Prognostic values of muscle mass assessed by dual-energy X-ray absorptiometry and bioelectrical impedance analysis in older patients with heart failure

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Abstract

Aim: This study aimed to compare bioelectrical impedance analysis (BIA) and dual-energy X-ray absorptiometry (DEXA) in measuring skeletal muscle mass (MM) and its prognostic implications in old patients with heart failure.

Methods: We prospectively evaluated MM measured by both BIA and DEXA in 226 hospitalized elderly (≥65 years) patients with heart failure. The cut-off values proposed by the Asian Working Group in Sarcopenia were used to define low MM. The prognostic endpoint was all-cause death.

Results: The median age of the cohort was 82 (interquartile range [IQR]: 75-87) years, and 51.8% of patients were male. According to the BIA and DEXA, 177 (78.3%) and 120 (53.1%) patients were diagnosed with low MM, respectively, and the two assessment tools showed poor agreement (Cohen's Kappa coefficient: 0.294). During the follow-up, 32 patients (14.2%) died; only low MM defined by DEXA (hazard ratio [HR] 2.45, 95% confidence interval [CI] 1.05-5.72, p=0.039), but not BIA (HR 1.03, 95% CI 0.35-3.06, p=0.955), was associated with poor prognosis after adjusting for pre-existing risk factors. Moreover, low MM defined by DEXA (net reclassification improvement [NRI]: 0.58, p<0.001), but not BIA (NRI: - 0.005, p=0.975), provides incremental prognostic predictability when considered with pre-existing risk factors and brain natriuretic peptide level at discharge.

Conclusions: In elderly hospitalized patients with heart failure, low MM defined by DEXA and BIA show significant discordance. The MM defined by DEXA, but not BIA, provides additional prognostic value to pre-existing prognostic models.

Key words: Heart failure, muscle mass, dual-energy X-ray absorptiometry, bioelectrical impedance analysis, prognosis

Introduction

Heart failure (HF) is one of the major diseases globally and the number of patients is increasing mainly because of the ageing society. [1-3] Despite the improvements in treatment of cardiovascular disease, the morbidity and mortality of patients with heart failure are unacceptably high. Sarcopenia is defined as the decrease in skeletal muscle mass and muscle strength or walking speed seen in the elderly which is strongly related to ageing. However, sarcopenia is also associated with other diseases, such as secondary sarcopenia and heart failure.[4] As numerous studies have already established that sarcopenia is generally associated with poor prognosis in patients with heart failure,[5,6] diagnosing sarcopenia in patients with heart failure is important in terms of risk stratification. Assessment of muscle mass (MM) comprises an important part of the current diagnostic criteria of sarcopenia. Indeed, the recently revised European consensus on definition and diagnosis (EWGSOP2)[7] and Asian Working Group for Sarcopenia (AWGS2019)[8] reported that assessing muscle mass is required to define sarcopenia. Regarding the measurement method of MM, these guidelines recommend dual-energy X-ray absorptiometry (DEXA) and bioelectrical impedance analysis (BIA) for evaluation of muscle mass. These two methods are quick and noninvasive; however, the agreement between them has been validated only in the general population[9-11] and cancer patients.[12] Only a limited number of studies with small sample sizes have evaluated the agreement between DEXA and BIA on measured muscle mass in patients with heart failure.[13] Moreover, although patients with heart failure are susceptible to fluid retention which may impact the accurate measurement of muscle mass using these modalities, it has been unclear whether muscle mass measured by DEXA and BIA provides the same prognostic information in

patients with heart failure. The purpose of this study was to examine the agreement between DEXA and BIA regarding appendicular skeletal muscle mass measurement and its prognostic value in older patients with heart failure.

Methods

Patients and data collection

We analysed patients who were enrolled into two prospective studies on elderly hospitalized patients with heart failure at Kameda Medical Center, which are the Prevalence and prognostic value of physical and social frailty in geriatric patients hospitalized for heart failure (FRAGILE-HF) and Comparison of various methods in evaluation of sarcopenia in patients with heart failure (SONIC-HF). The details of FRAGILE-HF have been published elsewhere.[14] SONIC-HF investigated the prognostic impact of measuring muscle mass and function using ultrasound as well as anthropometric measurements. Both studies have already finished patient enrolment and used exactly the same inclusion/exclusion criteria: included hospitalized patients aged ≥65 years with decompensation of heart failure who could ambulate at discharge. The exclusion criteria for both studies were: (1) previous heart transplantation or left ventricular assist device implantation, (2) chronic peritoneal dialysis or hemodialysis, and (3) acute myocarditis. Patients with missing brain natriuretic peptide (BNP) or N-terminal-proBNP measurements and patients with a BNP level <100 pg/mL or N-terminal-proBNP level <300 pg/mL at admission were also excluded as the diagnosis could be unclear in these cases. For those who were admitted more than once during the study period, only the first hospitalization was

registered. As part of the study protocol in both studies, investigators were asked to perform both DEXA and BIA in both studies before discharge as long as the hospital is well equipped to perform both tests during the hospitalization.

All participants were notified regarding their participation in the studies, and it was explained that they were free to opt out of participation at any time. Both studies complied with the Declaration of Helsinki and Japanese Ethical Guideline for Medical and Health Research involving Human Subjects. The study protocols of the two studies and joint analysis of the results were approved by the ethics committee of Kameda Medical Center.

Measurement of DEXA and BIA

The evaluations of muscle mass were performed by trained personnel before patient discharge. Body composition was measured by DEXA performed with QDR-Horizon A (Hologic, Inc., MA, USA). The X-ray releases a beam with different energies (100 and 140 kVp) that undergo different attenuation when passing through body tissues, allowing distinction between bone, fat, and fat-free mass. The calibration was performed daily to verify the linearity and accuracy of area measurements, density, and bone mass. The maximum weight acceptable for patients in the DEXA is 226 kg. Body composition assessed by BIA was calculated, considering age, sex, weight, and height. The BIA equipment used is the InBody 230 (Biospace Co., Ltd, Seoul, Korea), with multifrequency (20, 100 kHz) and tetrapolar eight-point tactile electrode system coupled with a digital scale.

We measured the appendicular skeletal muscle mass using DEXA and BIA, and the appendicular skeletal muscle mass index (ASMI) was calculated as the sum of muscle mass in the extremities divided by height squared (kg/m^2). The cut-off values proposed by the Asian Working Group in Sarcopenia were used to define low MM (BIA, male ≤ 7 kg/m^2 and female ≤ 5.7 kg/m^2; DEXA, male ≤ 7 kg/m^2 and female ≤ 5.4 kg/m^2).[8] Both DEXA and BIA were conducted within median 0 (interquartile range [IQR]: -2 to 1) days interval, which were performed when study patients were clinically in hemodynamically compensated state without any intravenous treatments for heart failure before discharge.

Prognostic outcomes

The prognosis of patients who participated in these studies were prospectively collected. The endpoint of this study was all-cause death, and patients' statuses were collected up to October 2019. After discharge, most patients were followed up in outpatient clinics and prognostic data were obtained from medical records of each hospital. For those without follow-up data in the outpatient clinic of each hospital, the prognostic data were achieved from telephone interviews with the medical records department of other medical facilities that took care of the patient or with their family.

Statistical analysis

Data were expressed as mean and standard deviation for normally distributed variables, and as median with IQR for non-normally distributed data. Categorical data were expressed as numbers and percentages. The

correlation between baseline characteristics of each group were compared using t-test, one-way analysis of variance test, Kruskal-Wallis test, or Chi-squared tests, as appropriate. When necessary, variables were transformed for further analyses. Cohen's kappa coefficient was used to assess agreement in presence of low MM defined by DEXA and BIA. The Bland–Altman plots were used to assess the agreement of the two methods in evaluating body composition.[15] The body compositions were evaluated in three parts: total (arms and legs), arms, and legs. In the Bland–Altman plots, the systematic bias was calculated as the mean difference between the values obtained by the two methods, and the 95% limits of agreement were calculated as the bias ± 2 SD of the differences between methods. The probability of all-cause death over free survival stratified by low MM/normal MM was calculated using Kaplan-Meier estimates, and were analysed using the log-rank test. For prognostic analysis, the hazard ratios (HRs) of low MM defined DEXA and BIA versus the normal MM group were adjusted for the Meta-Analysis Global Group in Chronic Heart Failure (MAGGIC) risk score in the Cox regression model.[16] The MAGGIC risk score is based on 13 independent predictors of long-term mortality, including age; sex; systolic blood pressure; left ventricular ejection fraction; body mass index; creatinine level; New York Heart Association (NYHA) class; diabetes mellitus; chronic obstructive pulmonary disease; current smoker; diagnosis of heart failure in the past 1.5 years; and not taking beta blocker, angiotensin-converting enzyme inhibitor, or angiotensin receptor blocker. The model validation for Japanese heart failure patients has been already shown.[17,18] In addition, we adjusted for log-transformed BNP (log BNP) at discharge in the prognostic model as it has been shown to improve prognostic predictability.[17] To assess whether low MM defined by DEXA and BIA was associated with improved

performance of the conventional risk model for predicting mortality, we constructed receiver operating characteristic (ROC) curves for logistic regression models with MAGGIC score plus log BNP, MAGGIC score plus log BNP plus low MM defined by BIA, and MAGGIC score plus log BNP plus low MM defined by DEXA. Areas under the curves (AUCs) were compared using the DeLong's method.[19] Continuous net reclassification improvement (NRI) and integrated discrimination improvement (IDI) were also calculated to evaluate the additive prognostic value of low MM defined by DEXA and BIA.[20] Statistical analyses were performed using R version 3.6.3 (R Foundation for Statistical Computing, Vienna, Austria; ISBN 3-900051-07-0, URL http://www.R-project.org). A two-sided P-value of <0.05 was considered statistically significant.

Results

Study patients and patient characteristics between those with and without low MM

During the study period, 226 hospitalized patients aged ≥65 years were registered in the study. The median age of the study population was 82 (IQR: 75–87) years old, and 51.8% were male. According to BIA and DEXA, 177 (78.3%) and 120 (53.1%) were defined as having low MM, respectively. Table 1 shows the baseline characteristics of the groups stratified by presence/absence of low MM according to BIA and DEXA. Overall, some differences in patient characteristics were commonly seen between those with and without low MM defined by BIA and DEXA; they were older and had higher BNP levels at the time of discharge. In contrast, lower blood pressure was associated with low MM only when it was defined by BIA. Female sex, current smoker, and lower sodium level were associated with low MM only when it was defined by DEXA.

The two assessment tools showed poor agreement in diagnosing low MM (Cohen's Kappa coefficient: 0.294, 95% confidence interval [CI]: 0.17-0.42, Table S1). In addition, agreement in MM measurement between the two methods were assessed using the Bland–Altman plots (Figure 1). There was a significant systematic difference (MM measured by BIA – MM measured by DEXA) between MM measured by BIA and DEXA, with the measured MM slightly lower when it was measured by BIA compared to DEXA in arms (-0.39, 95% CI: -0.48 to -0.31), legs (-0.80, 95% CI: -1.0 to -0.56), and total appendicular skeletal mass (-1.19, 95% CI: -1.47 to -0.91). When patients were divided into three groups according to tertiles of the relative values of differences between ASMI with BIA and DEXA, patients with low relative values were older, with a low prevalence of male sex and current smokers than in the other two groups. There was no difference in vital signs, left ventricular ejection fraction, serum creatinine, or BNP levels between the three groups (Table S2).

Prognostic differences between those with and without low MM

During the follow-up period of median 1.2 (IQR: 0.6-1.7) years, 32 patients (14.2%) died (16 cardiovascular deaths and 16 non-cardiovascular deaths). The Kaplan-Meier analysis showed that low MM defined by DEXA was significantly associated with higher all-cause mortality (P=0.003), whereas low MM defined by BIA was not (P=0.22) (Figure 2). In Cox regression analysis, only low MM defined by DEXA (HR 2.45, 95% CI: 1.05-5.72, p=0.039), but not BIA (HR 1.03, 95% CI: 0.35-3.06, p=0.955), was associated with poor prognosis after adjustment for MAGGIC risk score and log BNP level at discharge (Table 2).

Comparing incremental prognostic information of low MM with BIA and DEXA

To check if adding the presence/absence of low MM to known prognostic factors could yield additive prognostic information, we constructed three models (MAGGIC score + BNP, MAGGIC score + BNP + low MM with BIA, and MAGGIC score + BNP + low MM with DEXA). ROC curve analyses were performed for the logistic regression models of the three models. There was no significant difference in AUCs of the three models (MAGGIC score + BNP: 0.71 [95% CI: 0.62-0.80], MAGGIC score + BNP + low MM with BIA: 0.71 [95% CI: 0.62-0.80], MAGGIC score + BNP + low MM with DEXA: 0.74 [95% CI: 0.65-0.82]). The MAGGIC score + BNP + low MM with DEXA model showed marginally larger AUC compared to the MAGGIC score + BNP model (Figure S1). However, we found that adding low MM with DEXA, but not low MM with BIA, to MAGGIC score + BNP yielded significant NRI (NRI: 0.583, $p < 0.001$). Moreover, significant NRI changes was observed when the model was updated from MAGGIC score + BNP + low MM with BIA to MAGGIC score + BNP + DEXA (NRI: 0.583, $p < 0.001$) (Table 3).

Discussion

The main findings of this study were as follows: 1) the agreement between MM measured by BIA and DEXA is poor, and there is a systematic bias; 2) low MM defined by DEXA, but not BIA, was associated with mortality even after adjusting for pre-existing prognostic models; and 3) only low MM defined by DEXA, not BIA, provided incremental prognostic information on top of pre-existing prognostic models for heart

failure.

There have been very few studies that investigated the agreement between BIA and DEXA in patients with heart failure. A study that enrolled 55 patients with heart failure between 18 and 70 years (mean age of 56 years) with no heart failure hospitalization within 30 days, weight change of less than 5% within six months, and stable fluid status and medications reported wide limits of agreement in fat-free mass between BIA and DEXA,[13] which is in line with our results. Although the mechanism behind this discrepancy could not be examined in our study, previous studies have reported that MM measured by BIA and DEXA are both affected by tissue hydration, where overestimation of MM occurs in edematous status.[21] In general, the tissue hydration content ranges from 67 to 85%, depending on age differences and pathological conditions.[22] Although DEXA assumes that the hydration of tissue remains constant at 73%,[22] BIA estimates MM mathematically using the resistance that occurs when alternating current passes through the body water.[11] This may suggest that MM measured by BIA might be more affected by volume status than DEXA in terms of accuracy and may be one of the reasons for the discrepancy between measured MM as well as the prognostic value of low MM defined by two methods.

Importantly, the prognostic impact of low MM in patients with heart failure has been examined in limited number of studies. Recently, Konishi et al. have clearly showed low MM defined by DEXA was associated with prognosis independent of other prognostic factors.[23] In contrast, a study that evaluated the MM of 359

outpatients with heart failure with BIA showed that low MM was not associated with mortality independent of other covariates.[24] Although these studies have not simultaneously evaluated MM using BIA and DEXA and did not compare their prognostic predictability, these findings are consistent with our study results. As our study was not designed to evaluate the reason for the difference in prognostic predictability between the two modalities, and further research is needed to clarify the cause of this discrepancy and its impact on the diagnosis of sarcopenia in patients with heart failure.

This study had several limitations. First, this study included a small sample size, and few patients had normal MM. Thus, the power to detect differences might not be enough. Second, although this study is a single-center cohort study which enrolled patients prospectively, this analysis was not pre-specified and was performed in a retrospective manner. In addition, our study was conducted in a tertiary hospital, which may limit generalizability. Third, BIA and DEXA measurements were assessed during the stable period without any intravenous therapies for heart failure before discharge, but not exactly on the same day. However, the measurement interval was median 0 (IQR: -2 to 1) days. Fourth, although we showed that there is a systematic difference between MM measured by BIA and DEXA, it should be acknowledged that we did not perform MM measurement using other modalities, such as magnetic resonance imaging as the gold standard. This implies that even though only low MM defined by DEXA is associated with the prognosis, it is not clear which modality (i.e., BIA or DEXA) is accurately quantifying MM in older patients with heart failure. Lastly, we did not have data on serial changes in MM, which might be

associated with prognosis. Future studies that quantify MM with MRI and compare with BIA and DEXA in this population are needed to clarify this.

Conclusion

Our study results suggest that there is a significant discrepancy between BIA- and DEXA-measured MM. Low MM defined by DEXA, but not by BIA, was independently associated with mortality in elderly patients with heart failure and provided additive prognostic information to known risk factors. Until the reason for the different prognostic impact of low MM defined by DEXA and BIA is clarified, DEXA can be recommended to be used for older patients with heart failure.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Figure legends

Figure 1. Bland–Altman plots for muscle mass (arms + legs, arms and legs).

Dotted line is mean difference; broken lines indicate 95% limits of agreement.

Figure 2. Kaplan-Meier curves for all-cause death between the low MM and normal MM groups.

Kaplan-Meier curves stratified by the presence or absence of low MM based on (A) bioelectrical impedance analysis (BIA) and (B) dual-energy X-ray absorptiometry (DEXA).

Figure S1. **Receiver operating characteristic curves for all-cause death.**

MAGGIC + Log BNP only (red line), MAGGIC + Log BNP + low muscle mass with BIA (blue line), and MAGGIC + Log BNP + low muscle mass with DEXA (green line).

AUC, area under the curve; BIA, bioelectrical impedance analysis; DEXA, dual-energy X-ray absorptiometry; MAGGIC, Meta-Analysis Global Group in Chronic Heart Failure Score; Log BNP, log-transformed brain natriuretic peptide.

Table S1. Agreement between the two assessment tools

BIA, bioelectrical impedance analysis; DEXA, dual-energy X-ray absorptiometry; Low MM, low muscle mass; Normal MM, normal muscle mass.

Table S2. Differences in appendicular skeletal muscle mass index between the BIA analysis and DEXA method

Values are median [interquartile range], n (%), or mean (standard deviation).

ACE-I, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; BIA, bioelectrical impedance analysis; BNP, brain natriuretic peptide; COPD, chronic obstructive pulmonary disease; DEXA, dual-energy X-ray absorptiometry; HF, heart failure; Low MM, low muscle mass; Normal MM, normal muscle mass; NYHA, New York Heart Association

Table 1. Baseline characteristics

	BIA			DEXA		
Variables	**Normal MM**	**Low MM**	**P-value**	**Normal MM**	**Low MM**	**P-value**
	n=49	**n=177**		**n=106**	**n=120**	
Age (years)	75.0±7.6	82.7±6.8	<0.001	79.8±8.3	82.1 (7.0	0.03
Male (%)	28 (57.1)	89 (50.3)	0.491	32 (30.2)	85 (70.8)	<0.001
Systolic blood pressure (mmHg)	124±51	115±15	0.043	119±37	114±15	0.16
Diastolic blood pressure (mmHg)	66±9	62±10	0.005	63±10	62±10	0.297
Heart rate (bpm)	71±13	69±13	0.485	69±12	70±14	0.539
Left ventricular ejection fraction (%)	48±16	48±17	0.805	48±16	47±17	0.701
HF duration >18 months (%)	37 (75.5)	116 (65.5)	0.251	76 (71.7)	77 (64.2)	0.287
Comorbidities (%)						

Hypertension	36 (73.5)	107 (60.5)	0.131	73 (68.9)	70 (58.3)	0.128
Diabetes	20 (40.8)	55 (31.1)	0.267	38 (35.8)	37 (30.8)	0.511
COPD	5 (10.2)	19 (10.7)	>0.99	8 (7.5)	16 (13.3)	0.233
Current smoker	22 (44.9)	78 (44.1)	>0.99	29 (27.4)	71 (59.2)	<0.001
NYHA class (%)			0.189			0.401
I	44 (89.8)	139 (78.5)		86 (81.1)	97 (80.8)	
II	5 (10.2)	36 (20.3)		20 (18.9)	21 (17.5)	
III	0 (0.0)	2 (1.1)		0 (0.0)	2 (1.7)	
Prescription at discharge (%)						
ACE-I/ARB	32 (65.3)	115 (65.0)	>0.99	75 (70.8)	72 (60.0)	0.121
Beta blocker	38 (77.6)	134 (75.7)	0.937	84 (79.2)	88 (73.3)	0.377
Laboratory data at discharge						

Creatinine (mg/dL)	1.17±0.51	1.20±0.55	0.726	1.19±0.55	1.19±0.54	0.997
Sodium (mEq/L)	140±3	139±4	0.465	140±3	139±4	0.009
BNP (pg/mL)	196 [114, 336]	283 [150, 478]	0.028	211 [140, 403]	294 [151, 491]	0.078

Values are median [interquartile range], n (%), or mean (standard deviation).

ACE-I, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; BIA, bioelectrical impedance analysis; BNP, brain natriuretic peptide; COPD, chronic obstructive pulmonary disease; DEXA, dual-energy X-ray absorptiometry; Low MM, low muscle mass; Normal MM, normal muscle mass; NYHA, New York Heart Association.

Table 2. Univariate and multivariate Cox regression analyses for all-cause death

Variable	Univariate Cox model			Multivariable Cox model (adjusted for MAGGIC score)			Multivariable Cox model (adjusted for MAGGIC score + Log BNP)		
	Hazard ratio	**95% CI**	**p-value**	**Hazard ratio**	**95% CI**	**p-value**	**Hazard ratio**	**95% CI**	**p-value**
Low MM with BIA	1.90	0.66-5.40	0.232	1.11	0.34-3.28	0.846	1.03	0.35-3.06	0.955
Low MM with DEXA	3.33	1.44-7.70	0.005	2.60	1.12-6.10	0.027	2.45	1.05-5.72	0.039

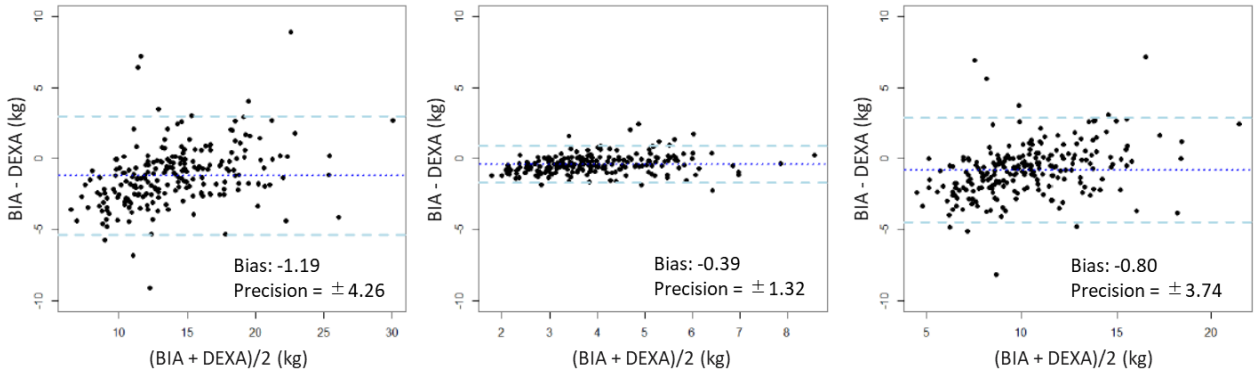
BIA, bioelectrical impedance analysis; Log BNP, log-transformed brain natriuretic peptide; CI, confidence interval; DEXA, dual-energy X-ray absorptiometry; Low MM, low muscle mass.

Table 3. Comparison of predictability for all-cause death between models based on MAGGC+Log BNP, MAGGIC + Log BNP + BIA, and MAGGIC +Log BNP + DEXA

		Updated model	
		MAGGIC + Log BNP + BIA **AUC: 0.71 [0.62-0.80]**	**MAGGIC + Log BNP + DEXA** **AUC: 0.74 [0.65-0.82]**
Baseline model	**MAGGIC+ Log BNP** **AUC: 0.71 [0.62-0.80]**	AUC comparison: P>0.99 NRI: -0.005, P=0.975 IDI: -0.0001, P=0.535	AUC comparison: P=0.355 NRI: 0.583, P<0.001 IDI: 0.021, P=0.019
	MAGGIC + Log BNP + BIA **AUC: 0.71 [0.62-0.80]**		AUC comparison: P=0.302 NRI: 0.583, P<0.001 IDI: 0.021, P=0.017

AUC, area under the curve; BIA, bioelectrical impedance analysis; DEXA, dual-energy X-ray absorptiometry; IDI, integrated discrimination improvement; Log BNP, log-transformed brain natriuretic peptide; MAGGIC Score, Meta-Analysis Global Group in Chronic Heart Failure Score; NRI, net reclassification improvement.

Figure 1



A) BIA vs DEXA (Arms + Legs)

B) BIA vs DEXA (Arms)

A) BIA vs DEXA (Legs)

Figure 2

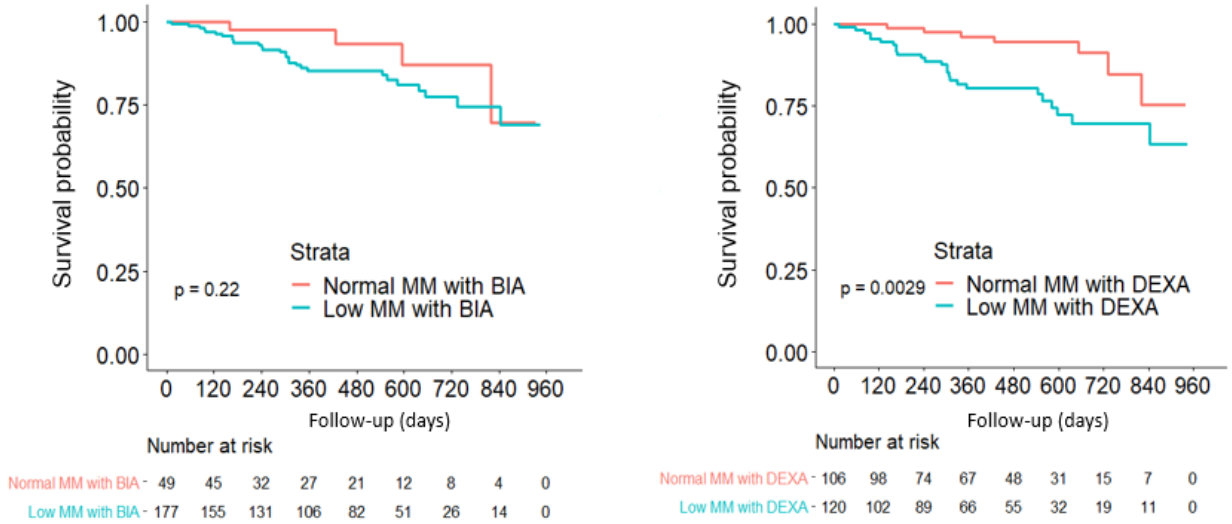

1.00
0.75
0.50
0.25
0.00
Survival probability
p = 0.22
Strata
Normal MM with BIA
Low MM with BIA
0 120 240 360 480 600 720 840 960
Follow-up (days)
Number at risk
Normal MM with BIA 49 45 32 27 21 12 8 4 0
Low MM with BIA 177 155 131 106 82 51 26 14 0
1.00
0.75
0.50
0.25
0.00
Survival probability
p = 0.0029
Strata
Normal MM with DEXA
Low MM with DEXA
0 120 240 360 480 600 720 840 960
Follow-up (days)
Number at risk
Normal MM with DEXA 106 98 74 67 48 31 15 7 0
Low MM with DEXA 120 102 89 66 55 32 19 11 0

Table S1. Agreement between the two assessment tools

		DEXA	
		Normal MM	**Low MM**
BIA	**Normal MM**	39	10
	Low MM	67	110

BIA, bioelectrical impedance analysis; DEXA, dual-energy X-ray absorptiometry; Low MM, low muscle mass; Normal MM, normal muscle mass.

Table S2. Differences in appendicular skeletal muscle mass index between the BIA analysis and DEXA method

	Low n=75	Intermediate n=74	High n=77	P value
BIA – DEXA (kg/m^2)	-1.4 [-1.9, -1.1]	-0.6 [-.07, -0.4]	0.1 [-0.1, 0.5]	<0.001
Age (years)	84.5±6.4	79.7±7.5	78.8±7.9	<0.001
Male (%)	19 (25.3)	37 (50.0)	61 (79.2)	<0.001
Systolic blood pressure (mmHg)	114±13	117±16	119±42	0.583
Diastolic blood pressure (mmHg)	61±10	62±10	64±9	0.136
Heart rate (bpm)	68±13	70±13	70±14	0.622
Left ventricular ejection fraction (%)	49±17	48±15	46±17	0.369
HF duration >18 months (%)	46 (61.4)	54 (73.0)	53 (68.8)	0.226
Comorbidities (%)				

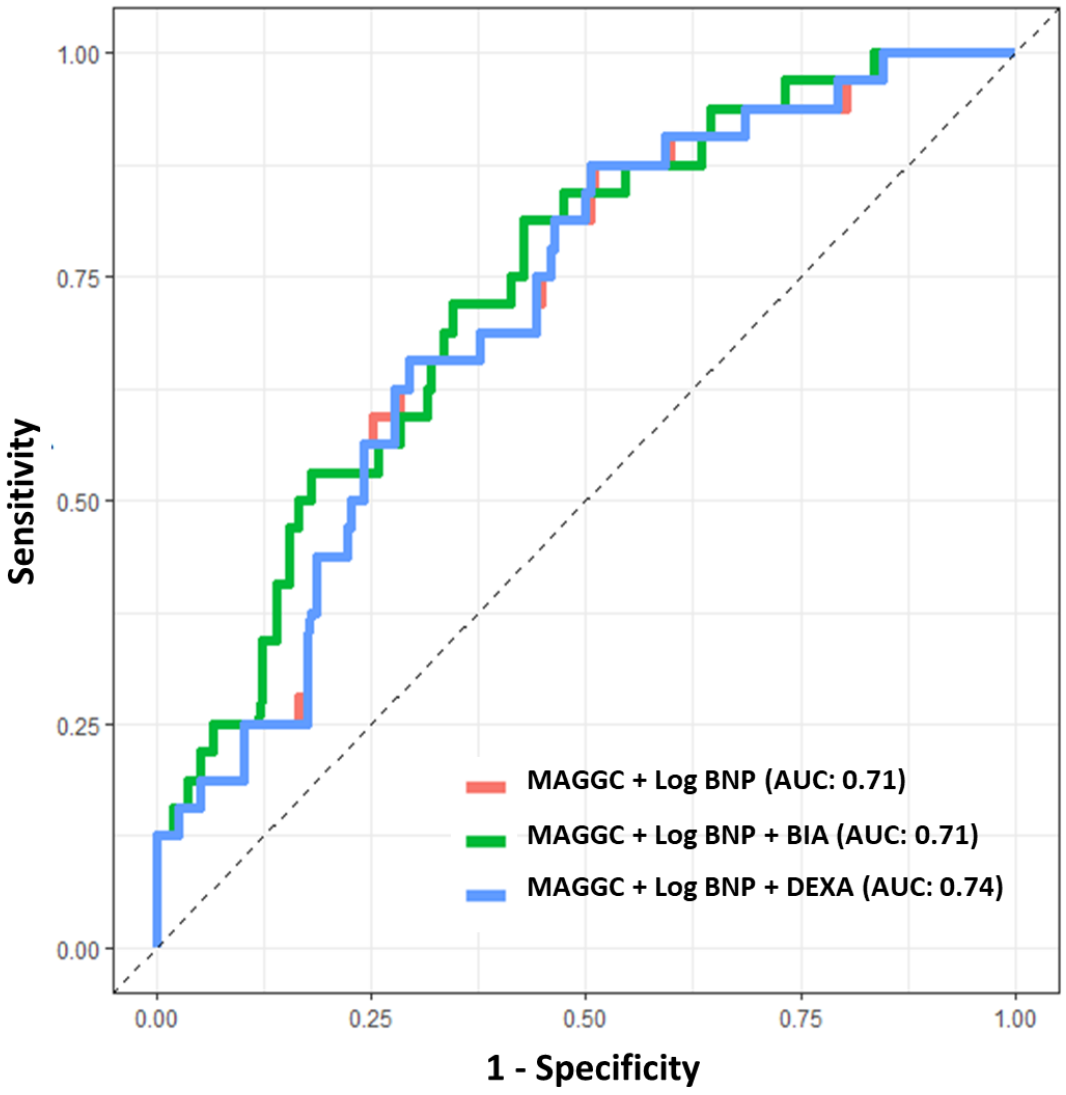
Hypertension	47 (62.7)	50 (67.6)	46 (59.7)	0.603
Diabetes	28 (37.7)	26 (35.1)	21 (27.3)	0.382
COPD	6 (8.0)	7 (9.5)	11 (14.3)	0.420
Current smoker	17 (22.7)	32 (43.2)	51 (66.2)	<0.001
NYHA class (%)				0.309
I	58 (77.3)	61 (82.4)	64 (83.1)	
II	17 (22.7)	11 (14.9)	13 (16.9)	
III	0 (0.0)	2 (2.7)	0 (0.0)	
Prescription at discharge (%)				
ACE-I/ARB	43 (57.3)	50 (67.6)	54 (70.1)	0.236
Beta blocker	52 (69.3)	57 (77.0)	63 (81.8)	0.191
Laboratory data at discharge				

Creatinine (mg/dL)	1.16±0.5	1.20±0.5	1.22±0.6	0.758
Sodium (mEq/L)	139±4	139±3	139±3	0.660
BNP (pg/mL)	290 [140, 491]	204 [136, 433]	294 [154, 461]	0.263

Values are median [interquartile range], n (%), or mean (standard deviation).

ACE-I, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; BIA, bioelectrical impedance analysis; BNP, brain natriuretic peptide; COPD, chronic obstructive pulmonary disease; DEXA, dual-energy X-ray absorptiometry; HF, heart failure; Low MM, low muscle mass; Normal MM, normal muscle mass; NYHA, New York Heart Association

Figure S1


1.00
0.75
0.50
0.25
0.00
Sensitivity
0.00
0.25
0.50
0.75
1.00
1 - Specificity
MAGGC + Log BNP (AUC: 0.71)
MAGGC + Log BNP + BIA (AUC: 0.71)
MAGGC + Log BNP + DEXA (AUC: 0.74)