Clinical Nutrition 29 (2010) 789–794

Contents lists available at ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Original Article

Preoperative and postoperative agreement in fat free mass (FFM) between bioelectrical impedance spectroscopy (BIS) and dual-energy X-ray absorptiometry (DXA) in patients undergoing cardiac surgery

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ARTICLE INFO

Article history:
Received 8 January 2010
Accepted 1 June 2010

Keywords:
Protein-energy malnutrition
Undernutrition
Fat free mass
Agreement
BIS (bioelectrical impedance spectroscopy)
DXA (dual-energy X-ray absorptiometry)
Cardiac surgery

SUMMARY

Background & aims: To measure undernutrition in terms of fat free mass (FFM), there are several options. The aim of this study was to assess agreement in FFM between the portable, bedside bioelectrical impedance spectrometry (BIS) and relatively expensive, non-portable dual-energy X-ray absorptiometry (DXA) in patients undergoing cardiac surgery.
Methods: In a prospective study, body composition measurements by BIS and DXA were performed two weeks prior and two months after cardiac surgery. Preoperative and postoperative agreement in FFM between BIS and DXA were analyzed with Bland and Altman plots.
Results: Twenty-six patients were analyzed. BIS overestimated preoperative and postoperative FFM by 2 kg compared to DXA (2.3 kg (95%CI: −3.5–8.1 kg) and 2.1 kg (95%CI: −4.5–8.7 kg), respectively). BIS underestimated FFM change by −0.5% (95%CI: −8.4–7.5%).
Conclusions: There is a large inter-individual variation between BIS and DXA. This hinders the interchange-ability of BIS and DXA in routine clinical practice and may lead to misclassifications and thereby inappropriate nutritional treatment and possible postoperative complications. To evaluate nutritional therapy in patients undergoing cardiac surgery, we advocate the use of DXA assessed FFM in parallel to BIS assessed extracellular and intracellular water and FFM.

1. Introduction

One-quarter of patients undergoing cardiac surgery are or become undernourished postoperatively resulting in more postoperative complications, prolonged length of stay and a decline in quality of life.[1–3] Most of these findings are based on the presence of unintended weight loss (WL) or low body mass index (BMI). Although BMI and WL help to identify undernourished patients, these parameters are not specific and do not provide information on body composition. Body mass consists of metabolically-active fat free mass (FFM) and inactive fat mass. Several studies showed that a low FFM relates to the occurrence of postoperative complications.[4,5]

There are several ways to measure whole body FFM. The most applicable reference standard in assessing whole body FFM in clinical practice, is dual-energy X-ray absorptiometry (DXA).[6,7] However, DXA is a relatively expensive, non-portable method and involves, although minor, exposure to radiation.

In contrast, bioelectrical impedance (BI) is a less expensive, portable bedside method of assessing FFM. The single frequency BI (SF-BI) method is expected not suitable for cardiac surgery patients because of variability due to obesity and fluid imbalance.[8] Population specific equations can overcome the variability of FFM using

Non-standard abbreviations: BIS, bioelectrical impedance spectroscopy; BW, body weight (kg); CABG, coronary artery bypass graft; CRP, C-reactive protein (mg/L); DXA, dual-energy X-ray absorptiometry; ECW, extracellular water (L); EuroSCORE, European system for cardiac operation risk evaluation score; FFM, fat free mass (kg); FFMI, fat free mass index (kg/m^2); ICW, intracellular water (L); SF-BI, single frequency-bioelectrical impedance; WL, weight loss.

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doi:10.1016/j.clnu.2010.06.002

the SF-BI for obese and non-obese.[9] However, neither SF-BI nor DXA can differentiate between the extracellular water (ECW) part and intracellular water (ICW) part of FFM.[6] In fluid imbalance and undernutrition this differentiation is essential as ECW reflects hydration and ICW reflects nutritional status.[10]

Bioelectrical impedance spectroscopy (BIS) has the potential to overcome these limitations in differentiating between ECW and ICW. The BIS uses multi-frequencies from which ECW and ICW can be derived separately.[6,8] In addition, BIS uses equations based on physical models instead of the regression equations used in SF-BI.

The aim of this study was to assess preoperative and postoperative agreement in FFM between BIS and DXA in patients undergoing cardiac surgery.

2. Methods

2.1. Study design

In this single-center prospective study, all adult patients (≥18 y) visiting the preoperative outpatient clinic of the Department of Cardiothoracic Surgery at the Academic Medical Center were asked to participate. Patients were scheduled for elective open-heart surgery (isolated CABG or heart valve surgery) and had no existing organ failure other than their heart disorder. Patients with pacemakers were excluded.

Two weeks prior to elective surgery and two months after surgery, body composition was measured using BIS and DXA. The study protocol was approved by the institutional review board and all participants gave written informed consent.

2.2. Patient characteristics

Patient-, cardiac-, and operation-related baseline characteristics and the European System for Cardiac Operation Risk Evaluation score (EuroSCORE),[11] were extracted from medical case notes and from the standard electronic database of the Department of Cardiothoracic Surgery. Hemoglobin, CRP, albumin and pre-albumin concentrations were analyzed according to routine hospital procedures.

2.3. Definition of undernutrition and obesity

Preoperative undernutrition was defined as ≥5% weight loss in the preceding month and/or ≥10% weight loss in the preceding 6 months and/or BMI ≤21.0 kg/m^2 and/or FFM index (FFM divided by their body height squared, FFMI) ≤14.6 kg/m^2 in women and ≤16.7 kg/m^2 in men.[2,12] For these calculations the mean FFM from BIS and DXA measurements was used.

Postoperative undernutrition was defined as ≥4% postoperative loss of FFM and/or BMI ≤21.0 kg/m^2 and/or FFMI ≤14.6 kg/m^2 in women and ≤16.7 kg/m^2 in men. More than 4% loss of FFM was based on twice the test–retest variation of measuring FFM using the BIS or DXA (<2.0%).[13,14] Obesity was defined as BMI ≥30.0 kg/m^2.

2.4. Body composition measurements

Patients were asked about their usual weight and any weight changes during the preceding six months. Body weight was measured using an electronic beam scale with digital read-out to the nearest 0.1 kg (SECA, Hamburg Germany) with all patients barefoot and in their underwear. Body height was measured to the nearest 0.5 cm (SECA, Hamburg Germany).

After this, whole body FFM and fat mass were estimated using the BIS. The principle of bioelectrical impedance is based on the conductance of an electric current through body fluid. The BIS measures the impedance at a range of frequencies from which the resistances of ECW and ICW are extrapolated and subsequently FFM is calculated (Appendix).[15] Additionally, also the ECW/ICW ratio (ECW divided by ICW) was calculated. The BIS measurements were taken about 3 h after eating and within 30 min of voiding with a BodyScout (5–800 μA; 5 kHz–1 MHz) (Fresenius Kabi, Germany). The four-electrode method, as described by Lukaski et al.[16] was used on the right side of the body.

Whole body FFM and fat mass were also determined using a dual-energy X-ray absorptiometry total body scanner (DXA) (model QDR 4500W; Hologic, software version Windows XP 12.4, Waltham, MA). This scanner produces two X-ray beams at 100 and 140 kVp. Attenuation of the two beams depends on mass and type of tissue. Whole body scans were performed and whole body lean tissue, bone mineral content and fat mass are calculated according to computerized algorithms provided by the manufacturer. Whole body FFM was calculated by adding lean tissue and bone mineral content.

2.5. Statistical analyses

Changes between pre- and postoperative visits in body composition and hemoglobin, CRP, albumin and pre-albumin were analyzed using the paired *t*-test, or, if not normally distributed, the non-parametric Wilcoxon signed rank test.

Because body composition alters after cardiac surgery,[3] agreement in FFM between BIS and DXA was analyzed separately pre- and postoperatively. Subsequently, agreement in the percentage of FFM change from the pre- to postoperative periods was analyzed. Agreement was analyzed using Bland and Altman plots.[17] In addition, the correlation between the mean FFM values of BIS and DXA measurements and the difference in FFM between BIS and DXA (BIS minus DXA), i.e. the Bland and Altman plot, was analyzed using the Pearson correlation test, or, if not normally distributed, the Spearman correlation test was used. A similar approach was used to explore the correlations between BIS and DXA measurements separately and the difference in FFM between BIS and DXA.

Normality was tested using the Kolmogorov–Smirnov test. A p value ≤0.05 was considered to indicate a statistical significance.

3. Results

3.1. Subjects

Between October 2006 and December 2007, 84 patients undergoing cardiac surgery were eligible for inclusion. In December 2006 and January 2007, and between July and September 2007 no patients were included because no research capacity was available ($n = 28$). Twenty-three patients refused to participate. After inclusion two patients withdrew informed consent, one patient was lost to follow-up and in one patient the operation was not carried out. In two patients BIS data were not complete because of technical problems. In the preoperative BIS data there was one extreme, not sound, outlier. These data were excluded from further analysis.

The remaining data from 26 patients were analyzed. Their preoperative baseline characteristics are summarized in Table 1. Preoperative undernutrition was present in 3.8% ($n = 1$, BMI ≤21.0 kg/m^2) compared with 23.9% ($n = 7$) postoperatively; seven patients lost ≥4% FFM, 1 patient had a low FFMI and no patients had a low BMI. Obesity was present in 38.5% ($n = 10$) preoperatively compared with 30.8% postoperatively ($n = 8$).