Selected echocardiographic and blood pressure parameters, including ventricular-arterial coupling, in predicting recurrence of atrial fibrillation after pulmonary vein isolation: Preliminary study

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INTRODUCTION

Pulmonary vein isolation (PVI) is the primary invasive treatment for patients with paroxysmal atrial fibrillation (AF) [1]. However, around 10%–35% of patients require a redo procedure in the first year due to AF recurrence [2]. Predicting these recurrences is crucial in cardiac electrophysiology but remains challenging despite advances in ablation techniques. Several factors, including patient characteristics and procedural variables, complicate this prediction [3, 4]. Ventricular-arterial coupling (VAC) is essential in understanding cardiac adaptations and AF recurrence post-PVI. This study examined the role of VAC dynamics in predicting AF recurrence post-PVI and aimed to identify factors influencing treatment efficacy.

METHODS

We prospectively recruited 49 patients (13 women and 36 men, aged 40–75 years) with paroxysmal AF scheduled for PVI at the University Hospital in Krakow. The study was conducted in the years 2019–2021. Participants had no other cardiovascular diseases, maintained sinus rhythm upon admission, preserved left ventricular (LV) ejection fraction, and normal carotid-femoral pulse wave velocity (PWV). The study, approved by the Jagiellonian University Ethics Committee, followed the Helsinki Declaration. All participants provided informed consent. Medical history, comorbidities, AF history, frequency and intensity of AF episodes, medication use, and lifestyle data were collected *via* standardized questionnaires, along with anthropometric and demographic data. PVI was performed using the cryo-balloon pulmonary vein catheter ablation method. Recurrence of AF was assessed by patients' symptoms at follow-up and by 72-hour Holter ECG monitoring performed within a month preceding the follow-up visit. Recurrence of AF was defined as recurrence of arrhythmia confirmed by Holter ECG monitoring or persistent episodes of arrhythmia in patients with negative observation for AF on Holter ECG.

Transthoracic echocardiography was performed to assess LV end-diastolic volume, LV end-systolic volume, stroke volume, left atrium volume indexed to the subjects' body surface area (LAVI), and LV global longitudinal strain (GLS). During echocardiographic recording of blood flow velocity in the LV outflow tract, the brachial peripheral systolic blood pressure and brachial pulse wave were simultaneously recorded. From the brachial signal, the aortic pulse wave and, subsequently, the central systolic blood pressure were estimated. The PWV was computed as a quotient of the measured distance covered between the two recorders and the transit time measured. We calculated the classical parameter of VAC, which reflects an interplay between the heart and the arterial system as a ratio of arterial elastance and LV elastance. Arterial elastance (Ea) was measured as a ratio

of end-systolic pressure (ESP) and stroke volume, where ESP was estimated as peripheral systolic blood pressure multiplied by 0.9 [5]. LV elastance (Ees) was calculated as a ratio of ESP and LV end-systolic volume [4]. Finally, the Ea/Ees ratio was calculated. Additionally, we calculated the newly proposed VAC parameter — the PWV-to-GLS ratio. In fasting patients, during recruitment and follow-up visits, venous blood samples were taken, and standard laboratory tests were performed, including N-terminal pro B-type natriuretic peptide. Additionally, on baseline visit, matrix metalloproteinases 3 and 9 (MMP-3, MMP-9) were assessed.

Statistical analysis

Statistical analysis was carried out with R software, version 4.0.5 and version 9.4 (SAS Institute, Cary, NC, US). A full and comprehensive description of the statistical methods can be found in Supplementary material.

RESULTS AND DISCUSSION

Patients (n = 49) at a mean age of 57.9 years who underwent their first PVI reported, after the mean (standard deviation) 13-month (2.5) follow-up, heightened engagement in physical activity (P = 0.008), alleviated European Heart Rhythm Association symptoms (P = 0.001), and reduced use on antiarrhythmic medications (P = 0.004). They had lower N-terminal pro B-type natriuretic peptide levels (148 pg/ml vs. 108 pg/ml; P = 0.047), while blood pressure remained within normal range throughout the observation period (baseline patient characteristics can be found in Supplementary material, *Tables S1* and *S2*). Following PVI, there was a decrease in LV volume at end-diastole and end-systole, as well as a decrease in LAVI (41 ml/m^2 vs. 37.6 ml/m^2; P = 0.012). Additionally, there was an improvement in LV GLS (–19.0% vs. –19.7%; P = 0.036), an increase in Ea (1.77 mm Hg/ml vs. 1.95 mm Hg/ml; P = 0.020), and an increase in Ees (2.77 mm Hg/ml vs. 3.2 mm Hg/ml; P = 0.002). However, other changes in VAC components, such as Ea/Ees and PWV/GLS ratios, were not statistically significant. During the study follow-up, 24.5% of patients experienced AF recurrence. This result was comparable to results in other studies [2, 6]. The Ea/Ees ratio was higher in patients without atrial fibrillation recurrence at one-year follow-up (Table 1), but the baseline value was not a predictor of AF recurrence in the regression model (P = 0.47). Baseline LAVI emerged as the sole predictor of AF recurrence in the multivariable models table (Supplementary material, *Table S3*). Given the limited sample size of the study, the results of the logistic regression analysis should be interpreted with caution. Rather than being regarded as definitive conclusions, they should be viewed as a set of hypotheses that require further investigation.

AF recurrence after PVI is influenced by patient characteristics, procedural aspects, and post-procedural management. Key patient factors include age, AF type, duration of arrhythmia, and comorbidities such as hypertension, diabetes, obesity, sleep apnoea, kidney disease, and structural heart disease [7]. Procedural factors include incomplete pulmonary vein isolation, gaps in ablation lines, and non-pulmonary vein triggers [7]. Fibrotic changes, atrial remodeling, and complex fractionated electrograms raise AF recurrence risk [8]. Post-procedural compliance with antiarrhythmic medications and other prescribed therapies is essential for maintaining sinus rhythm.

Epidemiological studies demonstrate a strong link between AF and heart failure with preserved ejection fraction (HFpEF). Moreover, AF is considered one of the primary precedents and predictors of the development of HFpEF [9]. Early changes in VAC observed in AF patients are likely to progress to the development of HFpEF. The impairment of VAC is related to inflammatory and mechanical overload caused by arterial hypertension and other comorbidities. In HFpEF, increased arterial stiffness increases the LV late systolic pressure. The increase in Ea is a result of endothelial dysfunction, decreased nitric oxide production, and vasoconstriction [5]. The increase in Ees arises from impaired diastolic function and a decrease in the contractile reserve of the left ventricle [5]. Therefore, AF is associated with early deterioration of VAC. In our study, Ea/Ees was significantly lower in patients with recurrence of AF, and the main contributor to this observation was an increase in left ventricular elastance, while arterial elastance increased to a lesser extent. This change may indicate potentially irreversible myocardial remodeling due to arrhythmia itself. In other studies, the aortic stiffness was an important risk factor in AF patients, which contributed to higher AF recurrence post-PVI [10].

Additionally, an enlarged left atrium (LA) size correlates with increased post-PVI AF recurrence risk, with LA diam-

Table 1. Comparison of VAC parameters in patients without atrial fibrillation versus patients with arrhythmia recurrence at one-year follow-up

Parameters	Free from AF recurrence post-PVI	AF recurrence	*P*-value
Number	37	12	
VAC components			
Ea, mm Hg/ml	1.97 (0.4)	1.92 (0.6)	0.41
Ees, mm Hg/ml	3.10 (0.9)	3.83 (1.4)	0.07
Ea to Ees ratio	0.68 (0.2)	0.53 (0.1)	0.01
PWV to GLS ratio	–0.48 (0.1)	–0.43 (0.1)	0.19

Data are presented as means (SDs)

Abbreviations: AF, atrial fibrillation; Ea, arterial elastance; Ees, left ventricular elastance; GLS, global longitudinal strain; PWV, pulse wave velocity; VAC, ventricular-arterial coupling

eter and volume serving as indicators of LA structural remodeling, potentially triggered by arrhythmia itself, which prompts AF initiation and persistence [10, 11]. Moreover, individuals with larger LA may require more energy and longer application durations during PVI, with severe LA scarring predisposing to AF recurrence due to reconduction between the LA and pulmonary veins.

CONCLUSION

LA enlargement was found to be the independent predictor of PVI efficacy. Improvement of selected VAC parameters was observed after one-year follow-up subsequent to the ablation procedure with better Ea/Ees in patients without AF recurrence. However, further studies are required to determine whether VAC is suitable for predicting AF ablation efficacy.

Supplementary material

Supplementary material is available at https://journals.viamedica.pl/polish_heart_journal.

Article information

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