Validating Body Fat Assessment by Bioelectric Impedance Spectroscopy in Taiwanese Hemodialysis Patients

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Objective: Obesity is becoming increasingly common in hemodialysis (HD) patients and is associated with inflammation and increased mortality. The primary aim of the present study was to evaluate the accuracy and variability of the bioimpedance device in measuring body fat in Taiwanese dialysis patients.

Design: Cross-sectional study.

Subjects: One hundred twenty-two adult patients receiving HD in a single hospital in Taiwan.

Setting: We compared the results of fat mass (FM) measured by dual-energy x-ray absorptiometry (DEXA) and bioelectrical impedance spectroscopy device (Body composition monitor, BCM).

Main Outcome Measurement: FM measured by BCM was calculated by subtracting fat-free mass (FFM) from body mass assuming fractional hydration of FFM of 0.73 or the proprietary prediction equations from the BCM model.

Results: Assessment of whole-body composition showed that percentage FM measured using the 2 techniques was highly correlated when using the BCM model or estimating from total body water using constant (0.73) hydration ($r = 0.87$, $P < .001$). There was no evident difference in measurement between patients gender. The Bland-Altman plot also showed good agreement of percentage of FM ($t = 3.82$; $P < .001$). In female patients, it was found that BCM significantly underestimated mean FM as compared to DEXA. However, the mean differences of the estimates between the methods were small (0.35 ± 3.00 kg) and with Bland–Altman plot the limits of agreements were −5.5 to 6.2 kg ($P = .40$) for FM in female patients.

Conclusions: Using DEXA as the reference test, BCM is a valid tool for the assessment of total body fat in HD patients. Hence, it may provide a more accessible tool for early detection of changes in body composition in these high-risk patients.

Introduction

PROTEIN-ENERGY WASTING (PEW) syndrome is very common in dialysis patients and severely affects their short-term survival. Along this line, the assessment of body composition in dialysis patients is of clinical importance. Low–body fat–free mass (FFM) had been shown to be a predictor of mortality in dialysis patients.[1-4] Moreover, a greater number of dialysis patients in Asia are obese, due to an overall increase in obesity and obesity-related disorders. This contemporary issue involving the treatment of both obese and nonobese sarcopenic patients has presented nephrologists with new challenges.[1] Current techniques used for the assessment of body composition in dialysis patients include subjective global assessment, anthropometric measurements, dual energy X-ray absorptiometry (DEXA), single-frequency bioimpedance analysis (SF-BIA), and multifrequency bioimpedance spectroscopy (BIS). DEXA is the most widely used and most thoroughly studied measurement technology in dialysis patients.[5-7] Despite its detailed and accurate assessment, this method is expensive, requires technical expertise, and cannot be repeated frequently due to the small amount of x-ray exposure during the examination. Additionally, few dialysis clinics have direct access to DEXA scanning.

Over the past few years, multifrequency BIS technique, a noninvasive, portable, and relatively inexpensive tool, allows clinicians to assess body composition. Such devices, including body composition monitor (BCM), may be useful to accurately measure and monitor changes in body fat

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mass (FM) and lean body mass (LBM) in both the general and dialysis populations. However, there are a number of factors that complicate the measurement of body composition in these patients, who often have significant changes in their fluid or components in different body compartments when compared with nonuremic eutrophic individuals. One major obstacle is the increase in the total body water (TBW), especially extracellular water (ECW) in relation to intracellular water (ICW), which impedes the accuracy of BC measurement when using current methods. For example, in patients with profound renal dysfunction, a nonphysiological expansion of ECW may confound estimates of hydration of FFM and lead to bias in the estimation of adiposity.[8] Hence, the expanded ECW may introduce systemic error into measures of FM affecting the precision and accuracy of measurements.[9]

During daily clinical practice, it may be difficult to detect loss of LBM or FM due to increased fluid retention. Hence, considering the increasing emphasis placed on identifying the dialysis patients at risk for malnutrition to provide earlier nutritional intervention, the development of noninvasive techniques to assess the nutritional status of these patients is important. The primary aim of the present study was to evaluate the accuracy and the variability of BCM in measuring body fat in Taiwanese hemodialysis (HD) patients.

Methods

Participants

Prevalent adult HD patients with dialysis vintages over 3 months were recruited. Both DEXA and BCM measurements were performed. Subjects with significant comorbid conditions such as cancer, heart failure, or severe liver disease and patients with mechanical valves, pacemakers, coronary artery stents, or implanted metallic devices were excluded. This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures were reviewed as well as approved by the Regional Hospital Ethics Committee. All subjects gave their written informed consent to participate in the study.

Measurement Procedures

The data was collected between May–September 2014. After fasting for a minimum of 8 hours and after avoiding hard physical exercise for 24 hours, participants were measured with DEXA and BCM on the day before dialysis.

Dual-Energy X-ray Absorptiometry (DEXA)

DEXA is a widely used reference method for body FFM and FM measurements.[10] DEXA was performed using a Lunar Prodigy (GE Medical Systems, Madison, WI). Whole-body scans were performed according to manufacturer's instructions, and body FM (FM_{DEXA}), LTM (LTM_{DEXA}) and bone mineral content were analyzed using the manufacturer's software. The DEXA method uses an X-ray tube with a filter to generate low-energy (40 kV) and high-energy (70 or 100 kV) photons. When photons at different energy levels pass through tissue, their absorptions can be expressed as a ratio of attenuation at lower or higher energy levels. DEXA estimate of FFM was calculated as a sum of LTM and bone mineral content estimates. All patients were examined by the same observer.

Bioelectric Impedance Spectroscopy

Whole-body bioelectric impedance spectroscopy (BIS) measurement using a body composition monitor (BCM: Fresenius Medical Care, Bad Homburg, Germany) was performed on each of the participants enrolled in the study by a specific member of the staff who had completed a training course in the BCM technique. The BCM measures the impedance spectroscopy at 50 different frequencies between 5 kHz and 1 MHz. Measurements were taken on the day before dialysis with the patient calm, supine, and relaxed in the dialysis bed for 10 minutes. Four electrodes were placed on the patient's hand and foot on the side contra lateral to their arteriovenous fistula. Specific exclusion criteria were dictated by the device and included history of a pacemaker, defibrillator, metallic sutures, or stent implantation and amputation of a major limb. As a multifrequency bioimpedance device, BCM not only provides extracellular (ECW_{BCM}), intracellular (ICW_{BCM}), and total body water (TBW_{BCM}) measurements but also estimates the body composition in terms of lean tissue mass (LTM_{BCM}—mainly muscle), fat mass (FAT_{BCM}), adipose tissue mass (ATM_{BCM}–mainly fat), and overhydration (OH) according to the body composition model.[11] This device combined BIS with the BCM model described in Chamney et al,[11] and it takes into account the dissimilar hydration of relevant tissues. Briefly, the device was modified to reflect the presence of excess fluid accumulated due to pathologic reasons, that is, patients with kidney failure. It has therefore set constants for each of the body composition compartment. This device has been shown to be as precise as the gold standard reference methods and has been validated against reference methods for volume status and body composition assessments in healthy and HD populations, with methods frequently used in the 4-compartment model. The percentage proportions of LTM_{BCM}, FAT_{BCM}, and ATM_{BCM} were denoted accordingly as $pLTM_{BCM}$, $pFAT_{BCM}$, and $pATM_{BCM}$.

Besides estimating body composition from the body composition model, LTM ($LTM_{TBW/0.73}$) was also calculated from TBW_{BCM} based on the assumption of a 73% hydration of the FFM.[8,12] Furthermore, $FM_{TBW/0.73}$ was derived from the difference between $LTM_{TBW/0.73}$ and body mass. The percentage proportions of $LTM_{TBW/0.73}$ and $FM_{TBW/0.73}$ were represented as $pLTM_{TBW/0.73}$ and $pFM_{TBW/0.73}$, respectively.

A summary of major abbreviations used in analysis is given in Appendix.