (14.3)	0.390
Stroke/TIA, *n* (%)	0 (0)	0 (0)	0 (0)	–
Acute kidney injury, *n* (%)	2 (4%)	0 (0%)	2 (9.5%)	0.090
Chest drainage volume 24 h after OPCAB, median (IQR) [ml]	715 (570–883.75)	700 (560–855)	720 (580–985)	0.694
Total chest drainage volume after OPCAB, median (IQR) [ml]	1030 (853.75–1383.75)	970 (735–1335)	1300 (903–1585)	0.111
Hemoglobin day-7, median (IQR) [g/dl]	9.95 (9.25–11.15)	10 (8.90–11.30)	9.90 (9.65–11.2)	0.821
Hematocrit day-7, median (IQR) (%)	30.45 (28.13–33.23)	29.70 (27.05–33.25)	31.10 (29.20–33.55)	0.637
Creatinine day-7, median (IQR) [mg/dl]	0.97 (0.81–1.12)	0.97 (0.83–1.10)	0.97 (0.80–1.25)	0.844
eGFR** day-7, mean ± SD [ml/min]	73.06 ±21.79	74.15 ±17.80	71.59 ±26.74	0.686

*Data are expressed as mean and standard deviation (SD), median and interquartile range (IQR), or number (n) and percentage (%) of patients depending on the data distribution. *Hyperlipidemia – previously reported in history and/or actively taking statins ** eGFR by MDRD = 175 × SCr (mg/dl)*$^{-1.154}$ *× age* $^{-0.203}$ *× 0.742 (if woman) (same ethnicity correction factors). ACEI – angiotensin-converting-enzyme inhibitors, AF – atrial fibrillation, BMI – body mass index, CCB – calcium channel blockers, CCS – Canadian Cardiovascular Society Angina Grade, CKD – chronic kidney disease, COPD – chronic obstructive pulmonary disease, eGFR – estimated glomerular filtration rate, Hb – hemoglobin,* HbA_{1c} *– glycated hemoglobin, ICU – intensive care unit, IQR – interquartile range, LVEF – left ventricular ejection fraction, MI – myocardial infarction, MNA – Mini Nutritional Assessment form, OPCAB – off-pump coronary artery bypass grafting, PAD – peripheral artery disease, PCI – percutaneous intervention, SCr – serum creatinine, TIA – transient ischemic attack.*

postoperative day (POD6). Tanita Segmental Body Composition Analyzer BC-418 MA (Tanita, Tokyo, Japan) was used for all the tests. Tanita is a segmental BIA device that measures impedance of the body segments with eight electrodes to estimate FM, FFM and total body water (TBW) content. The device uses high-frequency electrical current (50 kHz, 90 µA) and measures the impedance of the trunk and four limbs, analyzing a total of five different body segments [13].

Skeletal muscle % estimation

The muscle mass percentage at a distinct time point (D0 and POD6) was calculated by subtracting the TBW% from the FFM%. FFM% constitutes the percentage sum of skeletal and visceral muscle mass, bone mass, and TBW% – in other words, everything but the fat mass %. Considering that the magnitude of bone mass and visceral muscle mass change within a seven-day period is negligible, the calculated difference (Δ) corresponds to skeletal muscle mass percentage only. The Δ in muscle loss or gain was computed by subtracting the measurements on D0 from those of POD6.

Clinical outcome evaluation

Hospitalization data, such as duration of mechanical ventilation, length of intensive care unit (ICU) and hospital stay, pre- and postoperative laboratory tests, chest drainage volume as well as the in-hospital major adverse cardiac and cerebrovascular event rate were registered for every participant. Postoperative clinical characteristics are presented in Table I.

Statistical analysis

All categorical variables were presented as a number and percentage. Depending on the normality of distribution as assessed by the Shapiro-Wilk test, continuous variables were shown as mean ± standard deviation (SD) or median and interquartile range (IQR). The χ^2 test was used for dichotomous variables and Student's *t*-test or the Mann-Whitney test for unpaired samples.

Regression analysis was used to evaluate the relationship between baseline BIA and hospital LOS parameters. In order to identify prognostic indicators of prolonged hospital stay, univariate analyses were first performed using clinical and nutritional status indices as independent variables and hospital LOS as the response variable. All factors exhibiting univariate significance at a *p*-value < 0.05 were employed in a multivariate logistic regression. Analysis was adjusted for EuroSCORE II. The odds ratios (OR) and 95% confidence intervals (95% CI) of the entered factors were calculated accordingly. The discriminatory capacity of the model was tested using the area under the receiver operating characteristic curve (ROC). All tests were two-sided with the significance level of $p < 0.05$. Calculations were performed using SPSS version 29.0.1.0 (IBM Corporation, Armonk, USA). Box plots and ROC curves were illustrated by Adobe Illustrator (version 27.5, USA).

Results

Characteristics of the groups

The final study group consisted of 50 patients with a median age of 69 (IQR, 61–72.25) years; 10 (20%) patients were female. Twenty-one (42%) patients were obese (BMI > 30 kg/m^2), 19 (38%) patients were overweight (BMI ≥ 25 kg/m^2 and < 30 kg/m^2), and 10 (20%) had a normal BMI (18.5–25 kg/m^2). The mean BMI of the study population was 29.36 ±3.70 kg/m^2. According to the MNA score, none of the patients was malnourished (< 17 points). All the patients were considered low risk, as depicted by EuroSCORE II % operative risk of the entire cohort: 1.21 (0.80–1.85). Among the 50 patients, 29 (58%) of them stayed at the hospital shorter than 9 days, and 21 (42%) of them stayed 9 days or longer.

No differences were found between the groups in terms of anthropometric (BMI), standard assessment of nutritional status (MNA), and baseline clinical characteristics (Table I).

Apart from the length of ICU stay and mechanical ventilation length, which are derivatives of the original division related to the length of hospitalization, and the level of CK-MB 18 h postoperatively (which was borderline significant, $p = 0.046$), other postoperative characteristics did not significantly differ between the groups (Table I). These findings confirm the clinical preoperative and postoperative uniformity of study groups assessed using standard clinical and anthropometric parameters.

Body composition analysis

After grouping patients according to the length of hospitalization, preoperative and postoperative BMI did not differ significantly between the groups. Baseline body composition parameters differed significantly between patients with hospital LOS < 9 days and ≥ 9 days in terms of percentage composition of FM, FFM, TBW and skeletal muscle. In particular, FFM%, TBW% and skeletal muscle (%) were lower upon admission in the group of patients with a prolonged hospital stay ($p = 0.012$, $p = 0.011$, $p = 0.012$, respectively). In contrast to the preoperative values, the BIA showed no significant differences in body composition measurements between the compared groups after the OPCAB procedure (Figure 1, Table II).

The magnitude of percentage change (Δ) in FM%, FFM%, TBW% and skeletal mass (%) was determined by subtracting the preoperative values measured on D0 from the postoperative parameters on POD6, for both < 9 days and ≥ 9 days of hospitalization groups, separately, in an effort to assess the body composition changes before and after elective OPCAB. There were no significant differences in the magnitude of the change (Δ) of the compared parameters of body composition between the study groups (Table II).

Patients with longer hospitalization had significantly higher FM and FMI, and significantly lower FFM baseline parameters (p = 0.011, p = 0.04 and p = 0.012, respectively) (Figures 1 A, C, E). ROC curve analysis was performed to evaluate the potential of baseline body composition parameters for prediction of hospitalization length. Area under the curve (AUC) for FM% was 0.751, for FFM% was 0.749 and for FMI was 0.714 (Figures 1 B, D, F). The ROC curve showed that pooling the 3 parameters together (FM%, FFM% and FMI) yielded a higher AUC

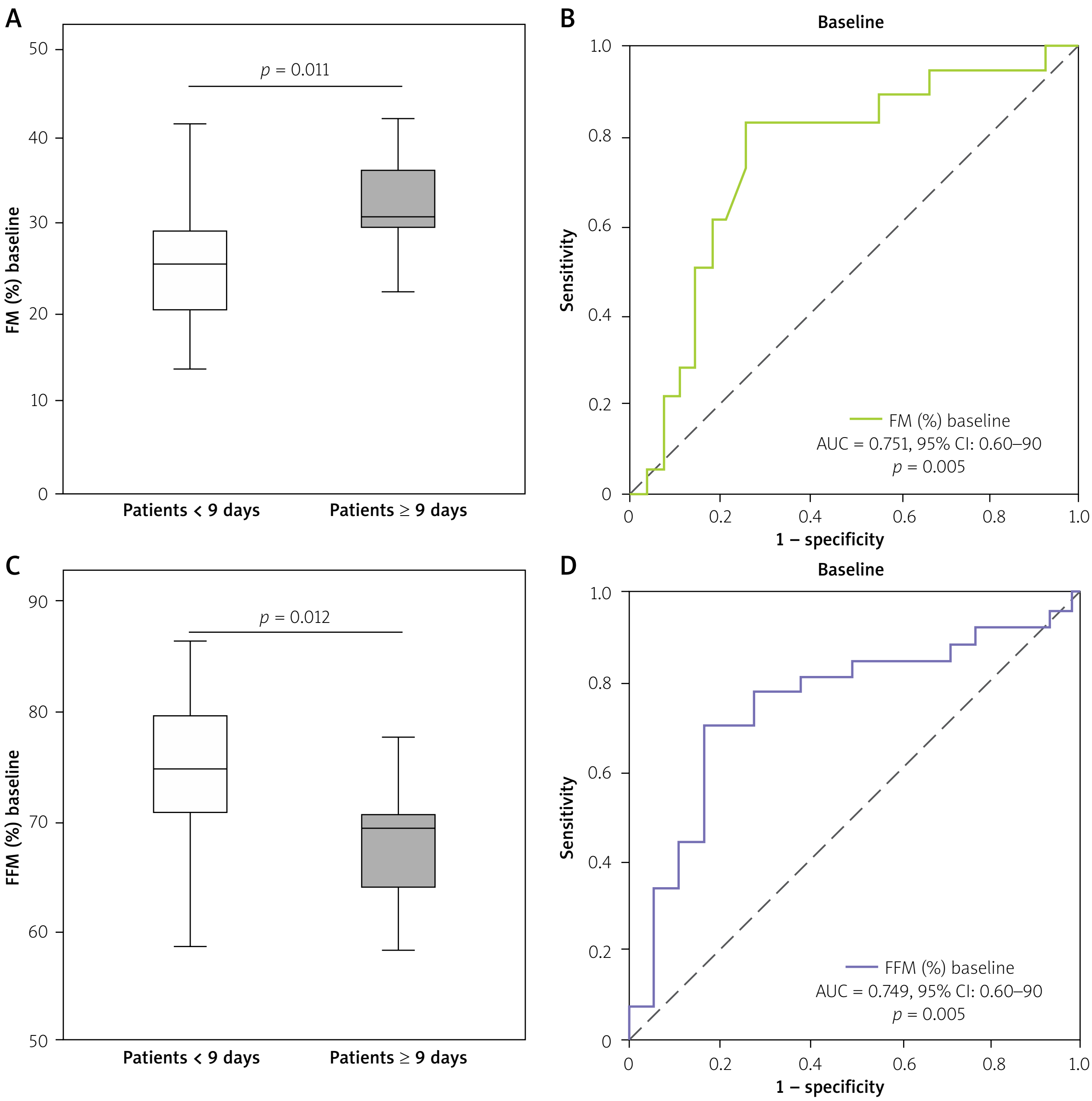
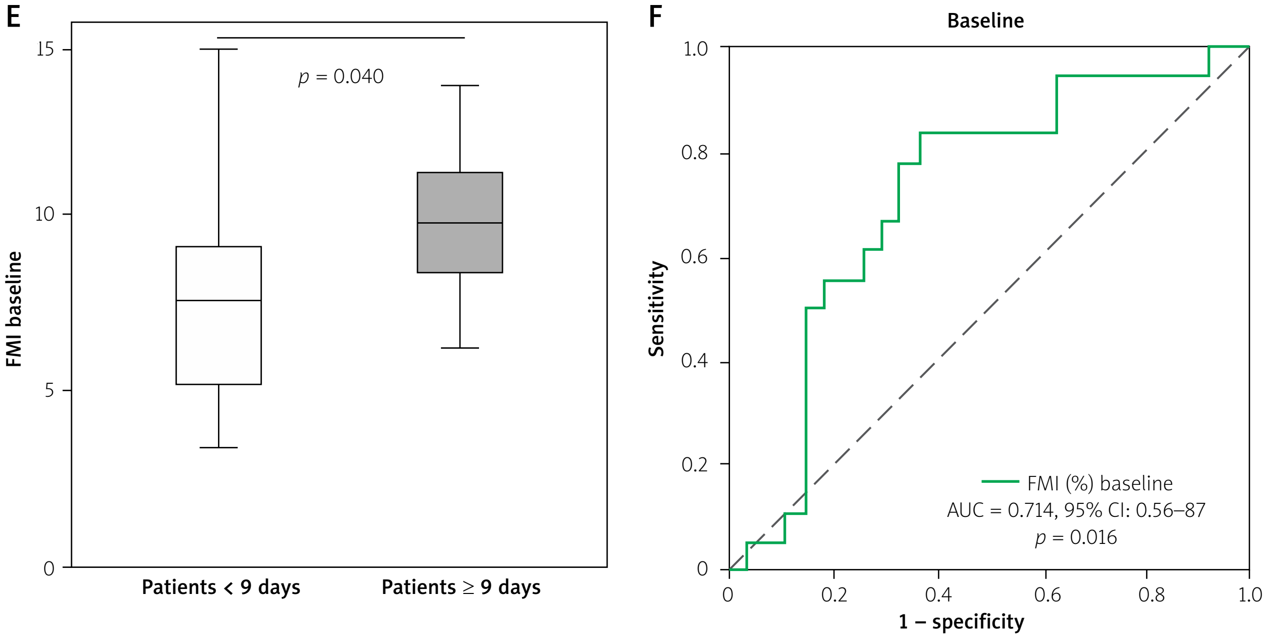


Figure 1. Baseline values of box-plot alterations and receiver operating characteristic (ROC) curves of body composition estimates according to hospital length of stay. Baseline values of box plots and receiver operating characteristic (ROC) curves: **A** – FM (%) baseline values of box plots for hospital length of stay comparison; **B** – FM (%) baseline ROC curve for prediction of increased length of stay in the hospital; **C** – FFM (%) baseline values of box plots for hospital length of stay comparison; **D** – FFM (%) baseline ROC curve for prediction of increased length of stay in the hospital

AUC – area under curve, CI – confidence interval, FM – fat mass, FMI – fat mass index, FFM – fat-free mass, LOS – length of stay, ROC – receiver operating characteristic.



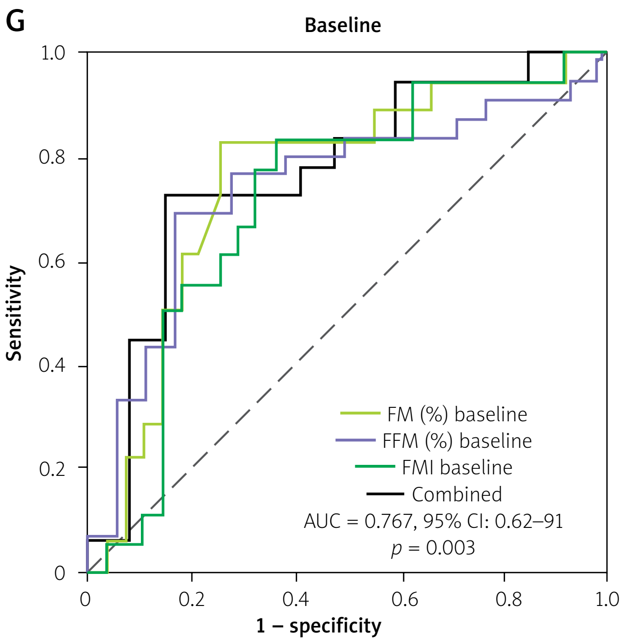


Figure 1. Cont. **E** – FMI baseline values of box plots for hospital length of stay comparison; **F** – FMI baseline ROC curve for prediction of increased length of stay in the hospital; **G** – Combined panel of parameters (FM (%), FFM (%) and FMI) baseline ROC curve for prediction of increased length of stay in the hospital

AUC – area under curve, CI – confidence interval, FM – fat mass, FMI – fat mass index, FFM – fat-free mass, LOS – length of stay, ROC – receiver operating characteristic.

than the value of each individual biomarker, as AUC was 0.767 (95% CI: 0.62–0.91) (Figure 1 G).

Based on the best FM%, FFM% and FMI accuracy cut-off determined by ROC curve analysis, the study population was divided into two subgroups: low FM% values (mean ± standard deviation (SD): 22.62 ±0.93) including 23 (51%) patients and high FM% values (34.17 ±0.99) including 22 (49%) patients; low FFM% values (mean ± standard deviation (SD): 66.05 ±0.96) including 23 (51%) patients and high FFM% values (77.66 ±0.94) including 22 (49%) patients; low FMI values (mean ± standard deviation (SD): 6.09 ±0.37) including 22 (49%) patients and high FMI values (10.76 ±0.39) including 23 (51%) patients (Table III, Figure 1).

High FM%, low FFM% and high FMI values were significantly associated with a crude 14-fold, 12-fold and 7-fold (respectively) increased hospital LOS in patients after the OPCAB procedure in univariate logistic regression analysis. The panel of these three variables as one combined variable showed a stronger significant association with increased hospital LOS as the crude impact was 15-fold (Table IV).

For subsequent adjustments, we used a multivariate logistic regression model to identify independent variables for increased hospitalization. All three studied baseline variables (FM%, FFM% and FMI) showed independent prediction potential for increased hospitalization in the adjusted by the EuroSCORE II model. High

Table II. Body composition analysis characteristics of patients by the length of hospital stay

Variable	Total	Hospital LOS < 9 days	Hospital LOS ≥ 9 days	*P*-value
Preoperative parameters:				
BMI [kg/m^2]	29.36 ±3.70	28.97 ±3.89	29.94 ±3.41	0.659
FM (%)	28.27 ±7.40	26.03 ±7.37	31.62 ±6.16	0.011
FMI [kg/m^2]	8.48 ±2.93	7.75 ±3.05	9.57 ±2.44	0.040
FFM (%)	71.72 ±7.37	73.94 ±7.38	68.39 ±6.16	0.012
FFMI [kg/m^2]	25.25 ±2.58	25.23 ±2.43	25.27 ±2.85	0.964
TBW (%)	52.51 ±5.41	54.14 ±5.41	50.06 ±4.51	0.011
Skeletal muscle (%)	19.22 ±1.97	19.8 ±1.97	18.33 ±1.64	0.012
Postoperative parameters:				
BMI [kg/m^2]	28.70 ±3.66	28 ±3.86	28.51 ±3.41	0.884
FM (%)	25.14 ±7.55	23.78 ±7.97	25.57 ±6.27	0.134
FMI [kg/m^2]	7.45 ±2.74	7.10 ±2.97	8.07 ±2.23	0.298
FFM (%)	71.96 ±7.10	73.35 ±7.35	69.46 ±6.10	0.067
FFMI [kg/m^2]	26.20 ±2.90	26.12 ±2.81	26.35 ±3.15	0.819
TBW (%)	54.79 ±5.66	56.01 ±5.83	52.59 ±4.78	0.069
Skeletal muscle (%)	20.05 ±2.07	20.51 ±2.12	19.22 ±1.75	0.061
Magnitude of changes (Δ) of body composition estimates between POD6 and preoperative measurements D0:				
Δ BMI [kg/m^2]	0.72 ±0.53	0.58 ±0.37	0.97 ±0.68	0.164
Δ FM (%)	–2.89 ±3.35	–2.84 ±3.06	–2.98 ±3.92	0.903
Δ FFM (%)	1.02 ±1.28	1.10 ±1.08	0.86 ±1.62	0.593
Δ TBW (%)	2.11 ±2.60	2.31 ±2.25	0.87 ±3.19	0.563
Δ Skeletal muscle (%)	0.77 ±0.95	0.86 ±0.83	0.61 ±1.16	0.438

Data are expressed as mean and standard deviation (SD). BMI – body mass index, D0 – 1 day before surgery, FFM – fat-free mass, FFMI – fat-free mass index, FM – fat mass, FMI – fat mass index, LOS – length of stay, POD6 – 6th postoperative day, TBW – total body water.

Table III. ROC curve results of discrimination for preoperative BIA parameters in terms of prolonged hospital LOS

BIA parameters	AUC (95% CI)	*P*-value	Cut-off	Sensitivity	Specificity	PPV	NPV	Likelihood ratio of a positive test
FM (%)	0.751 (0.60–0.90)	0.005	29.2	83%	74%	86%	68%	3.19
FFM (%)	0.749 (0.60–0.90)	0.005	70.8	70%	84%	70%	65%	4.38
FMI [kg/m^2]	0.714 (0.56–0.87)	0.016	8.37	78%	67%	78%	33%	2.36
Combined FM (%), FFM (%) and FMI [kg/m^2]	0.767 (0.62–0.91)	0.003	0.429	72%	85%	72%	15%	4.8

AUC – area under curve, CI – confidence interval, BIA – bioimpedance analysis, FFM – fat-free mass, FFMI – fat-free mass index, FM – fat mass, FMI – fat mass index, NPV – negative predictive value, PPV – positive predictive value.

FM% values had 15-fold, low FFM% values had 13-fold and high FMI values had 7-fold higher risk of experiencing longer stay in the hospital (p = 0.001, p = 0.001 and p = 0.005, respectively). Importantly, the combined panel of three variables (higher FM%, lower FFM% and higher FMI) had 16-fold higher risk of longer hospitalization (adjusted OR = 16.40, 95% CI: 3.52–76.34; p = 0.0004) (Table IV).

Discussion

Currently, multiple clinical indices and risk stratification models are used to predict the cardiac surgery outcome, but no highly specific tool is available [18, 19]. Considering that CABG promotes profound body composition changes and highly attenuates metabolically dependent FM and FFM, perioperative assessment of relevant parameters could compliment the prognostic accuracy of the established clinical risk algorithms [14, 20].

Prolonged hospital LOS after cardiac surgery has been proven to be associated with unfavorable outcomes [15, 21]. Perioperative management of coronary artery bypass patients aims to minimize hospital LOS as a means of preventing hospital associated complications and costs optimization [22]. New markers of prolonged LOS are needed to allow for better screening and preprocedural optimization of the low-risk CABG patients.

Table IV. Univariate and multivariate logistic regression analysis of prolonged hospital LOS predictors

Variable	Univariate analysis		
	OR	95% CI	*P*-value
High FM (%)	14.286	3.159–64.611	0.001
Low FFM (%)	11.875	2.677–52.670	0.001
High FMI [kg/m^2]	7.000	1.780–27.528	0.005
Panel of FM (%), FFM (%) and FMI [kg/m^2]	14.950	3.402–65.692	0.0003
FFMI [kg/m^2]	0.793	0.570–1.103	0.168
Age	0.980	0.909–1.056	0.593
Gender	0.400	0.097–1.651	0.205
BMI	1.035	0.891–1.202	0.651
EF	0.939	0.872–1.012	0.100
NYHA	1.690	0.606–4.714	0.316
Diabetes	0.655	0.360–1.190	0.164
EuroSCORE II	1.556	0.738–3.281	0.246
Variable	**Multivariate analysis**		
	OR	**95% CI**	***P*-value**
Higher FM (%) vs. lower baseline	14.78	3.21–68.08	0.001
Lower FFM (%) vs. higher baseline	12.458	2.74–56.6410	0.001
Higher FMI [kg/m^2] vs. lower baseline	7.334	1.81–29.6912	0.005
Panel of higher FM (%), lower FFM (%) and higher FMI (kg/m^2) vs. lower baseline	16.40	3.52–76.34	0.0004

CI – confidence interval, FFM – fat-free mass, FFMI – fat-free mass index, FM – fat mass, FMI – fat mass index, OR – odds ratio.

Fat mass

The most frequently observed consequence of CABG surgery is considerable reduction of adipose tissue mass and fat free mass during the recovery period. The demand for oxygen and energy increases in the postoperative period and this leads to upregulation in fat metabolism [23]. Hypermetabolism is caused by endocrine, metabolic and immunological factors (mainly insulin, glucagon, cortisol, catecholamines and cytokines TNF-α and IL-1). In patients undergoing surgery, lipolysis begins to dominate, and fatty acids become the primary source of energy, which leads to development of insulin resistance and a reduction of the typical anabolic effect of insulin [23].

The vast majority of patients in our study experienced a reduction in adipose tissue mass after OPCAB. These findings contrast with those of van Venrooij *et al.,* where no changes in fat mass were reported after the CABG procedure [14]. There is a paucity of data on how CABG surgery impacts adipose mass; however, the relationship between changes in fat mass and clinical outcomes becomes more apparent. In our study, patients with hospitalization time ≥ 9 days had significantly higher FM content than patients hospitalized for a shorter period. Due to the lack of data on caloric and nutrient consumption in the study group determination of the exact cause for post-operative fat mass decline in our cohort is problematic. In future studies more consideration of this occurrence is warranted.

Fat-free mass

A postoperative FFM% increase stands against the definition of malnutrition, but rather should be attributed to the body water constituent – a significant constitutent of FFM (FFM = skeletal muscle mass + body cell mass + total body water + bone mineral mass) [24]. Considering that the parallel changes of TBW% and FFM% reflected mild overhydration (2.11 ±2.60% vs. 1.02 ±1.28%, respectively), a relatively small gain of FFM can be assumed. The obtained perioperative fat-free mass index (FFMI) value ranges stand in the context of previously reported findings [15, 16].

The loss of FFM during convalescence has been related to a fast drop in muscle protein production rates in the first 4 h after the CABG procedure [25]. It is still undetermined whether postoperative FFM restoration after CABG is linked to the fluid balance or physical activity. It could be argued that in our study group the dominant lack of FFM reduction was due to the patients' participation in the early postoperative rehabilitation program and their resultant engagement in regular physical exercise, allowing for some regain of FFM [26]. In consequence, it is obligatory to describe the range of change of FFM during recovery from CABG surgery, which is of particular importance in the case of persistent FFM wasting after the operation [27]. Further research should examine whether such optimized early rehabilitation programs combined with the implementation of nutritional care could prevent or reverse FFM deterioration after CABG surgery [17, 28].

Hospital LOS according to BIA assessment

There is no recommended cut-off value of FM or FFM for the prediction of postoperative outcome in normal- or increased-BMI patients referred for CABG. Despite the absence of differences in the clinical course between the study groups, we were able to determine preoperative cut-off values among body composition parameters related to the length of hospitalization. FM > 29.2%, FMI > 8.37 kg/m^2, FFM < 70.8% and the combined parameter of FM%, FFM% and FMI > 0.429 were independent predictors of hospital LOS ≥ 9 days. It should be assumed that cut-off values may vary depending on demographic and anthropometric conditions, especially in the presence of chronic disorders. Currently, age, gender and BMI are the major factors decisively affecting the body composition in healthy individuals [29]. EuroSCORE II enables a comprehensive assessment of perioperative risk in cardiac surgery and is causally related to metabolic and musculoskeletal changes due to surgical procedures [30]. In our study, the body composition parameter panel was adjusted for EuroSCORE II. In addition, age, gender, BMI, ejection fraction, and EuroSCORE II were not significantly associated with prolonged hospitalization in univariate analysis, and only high FM and low FFM values and their derivatives were independent predictors of prolonged hospitalization in multivariate analysis in our study.

Despite the mean values of FM%, FFM%, TBW% and skeletal muscle (%) that were significantly different between the study groups before OPCAB, the magnitude of change of these measurements did not significantly differ between the groups. The body composition parameter patterns registered before the surgery were significantly reflected in the postoperative results. The clinical outcome is a result of many prognostic factors, the awareness of which, in both the preoperative and postoperative period, determines the occurrence of complications and the final outcome. Body composition monitoring is one of the commonly available technologies that enables individualization and optimization of the therapeutic process in cardiac surgery. BIA can be used not only in perioperative management but also in risk stratification.

Limitations

As this was a pilot study, the main limitation is the small number of patients. We aimed to detect body composition changes based on hospital LOS. The hospital LOS is affected by numerous factors apart from nourishment status. Patients' nutritional assessment was only evaluated by applying the MNA questionnaire and subjects were predominantly male. BIA was not compared with other techniques for evaluation of fluid content and the limitations of this study comprise the specified restrictions of BIA implementation. Touch-type electrodes were utilized in this study, despite adhesive electrodes being recommended by ESPEN (European Society for Clinical Nutrition and Metabolism). Many factors affect body composition parameters in the postoperative period and their independent influence requires a larger patient population and a multi-frequency current body composition analyzer to allow for intra- and extracellular fluids. These results have been proven relevant only in a uniform group of OPCAB patients and should be further refined in more diverse cohorts. The single-center analysis restricted utility of these results in broader practice, but it indicates the direction for further research.

Conclusions

Preoperative high FM, FMI and low FFM content are independent predictors of prolonged hospital length of stay in normal- and increased-BMI patients after OPCAB. Moreover, combining these three parameters with the ROC curve into one panel can increase their prediction power, and help clinicians in early stratification of patients and prediction of the hospitalization length for the CABG operation. We recommend using BIA to optimize perioperative management of elective cardiac surgery patients. Further research on larger, more diverse cohorts, focused on preoperative body composition assessment, could better identify risk factors associated with the in-hospital outcome.

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Conflict of interest

The authors declare no conflict of interest.

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