Journal of the American Society of Hypertension ■(■) (2018) 1–6

Research Article

Measurement of pulse wave velocity, augmentation index, and central pulse pressure in atrial fibrillation: a proof of concept study

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Manuscript received March 8, 2018 and accepted June 24, 2018

Abstract

Individualized weighing of the risk benefit of anticoagulation is recommended in patients with atrial fibrillation (AF) who have low established risk scores or, conversely, are at increased risk for bleeding. Parameters of arterial stiffness and wave reflection could improve risk stratification, but their use has not been evaluated in arrhythmia. We measured carotid-femoral pulse wave velocity (PWV), central augmentation index (AI), and central pulse pressure (CPP) using the SphygmoCor system in 34 patients (53 to 85 years; 25 males) with AF before and after elective electrical cardioversion. Agreement was assessed using the intraclass correlation coefficient (ICC) and the coefficient of variation, completed with Bland–Altman plots. After cardioversion, mean arterial blood pressure (MAP) and heart rate (HR) decreased significantly by 8 mmHg and 18 bpm, respectively. PWV decreased from 11.8 m/s to 10.7 m/s, AI increased from 24% to 29%, and CPP rose from 38 mmHg to 43 mmHg. The decrease in PWV was related to the decrease in MAP (beta = 0.57; $R^2 = 0.33$; $P < .001$), whereas changes in AI and CPP were related to the decrease in HR (AI: beta = −0.59; $R^2 = 0.35$; $P < .001$, CPP: beta = −0.55; $R^2 = 0.28$; $P = .001$). After adjustment for changes in MAP and HR, reliability analysis showed an excellent agreement for PWV (ICC = 0.89; 95% confidence interval (CI): 0.79–0.95) but moderate agreement for AI (ICC = 0.59; 95% CI: 0.17–0.80). Excellent agreement was also found for CPP (ICC = 0.89; 95% CI: 0.72–0.95). Measurement of PWV and CPP is reliable in patients with AF, as they appear unaffected by the presence of arrhythmia. J Am Soc Hypertens 2018;■(■):1–6.

Keywords: Arterial stiffness; atrial fibrillation; augmentation index; pulse wave velocity.

Introduction

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia in clinical practice affecting 0.5%–1% of the general population[1,2] and is a major cause of cardiovascular morbidity and mortality.[2,3] The number of patients with AF is expected to rise steeply in the near future due to increasing age[1] and prevalence of risk factors for AF, including valvular heart disease, myocardial infarction, heart failure, diabetes, and hypertension.[4]

Several risk factors and associated conditions of AF are also observed in vascular stiffening, possibly explaining why the presence of AF correlates with higher aortic pulse wave velocity (PWV) and why high pulse pressure is a risk factor for incident AF.[5,6]

Mortality and disability due to stroke can largely be mitigated by anticoagulation, but in certain subpopulations with low-risk scores for thromboembolic events and/or at high risk for bleeding, the decision to start anticoagulation requires individualized weighing of the risk-benefit ratio.

Conflicts of interest: None.
Grant support: None.

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1933-1711/$ - see front matter
https://doi.org/10.1016/j.jash.2018.06.016

Parameters of arterial stiffness and wave reflection may be helpful in both improving insight in mechanisms underlying the development and time course of AF, as well as in clinical decisions on starting anticoagulation. Measurement of these parameters during AF, however, has not been evaluated.

In the present study, the reliability of carotid-femoral PWV and central augmentation index (AI) in patients with AF was assessed by measuring these parameters before and after elective electrical cardioversion. Central pulse pressure (CPP) was considered a secondary outcome measure, as it is a composite measure integrating effects of both stiffness and wave reflection. As PWV intrinsically represents arterial stiffness, a biomaterial property, we contended that PWV values would not be influenced by the presence of AF. On the other hand, we hypothesized that the contrary is true for parameters of wave reflection as obtained from pulse wave analysis (PWA), such as AI, as these are highly dependent on ejection duration and incident wave shape.

Methods

Study Population and Trial Design

Patients with chronic AF scheduled for elective electrical cardioversion at the OLV Hospital in Aalst, Belgium, were considered eligible. Patients with prosthetic material present in the aorta or femoral arteries were excluded because this could make the acquisition of aortic PWV and wave reflection characteristics unreliable or impossible. The study protocol was approved by the institutional Ethics Committee review board, and written informed consent was obtained from all patients. This trial was registered with the ClinicalTrials.gov Identifier NCT02754349.

Measurements

Measurements were performed by a single trained investigator (R.C.) after 15 minutes of supine rest, before and after successful electrical cardioversion with a sustained sinus rhythm of at least 1 hour, confirmed by a 10-lead electrocardiogram.

Brachial artery blood pressure (BP) was recorded using a validated oscillometric device (Omron Scorpius 33, Omron Healthcare Europe BV, Hoofddorp, The Netherlands). BP was recorded three times, with a 2-minute interval between each measurement. The average was used to determine the brachial systolic BP (SBP) and diastolic BP (DBP). To account for the dependency of changes in PWV on changes in BP, we used mean arterial pressure (MAP) calculated as $DBP + 0.4(SBP - DBP)$.[7]

Arterial pressure waves were recorded at the radial artery with applanation tonometry. For the calibration radial artery pressure waves, we used the diastolic pressure and MAP, estimated from the numeric integral of the radial artery pressure wave over time.[8] From these radial waveforms, a corresponding central wave was reconstructed by the application of a validated generalized transfer function (SphygmoCor software, version 7, AtCor Medical, Sydney, Australia). The PWA software calculated the central augmentation pressure as the difference between the second and first systolic peaks and the central AI as augmentation pressure divided by CPP. These metrics are computed by the SphygmoCor system as an ensemble average of pressure waves (average number of beats before and after cardioversion = 14 and 11 respectively) recorded over a 10-second period.

Aortic PWV was measured with the same device by sequentially recording electrocardiogram-gated carotid and femoral artery pressure waves, using the intersecting tangent algorithm (default setting) to determine the foot of the waveform. The path length was calculated as 80% of the direct distance measured between the carotid and femoral measurement sites.[7] PWV was calculated as the path length divided by transit time (m/s). We averaged the results of two to three high quality recordings both before and after the cardioversion procedure, each result already being calculated as the ensemble average over (on average) 11 beats before and nine after cardioversion (standard deviation [SD] between repeat PWV measurements were 0.97 m/s before and 0.66 m/s after cardioversion).

Statistical Analysis

Demographic data are presented as numbers or means ± SD. Differences in hemodynamic measures before and after cardioversion were tested using the paired sample *t*-test.

Agreement between estimates of the same parameter was visualized using Bland–Altman plots.[9] Differences were expressed as percentages to allow comparison of parameters with different scales.

The influence of changes in MAP and heart rate (HR) on differences in PWV- and PWA-derived parameters was explored using linear regression through the origin. Although changes in PWV may be dependent on both changes in BP and HR, we chose only to adjust for MAP to keep both measures comparable in terms of adjustment and keeping in line with the recommendations of the Reference Values for Arterial stiffness Collaboration Workgroup.[7] Reliability was assessed by calculating the coefficient of variation and the intraclass correlation coefficient (ICC) using the 2-way mixed model for absolute agreement of the average measures.

Results

Of the 45 patients included, measurements after cardioversion could not be obtained because of persistent AF