

REVIEW

Left atrial deformation by strain analysis in patients with atrial fibrillation

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Abstract: Atrial fibrillation is the most common type of cardiac arrhythmia, being a major cause of morbidity and mortality. The electrical and morphological remodeling of the left atrium (LA) secondary to the fibrosis is a determinant to the maintaining of this arrhythmia and it is associated with the occurrence of atrial dysfunction. The atrial deformation parameters are reduced by these patients. The strain is defined as being the deformation of a comparable object with its initial form and the strain rate represents the speed with which the deformation happens. The atrial strain predicts the recurrence risk of the atrial fibrillation after cardioversion and after ablation, through improving the selection of the candidates for such procedures, it has the role of a prognosis in different cardiovascular diseases and levels the risk of stroke.

Keywords: left atrial function, atrial fibrillation, speckle tracking echocardiography, longitudinal strain.

Rezumat: Fibrilația atrială este cea mai comună aritmie cardiacă, fiind o cauză majoră de morbiditate și mortalitate. Remodelarea electrică și morfologică a atriului stâng secundară fibrozei este un determinant al menținerii acestei aritmii și se asociază cu apariția disfuncției atriale. Parametrii de deformare atrială sunt reduși la acești pacienți. Strainul se definește ca fiind deformarea unui obiect comparativ cu forma sa inițială iar strain rate-ul reprezintă viteza cu care se produce deformarea. Strainul atrial prezice riscul de recurență a fibrilației atriale postcardioversie și postablație, îmbunătățind selecția candidaților pentru astfel de proceduri, are rol de prognostic în diferite boli cardiovasculare și stratifică riscul de stroke.

Cuvinte cheie: funcția atrială stângă, fibrilația atrială, ecografie speckle tracking, strainul longitudinal.

INTRODUCTION

Atrial fibrillation (AF) is a supraventricular tachyarrhythmia that is characterised by an uncoordinated electrical activity that leads to the deterioration of the atrial mechanical function¹. It is initiated by the atrial automaticity foci that are situated at the posterior wall of the left atrium (LA) and the pulmonary veins, but also in other regions such as the superior vena cava, ligament of Marshall, crista terminalis, coronary sinus, left atrial appendage with a propagation into the atrial tissue and a degradation in a reentering type of activity, and it is supplemented by the reduction of the conduction speed^{2,3}.

Special echocardiographic techniques that analyze the mechanical left atrial function are the Tissue Doppler Imaging (TDI), speckle tracking (ST) and the velocity vector imaging (VVI).

TDI quantifies the myocardial deformation through the gradient of the velocities along the myocardial tissue, but it has a low spatial resolution and is an angle-dependent technique. The atrial strain measured through TDI has the role of a prognosis⁴.

The VVI technique is a method that combines speckle tracking echocardiography (STE) with the detection of the edges of the endocardium, being angle-independent⁴.

The strain measured through STE represent an intrinsic quantification of the atrial myocardial deformation, less dependent on preload or afterload and the geometrical assumption, with big feasibility and reproducibility⁵. This technique is capable of measuring the Lagrangian strain because it incorporates the initial length of the analysed myocardial segment, so that it is not susceptible to the tethering forces exercised by the surrounding tissues⁶.

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LEFT ATRIAL PHYSIOLOGY

The mechanical function of the LA has 3 phases: the reservoir phase, the conduit phase and the contractile phase. The reservoir corresponds to the peak atrial longitudinal strain (PALS); it is an essential phase for the ventricular filling because the energy that is stored in the LA is released at the moment of the opening of the mitral valve⁷. The peak of the reservoir function is modulated by the systolic function of the left ventricle (LV) but also by the LA compliance and size.

The conduit function implies the passive passage of the blood in the ventricle in the early diastole and contributes with a 35% percentage to the ventricle filling. Unlike the reservoir and conduit, the contractile (booster pump) function is dependent on the LA intrinsic contractility and on the electromechanical coupling⁸.

STRAIN AND STRAIN RATE IMAGING OF THE LEFT ATRIUM

The myocardial deformation unfolds on 3 levels, but in the case of the LA the longitudinal deformation will be analysed because it contains fibers with a predominantly longitudinal disposition. At the same time the studies conducted through nuclear magnetic resonance have demonstrated that the atrial fibrosis process that predisposes the occurrence of fibrillation presents a heterogeneous distribution that also includes circular fibers, so that the degree of atrial dysfunction is being underestimated⁹.

Normal values of the strain and the strain rate (SR) of the LA function have been described in many studies. A meta-analysis from 2017 that has included 2542 healthy subjects has measured these parameters through two dimensional (2D) STE and has detected that the average of the reservoir, conduit and contractile strain was of 39.4%, 23% respectively 17.4% when the QRS complex was used as a reference point. Through the usage of the P wave as a reference point the reservoir strain value was 37%¹⁰.

The consensus document of the *European Association of Cardiovascular Imaging and American Society of Echocardiography* from 2018 proposes the QRS complex as a reference point¹¹, but there are studies that state that through this approach the contractile function will have a positive value (considered unphysiologic) and the reservoir and conduit functions will be overestimated⁸.

Hayashi et al has demonstrated a strong correlation between the values of the atrial strain and the func-

tional parameters of the LA that were determined with the help of the three dimensional ultrasound (3D) when the chosen reference point was the P wave⁹.

Regarding the anthropometric influences on these parameters, it has been noticed that the big corporal surface significantly reduces the PALS and conduit strain, and an increased body mass index is associated with big values of the PALS¹⁰.

There is a slight difference between the systolic strain values from the apical 4-chamber view and apical-2 chamber view: $40.1 \pm 7.9\%$ respectively $44.3 \pm 6.0\%$ considering the pulmonary veins insertion and the presence of the interatrial septum in the first section. Cameli et al has determined the average value of 368 29.9 msec as the necessary time to reach the PALS at normal subjects¹².

Age determines the decrease of the strain of the 3 mechanical functions but with the increase of the SR of the contractile phase¹³. The increase of the contractile phase is necessary to maintain the ventricle filling¹⁴. Morris et al has observed a progressive decline of the reservoir function (by using the volumetric method and 2D-STE) alongside aging, a phenomenon that is accompanied by the inversion of the E/A ratio. This author has also analysed on a group of 329 healthy subjects the reservoir strain and contractile SR and has discovered the following intervals: $45.5\% \pm 11\%$ respectively $-2.11 \pm 0.61 \text{ s}^{-1}$.¹⁵ Alongside the volumetric changes that occur in conjunction with the progress of the diastolic dysfunction in the elderly it has also been observed that the global atrial systolic SR and the diastolic one have been altered with at least a decade before the volumetric changes. The reduction of reservoir strain begins at around the age of 60 and the reduction of the SR at about 50 years¹⁶.

The decreased reservoir function is correlated with high pressures at the level of the pulmonary capillary¹⁷.

Between the function of the LA and the LV there is a significant interaction.¹⁸ It has been tried to be established to what extent the LA deformation indices could be predicted by the LV deformation indices. Healthy subjects have been compared with patients with a history of acute pulmonary edema and it has been observed that the reservoir function and the conduit function are determined predominantly by the systolic function and the LV relaxation. The magnitude of the deformation of the two phases has been determined in a 30% proportion by the strain and the LV SR in healthy subjects, whereas by the subjects with systolic dysfunction this interdependence has reached

a 72% percentage, an impact that was not also maintained on the atrial contractile function¹⁹.

ATRIAL STRAIN IN ATRIAL FIBRILLATION PATIENTS

The atrial strain has a bigger sensitivity to the volumetric measurements when it comes to the evaluation of the atrial function in patients with AF. The PALS is considered the strongest predictor in the evolution from paroxysmic AF to permanent AF, his decreased values increasing the risk of permanentisation of the arrhythmia by 4 times after the adjusting of the other parameters. (the maximum indexed atrial volume, the active fraction volumetrically measured and the velocity of the E wave)²⁰. For the high-risk patients, the decrease of the reservoir function is an independent predictor for cardiovascular events. Watanabe et al has studied heterogeneity in patients with paroxysmic AF with regard to the necessary time to reach the PALS and has observed that this was significantly higher in atrial segments with a decreased bipolar voltage²¹.

The PALS is considered a noninvasive marker of the extension of the atrial fibrosis, reflecting the histological atrial remodeling on patients with AF. Patients with persistent AF have significantly lower values for the systolic strain as well as for the one of the early diastole versus the ones with paroxysmal episodes⁴.

The reservoir strain together with the strain and the pump SR are significantly lower in patients with episodes of paroxysmic AF with normal LA in comparison with patients in sinus rhythm, but that associate a LA dilatation²².

The pump function is a parameter with a high sensitivity and specificity especially in those without history of arrhythmia, his reduction predicts the ulterior occurrence of fibrillation, reflecting the atrial structural remodeling²³.

With the help of the VVI technique the deformation parameters were analysed on a group of 302 subjects (126 in sinus rhythm, 91 with paroxysmic AF and 85 with permanent AF) and the reservoir strain has had a significantly decreased values by the last category of patients. The conduit SR has had decreased values by the ones with episodes of paroxysmic AF versus the patients with sinus rhythm. Studies conducted on large population of people have concluded that the measuring of the strain through the VVI method has a high feasibility²⁴.

The PALS can detect the patients that had paroxysmic AF and a cryptogenic cerebrovascular accident in

the presence of a non-dilated LA and it bring information regarding the stratification of the risk of stroke even in the presence of a low CHAD-Vasc score⁹.

A cohort study that included 414 subjects has investigated the impact that the sex differences have on the relationship between the LA mechanics and the risk of a cerebrovascular accident, and it was discovered that there is a correlation between the decreased PALS and the presence of the cerebrovascular accident at women with paroxysmic or persistent AF⁴. Patients in permanent AF there is an opposite rapport between the risk of stroke and the myocardial deformation parameters of the reservoir, independent of age and LA volume²¹.

The atrial myocardial deformation can bring prognostic information regarding the maintaining of the sinus rhythm post catheter ablation (CA). In a study where 74 patients with paroxysmic AF and 44 with persistent AF that were subject to CA it was demonstrated that the best predictor of the maintaining of the sinus rhythm was the SR and the PALS of the interatrial septum, with a cut-off value of 25% for the last one. The strain in the conduit phase does not influence the maintaining of the sinus rhythm²⁵. A decreased value of the PALS preablation can suggest the existence of an advanced atrial fibrosis and it represents a better predictor in the maintaining of the sinus rhythm in comparison with the contractile strain. A study that included 33 patients that were subject to ablation thorough minimally invasive surgery has put into evidence that reverse LA remodeling occurs in 3-6 months after ablation, both when it comes to the volumetric parameters as well as the functional parameters. Thus the reservoir strain has increased from 18 ± 10 to $29 \pm 16\%$ at 12 months after ablation, the conduit strain from $-1.0 \pm 0.5 \text{ s}^{-1}$ to $-1.5 \pm 0.75 \text{ s}^{-1}$ and the contractile SR from $-1.4 \pm 0.7 \text{ s}^{-1}$ has reached the value of $-1.9 \pm 0.9 \text{ s}^{-1}$.²¹

After cardioversion, the atrial strain increases gradually, being an important predictor of the recurrent arrhythmia in the first 6 months following. Giovanni di Salvo et al has demonstrated on a group of 65 patients with AF on a normal structural heart that the systolic PALS and the SR of the inferior atrial wall after cardioversion represents the best predictor of the maintaining of the sinus rhythm; the value of 1.8 s-l having a sensitivity and specificity of 92%, respectively 79% in the prediction of the maintaining of the normal rhythm. He also pointed out that the atrial deformation parameters during the time of the conduit as well as the standard ultrasound parameters (including the

volumetric ones) were not able to discriminate the patients with a recurring arrhythmia versus the one without the recurrence of the AF²⁶.

The atrial dyssynchrony (difference in the time to peak value in the cardiac cycle for peak atrial longitudinal strain and ventricular global longitudinal strain) could predict that occurrence of AF, being considered a pattern of the heterogeneous fibrosis and the dysfunction, reflecting the regional atrial affectation in comparison to the global strain. The interatrial dyssynchrony and the mechanical dispersion (standard deviation of time to peak) could be superior to the peak of the longitudinal strain when it comes to the prediction of the recurrence of AF after CA²⁷.

A superior method to the 2D STE is 3D STE that can differentiate the patients with episodes of paroxysmic AF and dyssynchrony of the atrial electrical conduction, having the advantage of combining the longitudinal strain with the circumferential one.¹³ Furthermore it also identifies the nonresponsive patients postablation²⁷.

CONCLUSIONS

The LA is a marker for the adverse cardiovascular events, especially in patients with atrial fibrillation.²⁹ Considering the clinical role and the epidemiology of this arrhythmia the discovery of the ultrasound parameters that precociously identify the structural and functional alterations that favour the installation of the atrial fibrillation would be important. The atrial deformation identifies patients with a risk of the arrhythmia becoming permanent, being a better technique in following it long term and in establishing the prognosis in comparison to conventional ultrasound parameters.

Conflict of interest: none declared.

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