NOVEL ECHOCARDIOGRAPHIC TECHNIQUES FOR THE EVALUATION OF ATHLETES' HEART: A FOCUSON SPECKLE-TRACKING ECHOCARDIOGRAPHY

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Abstract

This review article analyses new data on cardiac function in athletes by novel echocardiographic techniques with a particular attention to the application of Speckle-tracking echocardiography (STE) to characterise biventricular and biatrial function in athletes. STE is a relatively new, largely angle-independent, non-invasive imaging technique that allows for an objective and quantitative evaluation of global and regional myocardial function. STE has enhanced our understanding of athletes' heart through a comprehensive characterisation of biventricular and biatrial function, providing novel insights into the investigation of physiological adaptation of the heart to exercise conditioning. These peculiarities can provide further useful data to distinguish between athletes' heart and cardiomyopathies. Furthermore, STE represents a promising tool to address new concerns on right ventricular function and to increase understanding of the complexity of the non-systemic circulation, especially in the athletic population.

Keywords. Imaging, athletes, strain, remodelling, exercise

Introduction

The heart of the athlete has intrigued clinicians and scientists for more than a century. Early investigations in the late 1800s and early 1900s documented cardiac enlargement and bradyarrhythmias in individuals with above-normal exercise capacity. Since that time, scientific understanding of the association between sports participation and specific cardiac adaptations has paralleled advances in cardiovascular diagnostic techniques. Now, it is well known that participation in high-volume, high-intensity training programmes results in significant morphological and functional remodelling of cardiac chambers. These central and peripheral cardiovascular adaptations facilitate the generation of a large and sustained cardiac output and enhance the extraction of oxygen from exercising muscle.

Speckle-tracking echocardiography

While older techniques of strain and strain rate, derived by tissue Doppler, are characterised by a low signal to noise ratio, with a lot of experience needed to interpret the data properly, STE is a relatively simple, reliable and reproducible tech- nique.[1.,2] Moreover, in contraat to tissue Doppler, which requires a precise alignment with the ultrasound beam, STE-based analysis of myocardial contraction allows the quantification of fibre deformation through virtually any plane of the space, regardless to the imaging plane. Using STE, blocks or kernels of speckles are semi-automatically traced frame by frame, providing local displacement information, useful to calculate all the spatial components of myocardial strain and strain rate.[1,2]

In particular, myocardial strain is a dimension- less parameter expressed as the percentage of myocar- dial deformation; negative values indicate shortening or compression, while positive values indicate lengthening or stretching. Depending on spatial resolution, selective analysis of epicardial, mid-wall and endocardial function may be possible, obtaining longitudinal, radial and circumferential strain.[3–5] In addition, STE off ers an evaluation of the occurrence, velocity and direction of left ventricular (LV) rotation.[6] STE can be applied to both ventricles and atria. However, while all LV segments can be analysed successfully in most patients, signal quality may be suboptimal for atria and the right ventricle, because of their thin walls.[1] It is noteworthy that whereas feasibility is best for longitudinal and circumferential strain, it is more challenging for radial strain.[1] The main limitations of this new echocardiographic technique are that STE relies on good imaging quality and that differences among vendors still exist, driven by the fact that STE analysis is performed on data stored in a proprietary scan line format, which cannot be analysed by other vendors' software. Thus, the lack of a standardisation of different speckle- tracking algorithms among vendors makes it difficult to establish normal values and to compare data generated by different centres. However, efforts are being made to improve the communication between vendors, and use similar algorithms for the assessment of myocardial strain also promoted by the American Society of Echocardiography.[6]

Left ventricular mechanics

The human heart has a complex structure of muscular fibres, organised in layers. LV subendocardial and subepicardial fibres have a longitudinal disposition, from the apex to the base, drawing a spiral around the ventricle (subepicardial are clockwise oriented, subendocardial are counter clockwise, seen from the apex to the base), while the mid-wall fibres are circumferential.[7] Contraction and relaxation of all these fibres generates a complex deformation and movement of the LV walls both in systole and diastole. The final global result is systolic blood ejection into the aorta and diastolic ventricular filling.

The left ventricle also had a wringing motion around its long axis induced by contracting myofibres in the LV wall, called twisting.[8] Twisting is generated by the opposite rotation of the LV base and the apex. Basal and apical LV rotation are expressed in degrees as well as twisting, which is their algebraic sum; torsion is obtained dividing twisting by the length of the LV cavity, in degrees/cm. LV twisting is followed by rapid isovolumic untwisting of the ventricle.[10] The left-handed helix of the epicardium dominates rotational motion due to its longer lever arm from the centre of the LV. The endocardial layer, with a right handed helix, moves together with the epicardium, although providing some opposition to epicardial motion.[11] As a result of twisting, epicardial and endocardial sarcomere shortening in all directions tends to be equilibrated during ejection, resulting in reduced stress between myocardial fibres.[12] During contraction, potential elastic energy is stored and its release (recoil) causes rapid untwisting [13,] and contributes to active suction of blood from the atria. The recent introduction of STE has drawn new attention to LV mechanics and to LV twisting. The STE technique can allow a reliable assessment of myocardial deformation along the three-dimensional (3D) geometrical axes (longitudinal, circumferential and radial strain) throughout the cardiac cycle and it has shown the ability to quantify transmural (endocardium and epicardium) twisting.

Left ventricular twisting and untwisting

Strain-derived LV twisting is probably the more intriguing novel parameter in the assessment of athletes' heart physiology. STE-based case–control studies on athletes' heart demonstrated lower values of LV twisting in professional soccer players and in elite cyclists. Notting *et al*. observed that the reduction in LV twist is mainly driven by a reduction in apical rota- tion, with the LV apex being more sensible and dependent to the sympathetic activity than the LV base, as demonstrated in an animal model by a greater b-adrenergic receptor density and/or increased myocardial responsiveness to adenylate stimulation in apical myocardium.

The reduction in apical rotation and in LV twisting observed in athletes seems to be related to training induced changes in sympathovagal balance, and could be interpreted as a functional reserve to help the athlete sustain the delivery of oxygen and energetic substrates to the muscles while performing a training session or a competition. This hypothesis seems to be confirmed by studies on healthy subjects showing an increase in LV twisting during laboratory-based submaximal exercise.

Although LV twisting seems to give a relevant con- tribution in studies investigating cardiac physiology, its role in the differential diagnosis, and particularly in the identification of pathological hypertrophy, is not well established and deserves more insights, contrary to the clinical utility of LV longitudinal strain. Indeed, Cappelli *et al.* found that in patients with hypertension, LV longitudinal strain was reduced while LV torsion was increased, compared with controls, with no differences between athletes and controls. Conversely, Galderisi and colleagues, analysing 19 sedentary controls, 22 top-level rowers and 18 young newly diagnosed patients with hypertension, found that, despite significant differences among the groups in LV longitudinal strains, LV torsion was similar among athletes, controls and hypertensive patients. Interestingly, while Soullier et al. demonstrated that patients with HCM had lower values of LV longitudinal, radial and twist compared with controls, while exercise induced a modest increase in LV longitudinal strain, it was not able to change LV twist in these patients.

According to these results, further data are necessary on LV twist mechanics before the widespread use of this parameter in clinical practice, particularly in the setting of the differential diagnosis between athletes' heart and pathological hypertrophy.

Conclusions

Deformation imaging has enhanced our understanding of athletes' heart through a comprehensive characterisation of biventricular and biatrial function, providing novel insights into the investigation of physiological adaptation of the heart to exercise conditioning. These peculiarities also seem to be promising to provide further useful data to distinguish between athletes' heart and cardiomyopathies. Despite the growing body of evidence in the past few years, more data based on STE echocardiography are needed to identify clearly the potential of these new imaging techniques in the clinical context. Furthermore, in view of the growing application of STE in the integrated imaging-based diagnosis of cardiomyopathies, despite recent studies demonstrating that exercise is not able to affect LV strain significantly during the agonistic season, further data are warranted to characterise the possible training- induced dynamic changes in LV strain values.

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