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Relation between parameters of body composition and echocardiography in patients with nonvalvular atrial fibrillation

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ABSTRACT

Purpose: Both nutritional status and echocardiographic parameters are associated with the risk of atrial fibrillation (AF). The aim of this study was to determine the relationships between parameters of transthoracic echocardiography and nutritional status assessment as risk factors for AF.

Methods: This cross-sectional study considered 120 consecutive patients hospitalized due to AF and 240 inpatients admitted due to exacerbation of cardiovascular conditions. Echocardiographic parameters and parameters of nutritional status were determined for each patient.

Results: Patients in the lowest body mass index (BMI) quartile and without visceral adiposity had the lowest standard echocardiographic parameters; however, the majority of these differences disappeared after the parameters were indexed to BSA. In logistic regression analysis, echocardiographic parameters were associated with slightly higher or similar AF risk comparing with parameters of nutritional status assessment. When the comparison was made in relation to cut-off values obtained in ROC analysis, then having a visceral adipose tissue (VAT) score ≥ 12 was associated with a lower increase in AF risk (odds ratio [OR]; 95% confidence interval [CI]: 3.09; 1.85–5.15) than the risk increase associated with e.g. left atrium diameter greater than 45mm ([OR; 95% CI] 10.483; 6.308–17.421).

Conclusions: The unitary values of echocardiographic and body composition parameters only slightly differed in relation to the risk of AF occurrence, however, the use of cut-off values significantly increases an impact of echocardiography on the prediction of AF. The U-shaped relationships between a patient's nutritional status and AF occurrence cannot be explained by the effect of body mass on cardiac structure and size.

Key words: atrial fibrillation, body composition, echocardiography, visceral adiposity

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Introduction

Disturbances in nutritional status and atrial fibrillation (AF) are significant current health problems. Obesity is one of the evidenced risk factors for AF [1, 2], although diabetes mellitus, hypertension, obstructive sleep apnea, enlargement of the left atrium, and cardiac failure also influence the risk of atrial arrhythmia [3, 4]. However, the importance of undernutrition as a risk factor for AF is understudied due to the exclusion of patients with a body mass index (BMI) < 18.5 kg/m^2 from the majority of studies on associations between patients' nutritional status and the risk of various cardiovascular conditions [1].

Echocardiography is a basic diagnostic tool for patients with cardiovascular disorders. In patients with AF, the tool helps to identify the cause of arrhythmia (e.g. valvular AF, nonvalvular AF, cardiomyopathy), to localize the site of arrhythmia complication (e.g. the presence of thrombus in the left atrial appendage), to predict the risk of arrhythmia recurrence (e.g. left atrium diameter), and to treat patients with arrhythmia (e.g. during left atrium appendage closure) [5]. It seems reasonable that individuals with greater height and body size have higher echocardiographic parameter values than people who are smaller [6]. However, reductions in body mass and changes in body composition after bariatric surgery (unrelated to changes in patients' height) led to a reduction in values of echocardiographic parameters of the left ventricle [7–9]. Moreover, the associations between heart dimensions and nutritional status are complicated by the distribution of adiposity, which an example is the relationship between epicardial adipose tissue (EAT) and left atrial size that was found to be positive for patients with paroxysmal AF and negative for patients with permanent AF [10]. Such effect of fat tissue on heart remodelling and risk of arrhythmia is explained by its paracrine, endocrine and proinflammatory properties [10–12]. These data suggest that the association between heart morphology and function and patient nutritional status may be more complicated than simply a relationship with body size or body surface area (BSA). As a result of left ventricle enlargement, hypertrophy, diastolic and systolic dysfunction, as well as an increase in left atrial diameter, area and volume is associated with a rise in patient morbidity and mortality [13], and risk of AF occurrence and recurrence after cardioversion [5], we tried to answer the following questions: (a) Are there any relationships between the parameters of transthoracic echocardiography and nutritional status assessment (e.g. BMI)? (b) Are there any relationships between the parameters of transthoracic echocardiography and adiposity distribution? and (c) What is the strength of the relationship between the parameters of echocardiography and nutritional status assessment and the risk of AF occurrence?

Materials and methods

Patients

This cross-sectional study considered 120 consecutive patients hospitalized due to nonvalvular AF and 240 inpatients admitted to hospital due to exacerbation of cardiovascular conditions (control group). The exclusion criteria were: history or clinical signs of inflammatory processes or neoplasm or valvular heart disease; a significant decrease in body weight during the three months prior to the current hospitalization (i.e. a quotient of [100% × (usual weight — actual weight)/ /usual body weight] being greater than 5%); the history of disorders affecting food intake or absorption; lack of informed consent for participation in the study; and an implanted cardioverter or cardiostimulator (a contraindication for bioelectrical impedance analysis, BIA). Patients were recruited to the study between July 01, 2015, and December 31, 2016.

During the first day of hospitalization, a medical history was obtained from each of the inpatients enrolled in the study and a physical examination was performed, including the measurement of anthropometric parameters of nutritional status. An electrocardiogram (ECG) and transthoracic echocardiography were also performed for each patient.

Biochemical determinations

Blood samples for routine determinations, including NH(2)-terminal pro-brain natriuretic peptide (NT-proBNP) were taken from the ulnar vein of each patient between 7 am and 8 am on the day of admission while the patients were in a fasting state.

Parameters of nutritional status assessment

A nutritional status assessment was performed for all the study participants. The following parameters were measured: height (cm), body weight (kg), waist circumference (WC, cm), hip circumference (HC, cm), mid-arm circumference (MAC, cm), as well as the handgrip strength of the predominant hand. All circumferences were measured using tape, skinfolds with a Harpenden MG-4800 skinfold manual caliper (produced by BATY, UK), and handgrip strength using an electronic dynamometer (manufactured by Kern, Germany). Body composition was determined using BIA and a TANITA BC 420 MA device (TANITA Corporation, Japan). The following BIA parameters were analyzed: fat mass (FM; % and kg), visceral adipose tissue (VAT) level (in the range 1-59, a level > 26 showing abdominal adiposity), fat-free mass (FFM, kg), predicted muscle mass (PMM, kg), which assesses both smooth and skeletal muscle mass, skeletal muscle mass (SMM, expressed in %, kg), bone mass (BM, kg), total body water (TBW; and kg), basal metabolic rate (BMR, kcal), and metabolic age (MA, years).

The following secondary parameters were calculated based on the above-mentioned indices:

- BMI (kg/m2) — calculated as a quotient of body mass expressed in kg and squared height expressed in m;
- an "ideal weight" — calculated according to the Lorentz formula: for female patients, ideal weight = [height (cm) – 100] – {[height (cm) – 150]/2}; and for male patients, ideal weight = [height (cm) – 100] – {[height (cm) – 150]/4};
- the quotient of actual (current) to ideal body mass × 100%; "body mass deficit" was diagnosed when this quotient value was below 100%;
- waist-to-hip ratio (WHR) — calculated as the quotient of WC and HC; the cut-off values for diagnosis of abdominal adiposity were 0.8 for females and 1.0 for males;

- waist-to-height ratio (WHtR) — calculated as the quotient of WC to height (cm) × 100; the established cut-off values of this index for diagnosis of abdominal adiposity (the central or android type of obesity) were 0.58 for females and 0.63 for males [14–16],
- skeletal muscle mass index (SMI) — calculated as a quotient of skeletal muscle mass obtained in BIA expressed in kg and squared height expressed in m.

Parameters of transthoracic echocardiography

Echocardiography was performed at admission by the same, experienced cardiologist, using a transthoracic ultrasound device (Aplio, TOSHIBA) and a 10 MHz radial probe. The following echocardiographic parameters concerning both left ventricle (LV) and left atrium (LA) were determined: interventricular septum thickness (IVST, mm) at end-diastole; posterior wall thickness (PWT, mm) at end-diastole; left ventricular end-diastolic dimension (LVEDD, mm); mean wall thickness (MWT, mm); relative wall thickness (RWT, mm); left ventricular mass (LVM, g); left ventricular mass indexed to body surface area (LVM/BSA, g/m^2); left ventricular ejection fraction (LVEF, %); left atrium diameter (LAD, mm); left atrium diameter indexed to body surface area (LAD/BSA, mm/m^2); left atrium area (LAA, cm^2) in apical four- and two-chamber views (LAA4 and LAA2); left atrium area in apical four- and two-chamber views indexed to body surface area (LAA4/BSA, LAA2/BSA, cm^2/ m^2); left atrium volume in apical four- and two-chamber views (LAV4 and LAV2, ml); and left atrium volume in apical four- and two-chamber views indexed to body surface area (LAV4/BSA and LAV2/BSA, ml/m^2). A left atrial volume was assessed using the biplane method. Left ventricular mass was calculated using the following formula:

$$LVM\ (g) = 0.8 \times \{1.04 \times ([LVEDD + IVST + PWT]^3 - LVEDD^3)\} + 0.6$$

Body surface area was calculated using the following formula:

$$BSA\ (m^2) = 0{,}01666667 \times height^{0.5} \times body\ mass^{0.5}$$

Bioethics

The investigation was conducted in compliance with the Declaration of Helsinki for medical research, after receiving permission from local Bioethical Committee No. 389/2015. Each patient gave written consent to participate in the study.

Statistics

Statistical analysis was conducted using a licensed version of statistical software STATISTICA version 13.1 (a data analysis software system) developed by StatSoft, Inc. (2017). The statistical significance level was set at a p-value < 0.05. The normal distribution of the study variables was checked using the Shapiro-Wilk test. The results were mainly presented as the mean ± standard deviation, or n, %. The statistical significance of differences between groups was verified using the Student's t-test, the Mann-Whitney U test and the Chi^2 test. Logistic regression analysis with a quasi-Newton estimation model was used to determine the odds ratio (OR) and 95% confidence interval (CI) of the one unit of the continuous (quantity) variables in relation to the risk of atrial fibrillation occurrence. Cut-off values for respective parameters of echocardiography and parameters of nutritional status assessment that have a predictive value for the risk of the atrial fibrillation were determined for maximal Youden indices by plotting the receiver operator curves (ROC). All the patients were then classified into two groups based on those cut-off values. For such obtained qualitative variables, using free internet calculator (https://www.medcalc.org/calc/odds_ratio.php), the OR was determined as the risk that atrial fibrillation would occur with an associated higher value of a respective variable (e.g. LAD ≥ 45mm or LVED ≥ 48mm), compared to the chance of the atrial fibrillation occurring in patients with its lower value (e.g. LAD < 45mm or LVED < 48mm).

Results

Clinical characteristics

While individuals with a BMI value in the lowest quartile were similar to patients from the higher quartiles in relation to the clinical variables, the lowest quartile group had significantly lower values for the majority of the estimated crude echocardiographic parameters (Tab. 1). However, when echocardiographic parameters were indexed to body surface area, these significant differences either disappeared or were less apparent. After adjustment for BSA, the only statistically significant difference between the patient groups divided in relation to BMI quartiles concerned the left atrium diameter, which was higher in patients from the lowest BMI quartile compared to the other patient groups (Tab. 1).

Associations between parameters of abdominal adiposity and echocardiography

Next, we compared the values of the echocardiographic parameters in a split analysis performed in relation to generally accepted cut-off criteria for WHR (data not presented in detail) and WHtR (Tab. 2) for abdominal adiposity, as well as in relation to the median VAT score in BIA, which was 12 (data not presented in

Table 1. Clinical and echocardiographic parameters in relation to quartiles of BMI

Parameter	**BMI < 24.42 (n = 90)**	**24.42 ≤ BMI < 27.66 (n = 90)**	**27.66 ≤ BMI < 31.59 (n = 90)**	**BMI ≥ 31.59 (n = 90)**
Age (years)	72.20 ± 9.37	70.43 ± 9.10	68.55 ± 8.99	69.10 ± 8.98
Male gender (n, %)	40 (44.44%)	42 (46.67%)	58 (64.44%)	39 (43.33%) #
Smoking habit (n, %), currently/in the past	27 (30.00%) 34 (37.78%)	25 (27.78%) 31 (34.44%)	22 (24.44%) 40 (44.44%)	10 (11.11%) 44 (48.89%)
Hypertension (n, %)	65 (72.22%)	84 (93.33%)*	78 (86.67%)	83 (92.22%)*
Diabetes mellitus (n, %)	22 (24.44%)	35 (38.89%) *	40 (44.44%)*	44 (48.89%)*
Past myocardial infarction (n, %)	11 (12.22%)	19 (21.11%)	16 (17.78%)	20 (22.22%)
CABG (n, %)	5 (5.56%)	7 (7.78%)	6 (6.67%)	12 (13.33%)
PCI (n, %)	16 (17.78%)	15 (16.67%)	11 (12.22%)	15 (16.67%)
Atrial fibrillation (n, %)	20 (22.22%)	25 (27.78%)	32 (35.56%)	45 (50%) *#
NYHA class (III-IV, n, %)	10 (11.11%)	6 (6.67%)	7 (7.78%)	23 (25.56%) *+#
NT-proBNP (pg/ml)	1800.84 ± 3254.82	972.79 ± 3254.82*	846.72 ± 1362.90*	1542.17 ± 2426.32#
Interventricular septum thickness at end-diastole (mm)	10.53 ± 1.69	11.06 ± 1.86*	11.79 ± 1.64*+	12.5 ± 1.84*+#
Posterior wall thickness at end-diastole (mm)	10.18 ± 1.88	10.64 ± 1.84	11.33 ± 1.64*+	12.0 ± 1.56*+#
Left ventricular end-diastolic dimension (mm)	47.02 ± 6.10	47.41 ± 8.71	49.24 ± 8.79	49.8 ± 8.26*
Mean wall thickness (mm)	10.35 ± 1.74	10.85 ± 1.81	11.56 ± 1.59*+	12.2 ± 1.62*+#
Relative wall thickness (mm)	0.45 ± 0.09	0.54 ± 0.58	0.57 ± 0.73	0.5 ± 0.40*
Left ventricular mass (g)	180.91 ± 59.65	197.18 ± 74.45	227.35 ± 70.90*+	249.30 ± 72.50 *+#
Left ventricular mass indexed to BSA (g/m^2)	109.07 ± 33.33	107.22 ± 36.45	113.67 ± 32.59	117.42 ± 31.19+
Left ventricular ejection fraction (%)	58.34 ± 11.98	57.66 ± 10.19	57.15 ± 10.76	55.2 ± 10.83
Left atrium diameter (mm)	39.11 ± 7.11	41.09 ± 5.44*	43.27 ± 6.77*+	46.1 ± 7.20*+#
Left atrium diameter indexed to BSA (mm/m^2)	23.78 ± 4.56	22.57 ± 3.05*	21.78 ± 3.48*	21.9 ± 3.74*
Left atrium area in apical four-chamber view (cm^2)	19.86 ± 6.23	20.41 ± 5.26	23.83 ± 10.58*+	27.50 ± 17.66*+
Left atrium area in apical two-chamber view (cm^2)	21.41 ± 5.21	21.91 ± 5.63	23.29 ± 5.58*	26.30 ± 5.31+#
Left atrium area in apical four-chamber view indexed to BSA (cm^2/m^2)	12.07 ± 3.79	11.18 ± 2.77	11.95 ± 4.97	13.0 ± 7.90+
Left atrium area in apical two-chamber view indexed to BSA (cm^2/m^2)	13.01 ± 3.91	12.01 ± 3.01	11.72 ± 2.76*	12.50 ± 2.79
Left atrium volume in apical four-chamber view (ml)	71.31 ± 36.28	73.00 ± 29.58	84.48 ± 28.15*+	99.7 ± 30.32*+#
Left atrium volume in apical two-chamber view (ml)	74.43 ± 36.16	77.43 ± 31.86	86.89 ± 30.46*+	102.6 ± 30.43*+#
Left atrium volume in apical four-chamber view indexed to BSA (ml/m^2)	43.21 ± 21.51	39.85 ± 15.36	42.46 ± 14.30	47.2 ± 14.37+#
Left atrium volume in apical two-chamber view indexed to BSA (ml/m^2)	45.15 ± 21.82	42.31 ± 16.74	43.58 ± 15.07	48.7 ± 15.15+#

AF — atrial fibrillation; BMI — body mass index; BSA — body surface area; CABG — coronary artery bypass graft; NT-proBNP — NH(2)-terminal pro-brain natriuretic peptide; NYHA — the stage of heart failure according to the New York Heart Association classification; PCI — percutaneous coronary intervention. Statistical significance of difference: *$p < 0.05$ between columns 1 and 2, 3, 4; + = $p < 0.05$ between columns 2 and 3, 4; #$p < 0.05$ between columns 3 and 4

Table 2. Echocardiographic parameters in patients in relation to type of adiposity diagnosed in relation to standard gender-related cut-off values of WHtR

Parameter	WHtR ≥ 0.58/0.63 (n = 200)	WHtR < 0.58/0.63 (n = 160)	p
Interventricular septum thickness at end-diastole (mm)	11.83 ± 1.94	10.99 ± 1.74	< 0.001
Posterior wall thickness at end-diastole (mm)	11.41 ± 1.79	10.57 ± 1.85	< 0.001
Left ventricular end-diastolic dimension (mm)	48.82 ± 7.70	47.81 ± 8.54	0.240
Mean wall thickness (mm)	11.62 ± 1.80	10.78 ± 1.76	< 0.001
Relative wall thickness (mm)	0.52 ± 0.41	0.53 ± 0.61	0.86
Left ventricular mass (g)	225.47 ± 72.28	199.09 ± 74.33	< 0.001
Left ventricular mass indexed to BSA (g/m^2)	114.88 ± 32.43	108.05 ± 34.63	0.055
Left ventricular ejection fraction (%)	56.04 ± 11.10	58.40 ± 10.67	0.043
Left atrium diameter (mm)	43.66 ± 7.29	40.74 ± 6.62	< 0.001
Left atrium diameter indexed to BSA (mm/m^2)	22.51 ± 3.80	22.46 ± 3.86	0.914
Left atrium area in apical four-chamber view (cm^2)	24.67 ± 14.21	20.65 ± 5.77	< 0.001
Left atrium area in apical two-chamber view (cm^2)	24.16 ± 5.82	22.09 ± 6.08	0.0012
Left atrium area in apical four-chamber view indexed to BSA (cm^2/m^2)	12.58 ± 6.38	11.36 ± 3.19	0.028
Left atrium area in apical two-chamber view indexed to BSA (cm^2/m^2)	12.35 ± 3.03	12.18 ± 3.49	0.627
Left atrium volume in apical four-chamber view (ml)	88.07 ± 32.01	74.57 ± 33.02	< 0.001
Left atrium volume in apical two-chamber view (ml)	91.11 ± 32.31	78.23 ± 34.79	< 0.001
Left atrium volume in apical four-chamber view indexed to BSA (ml/m^2)	44.97 ± 15.54	40.87 ± 18.01	0.021
Left atrium volume in apical two-chamber view indexed to BSA (ml/m^2)	46.31 ± 16.14	42.67 ± 19.46	0.053

BSA — body surface area; WHtR — waist-to-height ratio, with 0.58 as the cut-off value for abdominal adiposity in women and 0.63 as the cut-off value for men

detail). We found that patients with abdominal adiposity had significantly greater values for the majority of crude echocardiographic parameters analyzed, with the exception of LVEF, which was significantly lower. However, after indexing the echocardiographic parameters by BSA, the only statistically significant differences [in the split analysis] concerned LAA4 and LAV4 in relation to WHtR value and LAD and LAV4 in relation to VAT score. On the other hand, patients with a body weight deficit (n = 33; 9.17%) had lower values for the echocardiographic parameters analyzed, and the statistical significance of these differences disappeared after indexing to BSA (data not presented in detail). However, patients with body weight deficit had significantly higher blood NT-proBNP concentration than their counterparts (2707.09 ± 4458.03 vs. 1143.50 ± 2044.90 pg/ml; $p < 0.001$).

Spearman's correlation between echocardiographic parameters and BIA

In order to determine the strength of the relationships between the parameters of nutritional status assessment and the echocardiographic indices, we also performed a regression analysis using Spearman's correlations (Tab. 3). The strongest relationships concerned such crude echocardiographic parameters as LVM, LVEDD, LAD, LAA, LAV, IVST, and PWT. The relationships showed that BIA parameters of nutritional status assessment (body composition) explained 2–27% of the variance in echocardiographic parameters. However, the power of these associations decreased by 36–73% when they were indexed to BSA (Tab. 3). Similar observations were obtained both for the whole study group and separately for patients with AF and in the control group.

Risk of AF occurrence associated with echocardiographic and nutritional parameters

The lack of statistically significant relationships between parameters of adipose tissue distribution and the values of the echocardiographic parameters indexed to BSA might suggest that cardiac ultrasound morphology in our patients depended not on the patients' nutritional status, but on body size or individual, non-nutritional factors determining morphological and/or electrical cardiac remodelling. This hypothesis might run counter to, for example, evidenced data linking obesity with the risk of AF [1, 2]. Therefore, we performed analysis

Table 3. Spearman's correlation between parameters of transthoracic echocardiography and BIA (n = 360)

Parameter	VST	PWT	LVEDD	MWT	RWT	LVM	LVMI	LVEF	LAD	LAD/ /BSA	LAA	LAA/ /BSA	LAV	LAV/ /BSA
FM (%)	0.11; p = 0.06	0.13; p = 0.01	-0.04; p = 0.41	0.12; p < 0.001	0.13; p < 0.001	0.04; p = 0.53	-0.03; p = 0.64	0.01; p = 0.82	0.17; p < 0.001	0.02; p = 0.77	0.18; p < 0.001	0.10; p = 0.08	0.18; p < 0.001	0.13; p = 0.025
FM (kg)	0.32; p < 0.001	0.35; p < 0.001	0.18; p < 0.001	0.34; p < 0.001	0.22; p < 0.001	0.30; p < 0.001	0.10; p = 0.08	-0.07; p = 0.17	0.37; p < 0.001	-0.14; p = 0.015	0.38; p < 0.001	0.09; p = 0.11	0.36; p < 0.001	0.17; p < 0.001
VAT (score)	0.49; p < 0.001	0.50; p < 0.001	0.36; p < 0.001	0.50; p < 0.001	0.30; p < 0.001	0.50; p < 0.001	0.28; p < 0.001	-0.19; p < 0.001	0.48; p < 0.001	-0.11; p < 0.001	0.46; p < 0.001	0.1; p = 0.07	0.42; p < 0.001	0.20; p < 0.001
FFM (kg)	0.40; p < 0.001	0.41; p < 0.001	0.48; p < 0.001	0.15; p < 0.001	0.39; p < 0.001	0.52; p < 0.001	0.26; p < 0.001	-0.18; p < 0.001	0.36; p < 0.001	-0.28; p < 0.001	0.38; p < 0.001	-0.02; p = 0.69	0.38; p < 0.001	0.08; p = 0.15
TBW (kg)	0.40; p < 0.001	0.41; p < 0.001	0.47; p < 0.001	0.41; p < 0.001	0.14; p < 0.001	0.51; p < 0.001	0.25; p < 0.001	-0.18; p = 0.002	0.40; p < 0.001	-0.30; P < 0.001	0.38; p < 0.001	-0.02; p = 0.80	0.35; p < 0.001	0.09; p = 0.08
PMM (kg)	0.40; p < 0.001	0.41; p < 0.001	0.47; p < 0.001	0.42; p < 0.001	0.15; p = 0.01	0.52; p < 0.001	0.26; p < 0.001	-0.18; p = 0.002	0.39; p < 0.001	-0.27; p < 0.001	0.38; p < 0.001	-0.02; p = 0.68	0.34; p < 0.001	0.08; p = 0.14
SMM (kg)	0.40; p < 0.001	0.41; p < 0.001	0.47; p < 0.001	0.41; p < 0.001	0.14; p = 0.01	0.51; p < 0.001	0.26; p < 0.001	-0.18; p = 0.002	0.39; p < 0.001	0.28; p < 0.001	0.37; p < 0.001	0.02; p = 0.68	0.34; p < 0.001	0.08; p = 0.15
SMM (%)	-0.11; p = 0.06	-0.13; p = 0.02	0.02; p = 0.61	-0.12; p = 0.03	-0.13; p = 0.02	-0.05; p = 0.42	0.02; p = 0.67	-0.02; p = 0.97	-0.18; p < 0.001	-0.02; p = 0.72	0.19; p < 0.001	-0.10; p = 0.08	-0.19; p <0.001	-0.12; p = 0.03
BMR (kcal)	0.42; p < 0.001	0.43; p < 0.001	0.48; p < 0.001	0.43; p < 0.001	0.16; p < 0.001	0.54; p < 0.001	0.26; p < 0.001	-0.19; p < 0.001	0.42; p < 0.001	0.30; p < 0.001	0.41; p < 0.001	0.01; p = 0.78	0.37; p < 0.001	0.10; p = 0.08
MA (year)	0.33; p < 0.001	0.34; p < 0.001	0.05; p = 0.30	0.35; p < 0.001	0.29; p < 0.001	0.51; p < 0.001	0.16; p = 0.005	-0.06; p = 0.22	0.31; p < 0.001	0.06; p = 0.29	0.33; p < 0.001	0.19; p < 0.001	0.32; p < 0.001	0.23; p < 0.001

Data are presented as R and p. BIA — bioelectrical impedance analysis; BMR — basic metabolic rate; BSA — body surface area (m^2); FFM — fat-free mass; FM — fat mass; IVST — interventricular septum thickness at end-diastole (mm); LAA — left atrium area in apical four-chamber view (cm^2); LAA/BSA — left atrium area in apical four-chamber view indexed to body surface area (cm^2/m^2); LAD — left atrium diameter (mm); LAD/BSA — left atrium diameter indexed to body surface area (mm/m^2); LAV — left atrium volume in apical two-chamber view (ml); LAV/BSA — left atrium volume in apical two-chamber view indexed to body surface area (ml/m^2); LVEDD — left ventricular end-diastolic dimension (mm); LVEF — left ventricular ejection fraction (%); LVM — left ventricular mass (g); LVMI — left ventricular mass indexed to body surface area (g/m^2); MA = metabolic age; MWT = mean wall thickness (mm); PMM — predicted muscle mass; PWT — posterior wall thickness at end-diastole (mm); RWT — relative wall thickness (mm); SMM — skeletal muscle mass; TBW — total body water; VAT — visceral adipose tissue (score) using logistic regression in order to determine the power of the relationships between nutritional status assessment and the values of the echocardiographic parameters and the risk of AF diagnosis (Tab. 4). When continuous values of respective parameters were taken into account in logistic regression analysis, it occurred that parameters of echocardiography (e.g. LVED, LAD, LAD/BSA, LAA4/BSA, and LAA2/BSA) are linked only slightly less or similar to the risk of AF [expressed as OR value] than the parameters of nutritional status assessment (Table 4). However, when OR values were calculated in relation to cut-off values obtained in ROC analysis, the significantly higher OR values referred to echocardiographic than nutritional parameters (Tab. 4). In other words, for example, the risk of AF was much considerably increased in patients with left atrium diameter ≥ 45mm than those with obesity diagnosed on the base of the excess of FM found in BIA (FM>35% for females and > 25% for males) and abdominal distribution of adipose tissue (e.g. VAT score ≥ 12). Deficit of body mass did not significantly affect the risk of AF ([OR; 95% CI] 0.572; 0.250-1.305; p = 0.185).

Discussion

In our study, we found relationships between parameters of body composition and echocardiographic parameters (Tab. 1–3). However, indexing heart ultrasound parameters to BSA made their associations with parameters of nutritional status weaker (Tab. 3). Indices of body composition analysis explained 2-27% of crude (unindexed) and 2–8% of the indexed echocardiographic parameter values (Tab. 3). We further found that parameters of obesity and abdominal adiposity compared to parameters of transthoracic echocardiography predicted AF risk similarly or only little weaker, however, only when they were taken into account as continuous variables (Tab. 4). However, when we calculated OR variables in relation to cut-off values obtained in ROC analysis, the prediction power for echocardiography was stronger than for parameters of nutritional status assessment.

The links between obesity and the risk of AF and other cardiovascular conditions found in our study have been evidenced previously [1, 2, 17]. The evidence for the associations mentioned is strengthened through a reported favorable effect of weight reduction on the risk of AF occurrence [8, 9]. However, the relationships between parameters of body composition in BIA and parameters of echocardiography and between echocardiographic parameters and undernutrition have only been explored in one publication apiece [5]. The results of these works corroborate ours (Tab. 1, 3, 4). In a study by Mancusi et al. [18], obesity was associated with a 6.9 times higher prevalence of LV hypertrophy. In research by Huang et al. [5], obese patients had larger LAD, LAA, and LAV, both in univariate and multivariate analysis. Dibeklioglu et al. [19] showed that obesity in children was a risk factor for LV hypertrophy independent of hypertension, and Kurisu et al. [20] found an influence of BMI on the correlations between LVM and ECG indices used in the diagnosis of LV hypertrophy, such as the Cornell product and Sokolow-Lyon indices.

Our results are also consistent with the outcome of investigations exploring the effect of visceral adipose tissue distribution on echocardiographic parameters and risk of AF (Tab. 2). Yoon et al. [21] reported a significant trend in increasing values of LVM/BSA and LAD across VAT tertiles. In a study by Chau et al. [22], individuals with elevated waist circumference had a twofold higher risk of diastolic dysfunction of LV than those without central adiposity. In an investigation by Tugcu et al. [23], higher WC was significantly associated with higher LAV. Using multivariable logistic regression models, Son et al. [24] also found significant relationships between WC and enlargement of LA and LV and LV hypertrophy in healthy male Koreans. Mornar Jelavić et al. [16] reported that among patients with acute ST-elevation myocardial infarction (STEMI) treated with the percutaneous coronary intervention (PCI), those with abdominal adiposity defined by greater WHR values had higher rates of significantly stenosed proximal/middle coronary segments, while those with a greater WHtR had the highest rates of heart failure and total in-hospital complications. Markus et al. [7] used multivariable-adjusted linear regression models to analyze the effect of changes in body composition measured using BIA during a 5 year period on changes in LV geometry and function. They found that a 1 kg increase/decrease in TBW or FM was associated, respectively, with an increase/decrease of 0.89 g or 1.84 g in LVM, and an increase in FM was associated with LV concentric remodelling and impairment of systolic and diastolic function parameters, whereas an increase in FFM was associated with LV eccentric remodelling and improved systolic and diastolic functional variables. Moreover, Şeker et al. [25] reported that epicardial adipose tissue thickness was independently associated with abnormal LV geometry, hypertrophy, and dysfunction, as well as low-grade chronic inflammation. A study by Bairapareddy et al. [26] showed that EAT correlated with VAT, so we can assume that results by Şeker et al. [25] indirectly corroborate our observations.

In our study, we also found that both general (higher FM expressed in kg) and central (greater VAT score) adiposity were similar or only a little weaker indicators of the risk of AF occurrence as crude and indexed echocardiographic parameters (Tab. 4). Only the comparison of the predictive power of cut-off values established in ROC

Table 4. Risk of atrial fibrillation occurrence associated with clinical, nutritional status and echocardiographic parameters among inpatients with cardiovascular disorders (n = 360)

Clinical and echocardiographic parameter	OR; 95% CI	Parameter of nutritional status assessment	OR; 95% CI
Diabetes mellitus	0.779; 0.496-1.223	Age	1.003; 0.980-1.027
Hypertension	0.760; 0.413-1.399	Gender	0.968; 0.621-1.509
LVEDD (per mm)	1.062; 1.026-1.100	Weight (per 1 kg kg)	1.027; 1.014-1.041
LVEDD (≥ 48 mm)	28.928; 3.938-212.490	Weight ≥ 90 kg	3.081; 1.898-5.001
LVEF (%)	0.945; 0.926-0.966	Height (per 1 cm)	1.011; 0.989-1.035
LVED ≥ 50%	0.361; 0.198-0.660	BMI (per 1 kg/m^2)	1.087; 1.043-1.132
IVST (per mm)	1.157; 0.80-1.299	BMI≥30.27 kg/m^2	3.044; 1.913-4.843
IVST (≥ 11mm)	2.108; 1.321-3.363	Actual-to-ideal body mass ratio	1.018; 1.009-1.027
PWT per (mm)	1.267; 1.120-1.432	Waist circumference (per cm)	1.021; 1.004-1.037
LVM (per g)	Overabundance of data	WC ≥ 108cm	2.391; 1.521-3.759
LVM (≥ 185.90 g)	3.006; 1.846-4.895	Triceps skinfold thickness (mm)	1.021; 0.997-1.045
LAD (per mm)	1.190; 1.135-2.247	Subscapular skinfold thickness (per mm)	1.005; 0.979-1.031
LAD ≥ 45 mm	10.483; 6.308-17.421	Abdominal (suprailiac) skinfold thickness (per mm)	Overabundance of data
LAA4 (per cm^2)	1.113; 1.065-1.162	WHR	1.089; 0.573-2.071
LAA4 ≥ 21.50 cm^2	14.623; 8.089-26.437	WHR for abdominal adiposity	1.24; 0.704-2.186
LAA2 (per cm^2)	1.247; 1.181-1.316	WHtR	1.029; 1.003-1.057
LAA2 ≥ 23.90 cm^2	9.405; 5.670-15.598	WHtR for abdominal adiposity	1.519; 0.971-2.376
LAV4 (per ml)	1.039; 1.029-1.049	FM (per % of body mass)	1.056; 1.028-1.084
LAV4 ≥ 69.50 ml	10.617; 5.661-19.913	Obesity (FM, %)	2.015; 1.231-3.298
LAV2 (per ml)	1.042; 1.032-1.053	FM ≥ 32.60%	2.624; 1.606-4.289
LAV2 ≥ 93.60ml	10.271; 6.182-17.065	FM (per kg)	1.062; 1.038-1.087
LVM/BSA (g/m^2)	1.012; 1.005-1.020	FM ≥ 26 kg	4.095; 2.463-6.807
LVM/BSA ≥ 102.77g/m^2	2.304; 1.443-3.678	VAT (per 1 score)	1.140; 1.086-1.218
LAD/BSA (mm/m^2)	1.196; 1.115-1.283	VAT ≥ 12 (score)	3.091; 1.857-5.153
LAD/BSA ≥ 23mm/m^2	3.346; 2.120-5.279	FFM (per kg)	1.023; 1.008-1.044
LAA4/BSA (per cm^2/m^2)	1.195; 1.104-1.294	FFM ≥ 51.80 kg	1.799; 1.109-2.916
LAA4/BSA≥11.78cm^2/m^2	7.136; 4.368-11.660	PPM (per kg)	1.024; 1.002-1.046
LAA2/BSA (per cm^2/m^2)	1.381; 1.255-1.519	PPM ≥ 49.20 kg	1.799; 1.109-2.916
LAA2/BSA ≥ 6.78 cm^2/m^2	0.512; 0.03-8.27	SMM (per kg)	1.041; 1.004-1.071
LAV4/BSA (per ml/m^2)	1.071; 1.051-1.092	SMM ≥ 29.30 kg	1.815; 1.120-2.941
LAV4/BSA ≥ 39.03 ml/m^2	6.182; 3.706-10.315	SMM (per 1% of body mass)	0.907; 0.866-0.951
LAV2/BSA (per ml/m^2)	1.077; 1.055-1.098	SMM ≥ 52 %	1.050; 0.094-11.717
LAV2/BSA ≥ 46.25ml/m^2	7.707; 4.722-12.582		

Data are presented as odds ratio (OR) and 95 confidence interval (95% CI); ns — not significant. OR; 95% CI were calculated using logistic regression for quantitative variables, and using the proportional formula for qualitative variables. BMI — body mass index; BSA — body surface area; DM — diabetes mellitus; FFM — fat-free mass; FM — fat mass; IVST — interventricular septum thickness at end-diastole; LAA2 — left atrium area in apical two-chamber view; LAA2/BSA — left atrium area in apical two-chamber view indexed to body surface area; LAA4 — left atrium area in apical four-chamber view; LAA4/BSA — left atrium area in apical four-chamber view indexed to body surface area; LAD — left atrium diameter; LAD/BSA — left atrium diameter indexed to body surface area; LAV2 — left atrium volume in apical two-chamber view; LAV2/BSA — left atrium volume in apical two-chamber view indexed to body surface area; LAV4 — left atrium volume in apical four-chamber view; LAV4/BSA — left atrium volume in apical four-chamber view indexed to body surface area; LVEDD — left ventricular end-diastolic dimension; LVEF — left ventricular ejection fraction; LVM — left ventricular mass; LVM/BSA — left ventricular mass indexed to body surface area; ns- non-significant statistically; PMM — predicted muscle mass; PWT — posterior wall thickness at end-diastole; RWT — relative wall thickness; SMM — skeletal muscle mass; VAT — visceral adipose tissue; WHR — waist-to-hip ratio; WHtR — waist-to-height ratio analysis showed that AF risk was associated significantly stronger with e.g. LVED ≥ 48mm, LAA4 ≥ 21,50cm^2 or LAD ≥ 45 mm than with FM ≥ 26kg, VAT score ≥ 12, body weight ≥ 90kg, and BMI ≥ 30.27 kg/m^2. The associations between values of echocardiographic parameters and the risk of AF, the outcome of AF treatment and patients prognosis are well known, both in relation to the left atrium and left ventricle echocardiographic parameters [27]. Huang et al. [5] found that a higher risk of AF was independently associated with greater LAD and older age, but not with BMI and gender. In contrast, Winkle et al. [28] reported worse AF ablation outcomes among patients with a BMI ≥ 35 kg/m^2. Moreover, patients undergoing AF ablation who had a BMI ≥ 40 kg/m^2 had a higher risk of minor complications. These last observations may be explained by the above-mentioned data concerning the effect of adiposity (FM, VAT and EAT) on heart remodelling [7, 25]. The influence is related to a direct paracrine effect of EAT, the thickness of which correlates with visceral adiposity, as well as the endocrine and proinflammatory activity of VAT [10–12, 26].

The results of this study have some limitations. Firstly, our study group consisted of inpatients from one medical center and was relatively small. Secondly, our study had a cross-sectional design, so we were unable to observe AF occurrence over a long period of time among patients whose body composition had been determined previously.

Conclusions

The values of echocardiographic parameters are only slightly associated with patients' nutritional status and abdominal adiposity and these relationships become weaker after adjustment for body surface area. The risk of AF occurrence was slightly more strongly or equally predicted using unitary values of echocardiographic parameters than through parameters of body composition, however, the use of cut-off values for echocardiographic parameters importantly increased their predictive power in comparison to parameters of abdominal adiposity.

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