Exercise-Induced Atrial Remodeling
The Forgotten Chamber

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KEYWORDS

• Athlete's heart • Left atrium • Left atrial volume • Speckle tracking • Diastole • Endurance • Atrial fibrillation • Sport training

KEY POINTS

- The left atrium is not a symmetrically shaped 3-dimensional structure, so true left atrial size in athletes is more accurately reflected by a measurement of volume rather than area or linear dimension.
- In large populations of highly trained athletes, mild left atrial enlargement found by echocardiography (ECG) is relatively common (20% of patients) and may be identified as a physiologic adaptation to exercise conditioning.
- In both young and adult athletes, atrial abnormalities by ECG should be regarded as abnormal and lead to secondary investigation.
- Left atrial myocardial deformation assessed by strain is normal in elite athletes compared with age-matched sedentary controls and hypertensive patients, and is closely associated with functional capacity.
- Left atrial remodeling is associated with a higher risk of atrial fibrillation, especially in middle-aged male athletes with a history of intensive long-term endurance training.

BACKGROUND

The left atrium (LA) is located in the mediastinum, oriented leftward and posterior to the right atrium (RA). Its structure is characterized by a pulmonary venous component, a lateral appendage, an inferior vestibular component, and a prominent body that shares the septum with the RA.[1]

Clinical and echocardiographic evaluation of the LA can be essential for understanding many cardiac and noncardiac diseases. In fact, early detection of LA dysfunction provides new insight into pathophysiology and clinical management of several conditions such as atrial fibrillation (AF), arterial hypertension, heart failure, valvular heart disease, and cardiomyopathies.[1,2]

The athlete's heart is a cardiac adaptation to long-term exercise, characterized by an increase in wall thickness, cavity diameters, and left ventricular (LV) mass.[3–5]

Cardiac changes consist of morphologic and functional modifications, involving not only the left ventricle but also the LA. An increase of LA

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dimensions in trained athletes may represent another component of the athlete's heart and upper limits should be used to distinguish physiologic and pathologic cardiac remodeling.[3–5]

LA enlargement is a predictor of AF in the general population and in patients with structural cardiac disease. The prevalence of LA remodeling and the association with supraventricular arrhythmias has not been systematically addressed in highly trained athletes.[6]

Echocardiography (ECG) is most frequently an appropriate second-level imaging modality for investigation of symptoms or screening abnormalities in the athlete. It can be helpful in distinguishing patients with disease involving LA morphology and function from those with LA remodeling concerning athlete's heart.[7] In addition, new echocardiographic techniques, such as Doppler myocardial imaging (DMI), speckle tracking, and 3-dimensional ECG are able to assess LA myocardial function and to identify early LA impairment in patients with either physiologic or pathologic LV hypertrophy (LVH).[5]

ECHOCARDIOGRAPHY ATRIAL ABNORMALITIES IN ATHLETES

Although by standard ECG the criterion for right atrial abnormality (RAA) is simple (P-wave amplitude >2.5 mm in II, II, or AVF leads), the criteria consistent with LA abnormality (LAA) are 2-fold: prolonged P-wave duration of greater than 120 ms in leads I or II with negative portion of the P wave greater than or equal to 1 mm in depth and greater than or equal to 40 ms in duration in lead V1.

Debate exists on the exact prevalence of atrial abnormality in athletes but it may be more common in younger athletes.[8–12] A prevalence of 14% and 18% for LAA and RAA, respectively, has been described in junior elite athletes.[8] This high prevalence is an anomaly within the literature and is unlikely to be explained by the age difference of the cohort alone. For example, in a similarly aged cohort of more than 1300 elite (national or international level) athletes, Brosnan and colleagues[11] observed a prevalence of LAA in 1.2% and 0.5% of endurance and nonendurance athletes, respectively, and the prevalence of RAA abnormalities was similar (1.2% and 0.3%, respectively). In other large cohorts, similarly low frequencies of abnormalities have been detected. In another population of 649 collegiate athletes with mean age of 20 years, LAA was seen in 0.7% and RAA in 1.8% of athletes.[10] Finally, Pelliccia and colleagues[9] found the prevalence of LAA to be 4% and RAA to be 0.8% in 1005 trained athletes.

As a consequence, in adult athletes, atrial abnormalities should be regarded as abnormal and lead to deeper investigation. Isolated atrial abnormalities in younger athletes should lead to a careful physical examination by a qualified physician, and to detailed personal medical and family history. Computerized measurements of total P-wave duration are not standardized, and visual assessment is still recommended.[12]

LEFT ATRIAL ECHOCARDIOGRAPHIC EVALUATION: FROM STANDARD MEASUREMENTS TO NEW ECHO TECHNOLOGIES

By standard ECG, the LA size can be traditionally measured at the end of ventricular systole, when the LA chamber has its greater dimension, in long axis view (anterior-posterior diameter), and in 4-chamber view (longitudinal and transverse diameters).[7]

However, linear measurements are considered to be inaccurate and do not represent true LA size because LA is not a symmetrically shaped 3-dimensional structure, so measurement of volume rather than area or linear dimension is preferred[2,7] (**Fig. 1**).

LA passive volumes consist of preatrial contraction volume (*Vp*), measured at the onset of the P-wave on an ECG; minimal LA volume (*V*min), measured at the closure of the mitral valve in end-diastole; and maximal LA volume (*V*max), measured just before the opening of the mitral valve in end-systole. LA active volumes are LA reservoir volume or LA filling volume (*V*max − *V*min); LA conduit volume or LA passive emptying volume (*V*max − *V*p); and LA contractile volume (*Vp* − *V*min). The difference between maximum and minimum LA volume divided by the minimum LA volume is used as index of atrial compliance.[1]

Measurement of LA volume is recommended by ellipsoid model and Simpson method in 4-chamber and 2-chamber apical views. Normal indexed LA volume values for healthy sedentary subjects have been calculated in large population studies[7] (**Fig. 2**).

Mitral inflow patterns by pulsed wave Doppler examination demonstrate passive ventricular filling in early diastole (E velocity) and late active filling phase during atrial contraction (A velocity). Estimation of the peak A wave velocity is commonly used in studies that have evaluated atrial function.[13–15] By use of the standard Doppler analysis, one of the peculiar characteristics of the athlete's heart is that the increase of the LV mass verifies the absolute normality of