Validity of bioelectrical impedance analysis to assess fat-free mass in patients with head and neck cancer: An exploratory study

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ABSTRACT: *Background.* The purpose of this study was to validate bioelectrical impedance analysis (BIA) using the Geneva equation for fat-free mass (FFM) in patients with head and neck cancer.

Methods. In 24 patients with head and neck cancer, agreement between BIA (FFM_{BIA}) and dual energy x-ray absorptiometry (FFM_{DXA}) 1 week before (T_0), 1 month (T_1), and 4 months (T_2) after cancer treatment was analyzed.

Results. FFM_{BIA} did not differ from FFM_{DXA} (mean difference 0.71 $\pm$ 1.9, 0.30 $\pm$ 1.9, and 0.02 $\pm$ 2.1 kg) at any time point. Only at T_0, mean FFM correlated to the difference between FFM_{DXA} and FFM_{BIA} ($r = 0.48$; $p = .017$). Limits of agreement were 3.8, 3.7, and 4.1 kg, respectively. Concordance Correlation Coefficients were 0.98 at all time points.

Conclusion. BIA may be used to assess FFM with reasonable validity based on mean-level comparisons, but differences between BIA and DXA may vary by about 4 kg in an individual patient. These results require confirmation in a larger sample of patients with head and neck cancer. © 2013 Wiley Periodicals, Inc. *Head Neck* **36:** 585–591, 2014

KEY WORDS: bioelectrical impedance analysis, validity, fat-free mass, body composition, head and neck cancer

INTRODUCTION

Assessment of fat-free mass (FFM) is of clinical importance, as loss of FFM is the major characteristic of malnutrition. With a prevalence ranging from almost 20% to 55%, malnutrition is a frequently reported phenomenon in patients with head and neck cancer.[1,2] Malnutrition is associated with decreased immune function, resulting in an increased complication rate and decreased tolerance to cancer therapy.[3] Furthermore, malnutrition is associated with increased length of hospital stay[4] and has a negative impact on quality of life.[5,6] To improve nutritional status as early as possible, patients with head and neck cancer are routinely screened for malnutrition risk and referred to a dietitian perioperatively and during treatment with intensive (chemo)radiation. Assessment of FFM is an important element of nutritional assessment to correctly classify patients at risk, to monitor nutritional status during and after cancer treatment, and to tailor doses of chemotherapy to the patients' characteristics.[7]

Body composition measurement is important not only in the initial phase of cancer disease but also during and after treatment. In patients with head and neck cancer, almost two thirds of the weight lost during treatment is composed of FFM.[8] In underweight patients, loss of FFM may be clinically visible, but it may not be in normal or overweight patients and, thus, quantification of FFM is essential. Furthermore, body composition measurements are needed to evaluate whether weight gain is characterized by gain of FFM or fat mass.

Bioelectrical impedance analysis (BIA) is a widely used noninvasive, portable, and inexpensive method to assess body composition in humans.[9] BIA is based on impedance of a low-voltage current passing through the body.[9] Impedance (Z) consists of 2 components: resistance (R) and reactance (X_c), and the relationship can be represented by the equation: $Z^2 = R^2 + X_c^2$. Subsequently, body water, FFM, and fat mass can be calculated from impedance using regression equations based upon the empirical relationship between the impedance quotient ($length^2/R$) and water volume.[9]

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R, X_c, and impedance can be measured over a range of frequencies. A single-frequency BIA analyzer uses a 50 kHz current, which not only passes through extracellular water (ECW) but also is thought to penetrate the cell membranes, thus allowing for the estimation of total body water (TBW). The question of whether 50 kHz is a high enough frequency to completely penetrate the cell membrane in chronically ill patients has given rise to interest in the applications of multiple frequency and spectroscopy devices.[10,11] A multifrequency device, such as the one used in the current study (QuadScan, BodyStat, Isle of Man, UK) applies the bioelectrical current at a frequency of 5, 50, 100, and 200 kHz. Because the current applied at 5 kHz cannot penetrate the cell membrane, the impedance measured is purely resistive and allows for the estimation of the ECW compartment. The utilization of impedance data measured at one of the higher frequencies, ideally 200 kHz, allows for the estimation of TBW. Subsequently, intracellular water (ICW) can be calculated by subtracting ECW from TBW. Thus, multifrequency BIA has the advantage over single-frequency BIA in that it can be used to separately assess the individual fluid compartments.

Validity of both single-frequency and multiple-frequency BIA is population-specific, as it can be influenced by hydration status, fat fraction, and geometrical body shape, among other factors.[9] In regression equations used to calculate FFM, the assumption is made that FFM is constantly hydrated at 73%. Single-frequency BIA has been demonstrated to be valid in healthy subjects as well as in patients having normal hydration and normal electrolyte balance, if appropriate regression equations and standardized procedures are used.[9] The Geneva equation is a commonly used regression equation, as it is valid to predict FFM in healthy subjects 20 to 94 years, with varying body mass indices (BMIs) of 17.0 to 33.8 kg/m^2.[12] In clinical practice, however, hydration status may be disturbed (ie, increase in ECW/ICW ratio and increase in TBW/FFM) because of malnutrition.[13] As malnutrition is a common problem in patients with head and neck cancer,[1,2,12] validity of BIA might be limited in this group of patients.

In this exploratory study, our purpose was to test the validity of BIA using the Geneva equation to assess FFM in patients with head and neck cancer in both the pretreatment and posttreatment periods.

MATERIALS AND METHODS

This longitudinal study was approved by and performed in accord with the standards of the Ethics Committee of the University Medical Center Groningen and Medical Center Leeuwarden (METc 2007/244), The Netherlands. Informed consent was obtained from all participants.

Study design

A consecutive series of 59 adult patients with histologically confirmed head and neck carcinoma was asked to participate in this prospective study between March 2008 and September 2009. All patients were to be treated within the setting of the multidisciplinary head and neck cancer group of the University Medical Center Groningen and Medical Center Leeuwarden, The Netherlands. Patients willing to participate were assessed after a scheduled visit to the hospital. Diagnosis and treatment information were retrieved from medical records and included: tumor localization, T classification, type of cancer treatment, and dates of start and end of cancer treatment.

Inclusion criteria were age $\geq$18 years, white ethnicity, primary or recurrent squamous cell carcinoma in the oral cavity, oropharynx, hypopharynx or larynx, and those awaiting treatment with curative intent consisting of radiotherapy (including unilateral or bilateral neck irradiation) either alone or in combination with chemotherapy or after surgery.

Exclusion criteria were a secondary tumor in another region than the head or neck, a recurrent, residual, or new tumor diagnosed within 4 months after inclusion, visible edema, cutaneous disease, BMI $<$16 kg/m^2 or $>$34 kg/m^2, and comorbidity (liver, kidney or cardiac disease, chronic obstructive pulmonary disease, muscular disease, or uncontrolled diabetes mellitus).[12]

Measurements

All measurements except for body height were carried out at 3 time points: T_0, the week before the start of cancer treatment; T_1, 1 month after the end of cancer treatment; and T_2, 4 months after the end of cancer treatment.

Patients were not allowed to eat or drink during the 4 hours preceding the measurements. Patients were measured in their underwear, without shoes, and after voiding their bladders.

Body height was measured to the nearest 0.1 cm at the first study measurement using a stadiometer (Seca 222, Seca Medical Scales & Measuring Systems, Birmingham, UK). Body weight was measured to the nearest 0.1 kg on a calibrated Seca 701 scale (Seca Medical Scales & Measuring Systems). Patients were asked to provide an estimate of their usual body weight (without clothes and shoes) at 6 months and 1 month before the start of cancer treatment. BMI (kg/m^2) was calculated as actual body weight/height^2. Percentage weight loss in the last month was calculated as: [(body weight 1 month ago – actual body weight)/body weight 1 month ago] $\times$ 100. Percentage weight loss in the last 6 months was calculated similarly. Malnutrition was defined as weight loss $\geq$10% in the last 6 months or $\geq$5% in the last month.[14–16]

BIA was used to measure R, Xc, and impedance (Z), using the BodyStat QuadScan 4000 (BodyStat). Patients were put in a supine position 15 minutes before and during the measurement. The measurements were performed according to a strict protocol following standardized procedures.[17] The instrument was calibrated in accord with the manufacturer's instructions. Bioimpedance measures were taken at 3 frequencies (5 kHz, 50 kHz, and 200 kHz) by the QuadScan device. The device software generated measures of TBW from the 200 kHz data and measures of ECW from the 5 kHz data. Subsequently, ICW was calculated by deducting ECW from TBW. Furthermore, ECW/ICW ratio was calculated. R and Xc measured at 50 kHz were used to estimate FFM with the Geneva equation[12]: $-4.104 + (0.518 \times \text{cm height}^2/R_{50\text{kHz}}) + (0.231 \times \text{kg weight}) + (0.130 \times Xc_{50\text{kHz}}) +$

(4.229 × sex [men = 1, women = 0]). Phase angle was calculated as arc-tangent (Xc_{50kHz}/R_{50kHz}) × 180°/π) and expressed in degrees.[18] Impedance ratio was calculated as $impedance_{200kHz}/impedance_{5kHz}$.[19]

At each study measurement, the BIA measurement was followed by a dual energy x-ray absorptiometry (DXA) scan (fan beam), with a Hologic Discovery A (Hologic, Bedford, MA). Scans were analyzed using the system's software and provided estimates of regional and whole-body total mass, lean tissue, fat, and bone mineral mass. FFM, as assessed by DXA (FFM_{DXA}), was calculated as the sum of lean mass and bone mineral mass. Appendicular skeletal muscle index (kg/m^2) was calculated as lean mass of arms and legs/length^2. FFM_{BIA} was compared to the reference value FFM_{DXA}.[16] Mean FFM was calculated as (FFM_{BIA} + FFM_{DXA})/2.

Statistical analysis

Statistical analysis was performed using SPSS 18.0 for Windows software (SPSS, Chicago, IL) and the programming system R (R Development Core Team, Vienna, Austria, 2011). The FFM measurements by DXA and BIA were tested for normality by the Shapiro–Wilk normality test. Per time point, the equality of means (systematic bias) was tested by the paired *t* test and the equality of variance by the F test. This strategy may lead to the conclusion that the measurements are similarly distributed.

Results are expressed as mean ± SD. In all analyses, statistical significance was set at $p < .05$. Changes in body composition, volume of body fluids, and phase angle over time were analyzed by the likelihood ratio test from random effects models using a random intercept for each patient and time points as fixed effects.[20] Pearson's correlation coefficient *r* was used to analyze the relationship between mean FFM and the difference between FFM_{DXA} and FFM_{BIA}.

Various aspects of validity were investigated per time point, as we expected differences in mean FFM over time because of the head and neck cancer treatment between T_0 and T_1. First, paired *t* tests were performed to analyze mean differences in FFM_{BIA} and FFM_{DXA}. Scatter plots of the FFM_{DXA} and FFM_{BIA} measurements are given with the regression line of the DXA measurements on those of the BIA. This quickly reveals how the BIA measurements co-vary with the corresponding DXA measurements and how well the DXA measurements can be predicted by the corresponding BIA measurements. When the difference between measurements is small, then a regression line with its 95% prediction interval may well illustrate the predictability (coverage) of the DXA measurements by BIA.

The F(22,22)-test for equality of variances was performed to test whether the SDs of FFM_{BIA} significantly differed from the SDs of FFM_{DXA}. Bland–Altman plots were constructed to diagnose for (1) outliers, (2) increase of measurement variance with increasing FFM size, (3) limits of agreement, and (4) systematic error that may be detected by observation of correlations between the mean FFM and the difference between FFM_{DXA} and FFM_{BIA}. Furthermore, the agreement between the DXA and BIA measurements was determined by the concordance correlation coefficient (CCC),[21] which is the product of accuracy and precision, where accuracy is a coefficient expressing the degree of equality of 2 measurements with respect to the means and SDs, and precision is defined as the degree of linear relationship (correlation).

The effects of measurement methods over time are estimated by random effects models, designating patients as random, and time points (T_0, T_1, and T_2), as well as measurement methods (DXA and BIA) as fixed effects. To evaluate equivalence of conclusions, time effects are estimated for each method (DXA and BIA) in separate models.

TABLE 1. Patient characteristics ($n = 24$).

Variables	No. of patients (%)*
Sex	
Male	20 (83)
Female	4 (17)
Tumor localization	
Larynx	6 (25)
Hypopharynx	2 (8)
Oropharynx	9 (38)
Oral cavity	7 (29)
T classification	
T1	1 (4)
T2	7 (29)
T3	4 (17)
T4	12 (50)
Malnourished†	4 (17)
BMI (kg/m^2)	
<18.5 (underweight)	4 (17)
18.5–25 (normal weight)	12 (50)
>25–30 (overweight)	5 (21)
>30 (obese)	3 (13)
Age, y, mean (SD)	60.4 (8.3)

Abbreviation: BMI, body mass index.

*The sum of percentages may be dissimilar to 100% because of rounding.

†Weight loss ≥10% in the last 6 months or ≥5% in the last month.

RESULTS

In total, 35 patients were willing to participate in this study. The main reason for nonparticipation was the expected physical or mental burden ($n = 16$). Other reasons were: too busy because of the disease itself ($n = 6$) and not interested ($n = 2$). Six patients were excluded: 2 patients had a metal hip prosthesis, 2 patients had an extreme BMI (<16 kg/m^2 and >34 kg/m^2), 1 patient had ankle edema, and 1 patient did not receive postoperative radiotherapy. Of the 29 included patients, 5 dropped out during the study period: 2 patients died, and 3 patients dropped out because of fatigue. Data from the remaining 24 patients were used in all analyses.

Baseline characteristics of the patients are listed in Table 1. Prevalence of malnutrition was 17% (4 of 24 patients) at T_0, 46% (11 of 24 patients) at T_1 and 21% (5 of 24 patients) at T_2. The majority of the patients (71%) were aged <65 years.

The Shapiro–Wilk Normality test on FFM_{DXA} at T_0, T_1, and T_2 ($p = .976$, $p = .747$, and $p = .629$, respectively), as well as on FFM_{BIA} ($p = .469$, $p = .602$, and $p = .568$, respectively) indicated no violations of normality. Hydration of FFM (TBW_{BIA}/FFM_{DXA}) was 0.75,

TABLE 2. Changes in body composition during and after head and neck cancer treatment ($n = 24$).

	T_0	T_1	T_2	p value
Body $weight_{scale}$, kg, mean (SD)	74.4 (17.3)	71.3 (14.4)	71.5 (12.8)	< .0001
Body $mass_{DXA}$, kg, mean (SD)	75.3 (17.4)	72.1 (14.6)	72.3 (13.0)	< .0001
BMI, kg/m^2, mean (SD)	23.7 (4.7)	22.7 (4.0)	22.8 (3.4)	< .0001
FFM_{DXA}, kg, mean (SD)	56.4 (10.9)	54.2 (10.0)	54.4 (9.9)	.00014
FFM_{BIA}, kg, mean (SD)	55.7 (10.0)	53.9 (9.4)	54.4 (9.4)	.00016
TBW (l), mean (SD)	42.0 (7.6)	41.1 (6.9)	41.0 (6.8)	< .0001
TBW/FFM_{DXA}, kg, mean (SD)	0.75 (0.02)	0.76 (0.03)	0.76 (0.03)	< .0001
ECW (l), mean (SD)	18.2 (2.79)	18.0 (2.64)	18.0 (2.65)	.0186
ICW (l), mean (SD)	23.8 (4.8)	23.1 (4.3)	23.0 (4.3)	< .0001
ECW/ICW ratio (l), mean (SD)	0.77 (0.07)	0.79 (0.06)	0.79 (0.07)	.004
Phase angle (degree), mean (SD)	6.2 (0.73)	5.8 (0.62)	5.9 (0.72)	< .0001
Impedance ratio (l), mean (SD)	0.79 (0.03)	0.80 (0.02)	0.77 (0.15)	< .0001

Abbreviations: DXA, dual x-ray absorptiometry (DXA); BMI, body mass index; FFM, fat-free mass; TBW, total body water; ECW, extracellular water; ICW, intracellular water.

0.76, and 0.76 at T_0, T_1, and T_2, respectively (Table 2). Body weight, BMI, FFM, volume of body fluids, phase angle, and impedance ratio significantly declined ($p < .05$) during the treatment period (T_0 to T_1). Only at T_2, ECW/ICW ratio of malnourished patients tended to be higher (0.85 ± 0.07) than that of well-nourished patients (0.77 ± 0.05; $p = .071$). No differences in TBW/FFM between malnourished and well-nourished patients were found at any time. Moreover, no significant differences were found in TBW/FFM between patients with a BMI ≤ 25 kg/m^2 and a BMI >25 kg/m^2.

FFM_{BIA} did not significantly differ from FFM_{DXA} at any time point (FFM_{DXA} minus FFM_{BIA} = 0.7 ± 1.9 kg, 0.3 ± 1.9 kg, and 0.02 ± 2.1 kg; $p = .081$, $p = .447$, and $p = .957$, respectively). Furthermore, no differences in FFM_{BIA} minus FFM_{BIA} between malnourished and well-nourished patients were found at any time point ($p = .798$, $p = .111$, and $p = .241$, respectively).

The difference between body mass assessed by DXA and by weight scale was 0.8 ± 0.5, 0.9 ± 0.5, and 0.8 ± 0.6 at T_0, T_1, and T_2, respectively.

Scatter and Bland-Altman plots

Figure 1A and 1B present a scatter plot of the BIA (horizontally) and the DXA measurements (vertically) of FFM for T_0 and T_1. Visual inspection of the plots does not indicate any systematic underestimation or overestimation of the FFM_{BIA} values compared to FFM_{DXA}. The size of the prediction interval is about ± 4 kg along the whole range of FFM_{BIA} values. Figure 2A and 2B show Bland–Altman plots of the mean of the measurements by DXA and BIA (horizontally) and the difference between the 2 measurements (vertically; FFM_{DXA} minus FFM_{BIA}) for T_0 and T_1. The lower/upper 95% limits of agreement for T_0, T_1, and T_2 are -3.03, 4.46; -3.43, 4.04; and -4.07, 4.12, respectively.

The correlation between the mean FFM and the difference between FFM_{DXA} and FFM_{BIA} at T_0, T_1, and T_2 are $r = 0.48$ ($p = .017$), $r = 0.29$ ($p = .175$), and $r = 0.26$ ($p = .228$), respectively. Visual inspection reveals no increase of the spread of measurements as the mean increases along the horizontal axis. The obtained CCCs of 0.98 for all 3 time points (T_0, T_1, and T_2) indicate a strong agreement between FFM_{DXA} and FFM_{BIA}. Furthermore, the change in FFM_{BIA} between T_0 and T_2 is strongly associated with the change in FFM_{DXA} between T_0 and T_2 (CCC = 0.837). In the random effects analysis,

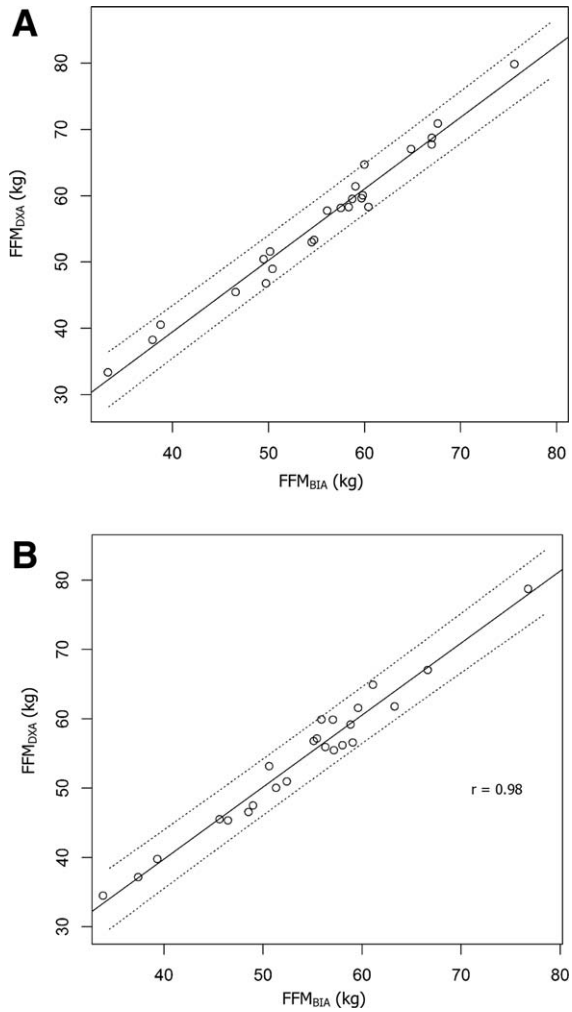

FIGURE 1. (A) Fat-free mass (FFM) measurements by dual x-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA) at T_0. (B) Measurements by DXA and BIA at T_1. The size of the prediction interval is about $\pm$ 4 kg along the whole range of FFM_{BIA} values in both panels.

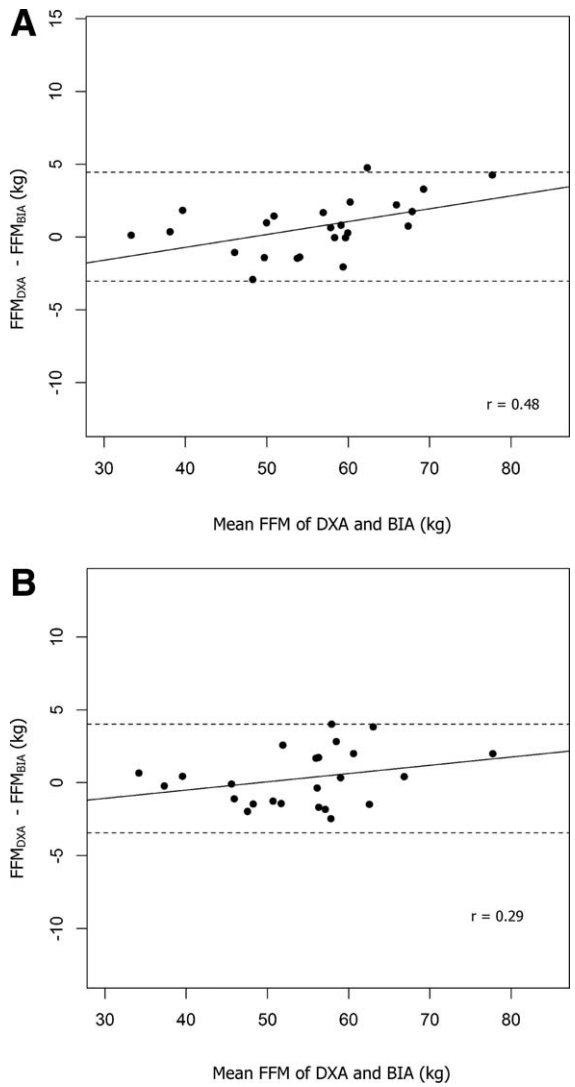

FIGURE 2. (A) Bland–Altman analysis for fat-free mass (FFM) between dual x-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA) at T_0. (B) Bland–Altman analysis for FFM between DXA and BIA at T_1. The dotted lines represent the limits of agreement defined as ±1.96 times the SD of the difference in both panels.

no significant differences between the methods were found.

The models using a random patient effect, fixed time, and method (BIA/DXA) effects revealed an effect by BIA of -0.35 kg that was not significant from the likelihood ratio test ($p = .25$) and with respect to T_0 a fixed time (treatment) effect of -1.97 kg at T_1 and -1.67 kg at T_2, respectively, both being significant ($p < .0001$ by the Wald test). Based on the FFM_{DXA} data, specifically, these effects were -2.17 kg and -2.02 kg, and based on the FFM_{BIA} data these effects were -1.76 kg and -1.33 kg. All fixed effects were significant at the 0.005 level.

DISCUSSION

This study is the first to test the validity of BIA for the assessment of FFM in patients with head and neck cancer. We compared FFM_{BIA} using the Geneva prediction equation[12] with FFM_{DXA}. The results of our study show that there is no systematic difference between the BIA and DXA measurements. On the group level, BIA slightly underestimated FFM by <1 kg, both pretreatment and posttreatment. Furthermore, on the individual level, differences between BIA and DEXA were <4.0 kg in approximately 95% of the patients. These limits of agreement should be evaluated against the range of the mean FFM measurements, which was 33 to 80 kg. Given that the limits of agreement are <10% of the mean FFM, the level of agreement between DXA and BIA in these patients can be considered quite good.[22] Because FFM_{DXA} and FFM_{BIA} measurements are equally distributed and strongly associated (all CCC = 0.98), both need to be almost equally valid with respect to a gold standard to measure FFM (eg, the multicomponent model).[23]

Although the validity of various 50 KHz single-frequency BIA equations has been well studied in comparison to densitometry and deuterium dilution for body compartments other than FFM (eg, % body fat and TBW), only a few studies have investigated the agreement between 50 kHz BIA and DXA for FFM, although none have evaluated the Geneva equation. All of these studies have been performed in nonclinical populations.[24–26] In the assessment of FFM, DXA agreed well with BIA in both elderly subjects ($r = 0.85$)[24] using the Roubenoff equation and healthy subjects ($r = 0.96$) using the Kotler equation.[25] However, similar to our study, Pateyjohns et al[26] found a significant correlation ($r = 0.35$) between the size of the mean FFM and the difference between BIA and DXA in a study in healthy overweight and obese men (BMI 28–43 kg/m^2). In that study, the obesity-specific BIA equation developed by Segal et al[27] was used for obese subjects and the Lukaski equation was used for nonobese subjects.[28] These regression equations were validated against densitometry and hydrodensitometry, respectively. Although not statistically significant, the Geneva equation seemed to slightly underestimate FFM in our patients with head and neck cancer, whereas in the study by Pateyjohns et al,[26] the Lukaski and Segal equations were observed to overestimate FFM by 2.5 kg. Furthermore, the limits of agreement found in our study were much smaller than those reported by Pateyjohns et al[26] (<4.0 kg vs 7.9 kg, respectively). The fact that they were evaluating single-frequency BIA using 2 different equations that had been validated by methods other than DXA, may have been responsible for the large difference observed between BIA and DXA FFM measurements in the study by Pateyjohns et al.[26]

From the findings of the current study, we consider BIA using the Geneva equation appropriate for FFM assessment in patients with head and neck cancer in clinical practice. Compared to DXA, BIA has the advantages of being inexpensive, noninvasive, and it can be performed by the clinical dietitian as part of a comprehensive nutrition assessment. Monitoring of FFM is important because body weight poorly reflects the size and changes in FFM during illness.[11] Loss of FFM suggests loss of body cell mass, the protein rich compartment of the body that is adversely affected in catabolic states and is related to clinical outcome.[9] Currently, it is unclear

how body composition changes in the long-term in patients with head and neck cancer. The pitfall in current practice is that after initial weight loss, body weight may increase after recovery from treatment, but the weight gain may be characterized by increase of fat mass instead of FFM. Furthermore, we previously demonstrated that lean mass depletion may be present already at diagnosis, despite a normal BMI.[8] In clinical practice, use of BIA may enable early identification and initiation of treatment of lean mass depletion and malnutrition.

The cause of the relationship between the magnitude of FFM and the difference between FFM_{BIA} and FFM_{DXA} observed in our study at T_0 remains unclear. We chose the Geneva equation to assess FFM, because in absence of a cancer-specific equation for FFM, the Geneva equation seemed most appropriate because of its validity in subjects with a wide range of age and BMI.[13] However, during illness, the assumptions underlying prediction equations developed in healthy subjects may not be equally valid for all types of patients. In particular, BIA prediction equations to assess FFM assume that FFM is constantly hydrated at 73%.[29] In healthy subjects, TBW/FFM normally ranges between 0.69 and 0.76 and this ratio has been observed to vary between 0.67 and 0.82 in different patient populations.[30] In our study, hydration of FFM was >73% at T_0, as well as at T_1 and T_2 (median 0.75–0.76). However, in our study, altered hydration could not explain differences between FFM_{BIA} and FFM_{DXA} at T_0. Moreover, age, body weight, BMI, malnutrition, time lying in supine position before the BIA measurement, and technical error (difference between weight by scale and weight by DXA) did not seem to be related to the difference between FFM_{DXA} and FFM_{BIA} at T_0 either.

This study had some limitations. First, prevalence of malnutrition may have been underestimated. The majority of the nonparticipants declined participation because of anticipated physical or mental burden. In these patients, malnutrition may have played a role in their decision not to participate. Because of the small sample size, this study lacks statistical power. The prevalence of malnutrition may also have been underestimated by the use of self-reported usual body weight. The asked body weight at 6 months and 1 month before the start of cancer treatment was either a recalled self-measured body weight, or a recalled estimated body weight. A recalled body weight is not 100% accurate. To avoid inaccuracy in body weight because of differences in weight of clothing, we asked for body weight without clothes. From data of the National Health and Nutrition Examination Survey 2001 to 2006, it is known that men in the age of 50 to 59 years (n = 912) and 60 to 69 years (n = 964), the age groups most representative of our studied population, slightly (not significantly) overestimate their body weight by 0.07 kg (95% confidence interval (CI), -0.19 to 0.33) and 0.24 kg (95% CI, -0.03 to 0.51), respectively. Women in these age groups are known to underreport their weight by -1.41 kg (95% CI, -1.74 to -1.08) and -1.00 kg (95% CI, -1.25 to -0.76), respectively.[31] Although, on the group level, differences between measured and self-reported body weight are very small, individual differences may be larger (ranging from about -8 to 8 kg). Because of the small sample size, we cannot rule out that prevalence of malnutrition has been underestimated or overestimated. We found no statistically significant differences in FFM_{BIA} minus FFM_{DXA} (p = .798) and in hydration status (p = .959) between malnourished and well-nourished patients at T_0, but the small sample size may have caused a type II error. Therefore, future studies with a larger sample size and sufficient power are needed to cross-validate our findings.

Second, this study was limited by the reference method used. We used DXA as our reference method for the assessment of FFM, because we did not have access to the more sophisticated technology required for the use of a multicomponent assessment model. DXA is a widely accepted reference method for the assessment of FFM because of its good precision (variation coefficient 1.2%[32] to 2%[33] for the measurement of lean mass [ie, FFM without bone mass]),[34] but is also, in part, based on the assumption that FFM is constantly hydrated at 73%.[35] Although hydration of FFM was slightly elevated in our patients, we assume that the effect of FFM hydration on the agreement between BIA and DXA is minimal, as variations of ±5% in the water content of FFM have been reported to result in only small errors (<0.5 kg) in FFM measured by DXA.[36]

In conclusion, the current study provides evidence that BIA may be an acceptable tool for assessment of FFM in patients with head and neck cancer in the clinic, based on good agreement in terms of group mean-level comparisons, and based on limits of agreement indicating that differences between BIA and DXA may vary by no more than 10% in an individual patient. The results of this exploratory study need to be confirmed in a larger sample of patients with head and neck cancer.

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