Assessing LV remodeling in nuclear cardiology

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The concept of ''cardiac remodeling'' was first introduced in the 1970s to describe the structural changes in left ventricular (LV) volume subsequent to a large myocardial infarction,[1] but can also be related to other processes, particularly congestive heart failure (CHF) caused by diabetes mellitus, hypertension, valvular disease, kidney disease, or advanced age.[2-4] Considering that about 50% of heart failure patients (HFP) have preserved LV ejection fraction (EF)[5] and that many have normal myocardial perfusion, it makes sense for nuclear imaging techniques aimed at the diagnostic assessment and monitoring of such patients to also evaluate alternative cardiac parameters, such as diastolic function and ventricular shape/size.

Most imaging approaches to measuring LV geometry have been reported in echocardiography, often for the purposes of monitoring post-infarction remodeling and assessing response to therapy with angiotensin-converting enzyme inhibitors, beta blockers, and angiotensin receptor blockers.[6-10] However, almost all echocardiographic descriptions of geometric changes have been two-dimensional (2D), failing to take into account the actual three-dimensional (3D) nature of the LV.[11-14] In contrast, myocardial perfusion imaging using SPECT or PET is an intrinsically 3D technique, and is ideally suited to accurately, reproducibly and automatedly measure parameters of LV size and shape.[15,16] The paper published in this issue of the Journal by Gimelli et al.[17] investigates the usefulness of a specific parameter of LV shape as a potential additional marker of multivessel coronary artery disease (CAD), in a population of 343 patients with normal EF undergoing gated 99mTc-tetrofosmin SPECT on a new-generation, Cadmium-Zinc-Telluride (CZT) cardiac camera.

The measurement of LV eccentricity (eccentricity index, EI) used by Gimelli et al. is three-dimensional, but global in nature—in other words, the 3D maximal count mid-myocardial surface of the LV is fit to an ellipsoid, whose major axis b and minor axes a and c are used to compute the index according to the equation:

$$\mathrm{EI} = \sqrt{1 - \frac{a * c}{b^2}}. \quad (1)$$

If the minor axes have the same length, the ellipsoid can be considered as an ''ellipsoid of revolution'' obtained via a rotation around its major axis, and the previous equation can be simplified as

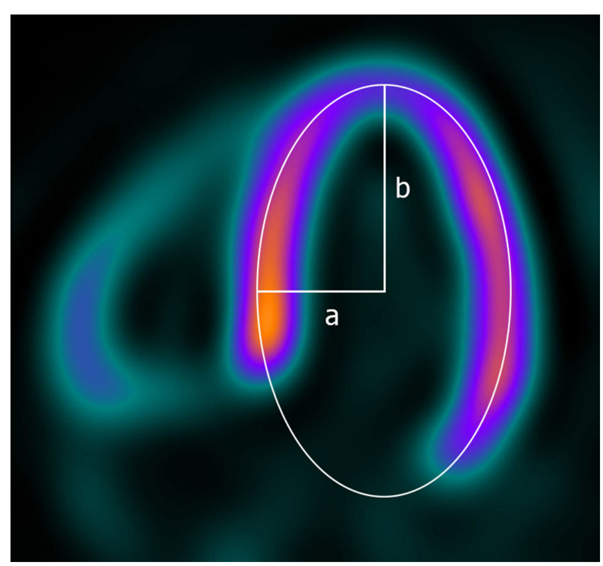

Figure 1. Best-fit ellipse to a horizontal long-axis image from a Flurpiridaz F-18 PET study. The ellipsoid obtained by rotating the ellipse around b is usually prolate since $b > a$, but becomes more spherical the closer in length a is to b.

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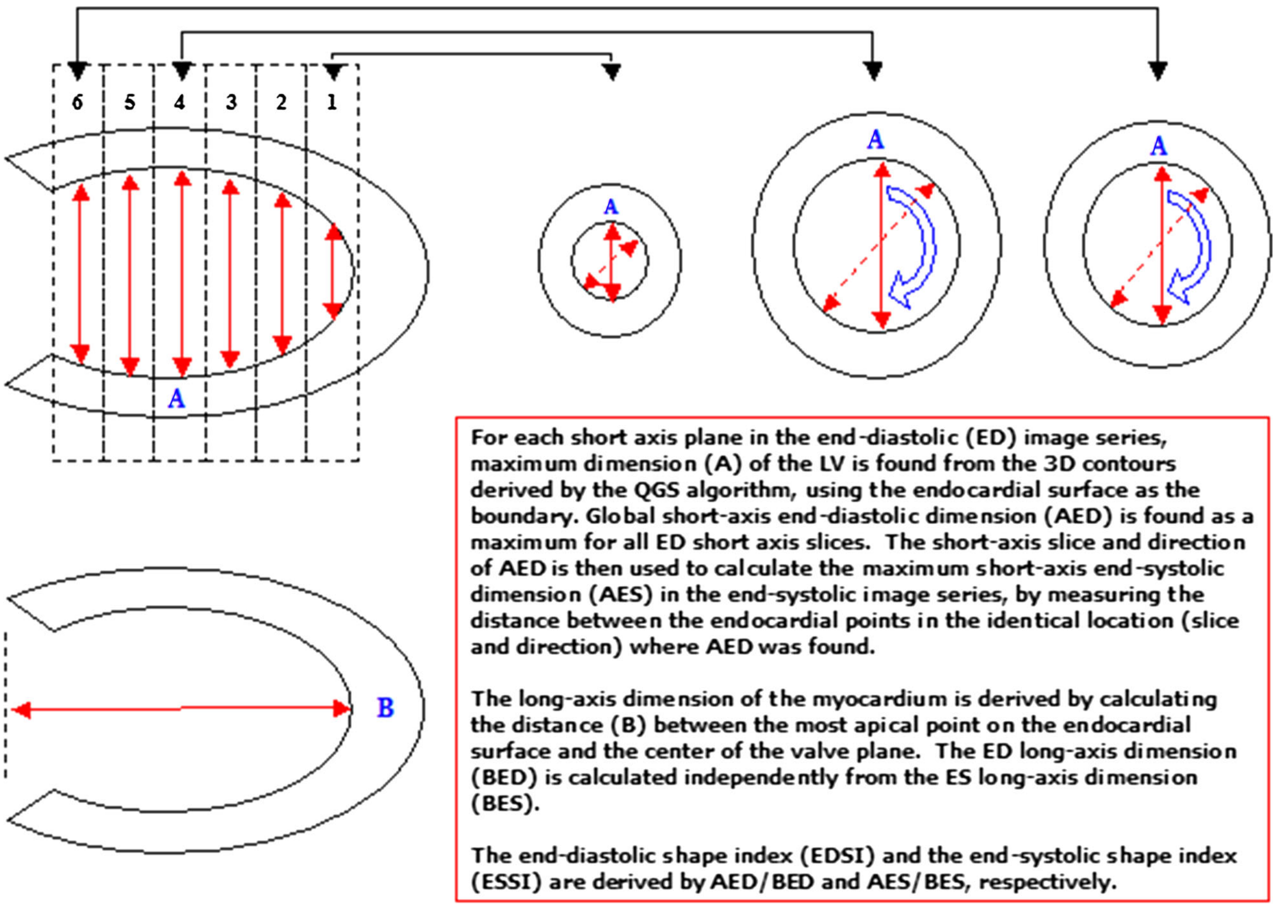

Figure 2. Calculation of the LV's SI by use of the maximum short-axis (**A**) and long-axis (**B**) dimensions of the LV cavity, automatically and independently calculated by software[18] (Reproduced with permission).

$$\mathrm{EI} = \sqrt{1 - \frac{a^2}{b^2}}. \quad (2)$$

This type of ellipsoid is also called a spheroid, and is in fact closer to a sphere the closer a is to b (Fig. 1)—for a perfectly spherical LV, $a = b$ and EI = 0.

Another parameters measuring LV eccentricity, the shape index (SI or LVSI) is more regional in nature, as it is defined as the ratio of the maximum short-axis dimension A of the LV cavity to the long-axis dimension B, from the endocardial apex to the center of the valve plane (Fig. 2).[18]

$$\mathrm{SI} = \frac{A_{\max}}{B} \quad (3)$$

Thus, local ''bulging'' of the LV can be captured and will be reflected in a higher SI, whose numeric value (contrary to the EI) will be closest to 1 when the LV is most spherical. While this approach could be potentially affected by perfusion defects, the myocardial surface-estimating algorithm's ability to ensure the continuity of surface gradients even in the complete absence of myocardial uptake makes it less of a concern.[15]

Of note, both the EI and the SI can be calculated for ungated images as well as for the individual phases of gated acquisitions, with the end-systolic measurement having been reported as most significantly correlated with hospitalization for CHF in subgroups with and without LV dysfunction.[18] The investigation by Gimelli et al. presumably focused on the ungated EI, but since all acquisitions were gated it should be straightforward to extend the analysis to the end-systolic and end-diastolic frames, perhaps using both EI and SI.

Employing EI or SI as a marker of severe and extensive, multivessel CAD would be most useful in cases of triple-vessel disease with balanced reduction of flow, since SPECT is a technique that assesses myocardial hypoperfusion relative to the LV's highest uptake region. The specific CZT SPECT camera used in Gimelli's study is potentially capable of overcoming this limitation and directly measure coronary flow reserve

(CFR) via ''dynamic acquisition,'' but that protocol is still not generally used in clinical practice, and remains at this time most commonly done with PET. As far as SPECT is concerned, however, other parameters (such as summed perfusion scores, LV cavity volumes, and transient dilatation (TID)) could have been helpful in identifying multivessel CAD, and it would have been interesting to see if EI or SI had incremental value over them.

As mentioned before, LV remodeling has been traditionally measured with echocardiographic techniques in order to assess serial changes in LV geometry, either in conjunction with clinical trials of new therapies for heart failure and other cardiovascular diseases, or post-infarction. Echocardiographic classifications of remodeling make ample use of the ratio of LV myocardial thickness to cavity radius, also termed relative wall thickness (RWT), as well as the end-diastolic cavity volume and the LV myocardial mass.[2] The relatively low spatial resolution of nuclear cardiology images is not particularly well suited to measuring ''small'' structures such as myocardial thickness and mass,[16] but LV cavity volumes as well as TID, shape, and diastolic function can be quantified with a high degree of precision. In this context, LV parameters such as the eccentricity index and the shape index can be an important addition to the armamentarium of highly diversified quantitative measurements provided by nuclear cardiology techniques, with potential future application to patient subpopulations (diabetics, hypertensives, etc.) in which early LV remodeling may be of particular interest and significance.

Disclosure

The authors receive royalties from Cedars-Sinai Medical Center for algorithms incorporated in commercially distributed software that performs automatic quantification of perfusion, function and other cardiac parameters, including LV shape.

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