SCIENTIFIC EDITORIAL

Reporting of three-dimensional echocardiography-derived left ventricular volumes comes of age

La mesure de la FEVG en échocardiographie 3D est arrivée à maturité

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Assessment of left ventricular function is the most requested indication for a transthoracic echocardiogram. This is because left ventricular volumes and ejection fractions play a crucial role, not only in managing, but also in predicting patient outcomes. Echocardiographic laboratories have made great strides in changing how left ventricular function is evaluated. There has been a movement from subjective qualitative reporting or ‘eye-balling’ to quantitative assessment, which provide volumes and calculated ejection fractions.

More recently, the focus has been on improving echocardiographic volume measurements using three-dimensional transthoracic echocardiography. It has been well demonstrated that two-dimensional echocardiographic measurements of left ventricular volumes underestimate ‘true’ volumes compared with the reference standard of cardiac magnetic resonance imaging. This is because, with two-dimensional echocardiography, the imaging plane can be foreshortened and geometric assumptions are needed, as only the two- and four-chamber views are measured \cite{1,2,3}. Regional wall motion abnormalities or aneurysms located in walls not seen in the two- and four-chamber views are not accounted for by these measurements.

With three-dimensional echocardiography, a true volumetric assessment is performed, as all left ventricular wall segments are assessed. Multiple publications have demonstrated that three-dimensional echocardiography-derived left ventricular volumes and ejection fractions are more accurate and reproducible compared with cardiac magnetic resonance imaging \cite{1,2,4}. This has led to guidelines supporting the clinical reporting of three-dimensional echocardiography-derived left ventricular volumes \cite{5,6}.

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In practice, however, the reporting of three-dimensional echocardiography-derived left ventricular volumes and ejection fractions is not widespread. Initially, this was because of workflow issues, as acquisition of two- and three-dimensional echocardiographic datasets required switching transducers during the study, the analysis software was off-cart, and extensive training was required for three-dimensional echocardiographic data acquisition and analysis [1,7–9]. Many of these issues have now been addressed with integrated two-dimensional and three-dimensional echocardiographic transducers, simplification of acquisition protocols and the recent development of algorithms that allow automated left ventricular chamber quantification from three-dimensional echocardiographic data sets [10,11]. It is this last development that will have the greatest impact on the integration of three-dimensional echocardiography-derived left ventricular volumes and ejection fractions into routine clinical practice.

Automated techniques that require minimal or no manual correction of endocardial borders could be easily integrated into the clinical laboratory, as training would not be required to operate the program once the data set was acquired; it would also be time-saving. Examination durations would be reduced because acquisition of only a single three-dimensional echocardiographic dataset of the left ventricle would be required, compared with obtaining non-foreshortened two- and four-chamber views, and then manually analysing these views. For patients with arrhythmias such as atrial fibrillation, this technique would increase the accuracy of assessment of left ventricular function, as multiple beats could be easily measured and averaged for reporting. Finally, as the analysis is automated, reproducibility would also be higher, as human variability in analysis would be eliminated. In theory, this would allow a patient to go into any echocardiography laboratory in the world and obtain left ventricular volume measurements that could be followed in different laboratories.

To date, single- and multicentre studies testing these algorithms have demonstrated that they are accurate and robust alternatives to conventional manual methods [10,11]. Additionally, measurements across laboratories were consistent and reproducible. However, these studies were limited, as they only enrolled patients with sufficiently good images to allow automated analysis, and so the true value of these algorithms in consecutive patients, such as would be seen in routine practice, is unknown.

In this issue, Levy et al. addressed this knowledge gap by performing a prospective real-life clinical study to evaluate the accuracy and feasibility of commercially available automated three-dimensional echocardiography left ventricular volume analysis software compared with cardiac magnetic resonance imaging. [12] The authors recruited 63 consecutive patients who had a three-dimensional transthoracic echocardiography study and a cardiac magnetic resonance imaging study performed within 24 hours; they included patients with atrial fibrillation, provided their heart rates were <100 beats/minute, but excluded those with poor transthoracic imaging.

In their results, Levy et al. reported that 14% of patients had to be excluded because of poor three-dimensional echocardiographic image quality precluding reliable analysis. In their remaining 54 patients, three-dimensional echocardiographic volume rates were high, even in 20 patients with left ventricular volumes > 200 mL. Unsurprisingly, the authors found that while left ventricular volumes derived from automated three-dimensional echocardiographic analysis correlated well with cardiac magnetic resonance imaging-derived volumes, overall, they were smaller. Additionally, they reported that these measurements were highly reproducible.

What is interesting about these results is the investigation of the accuracy of the border settings. Algorithms designed to automatically detect borders function by first matching the data set under assessment to a shape in a library of contours that have been traced manually by experts, and then adjusting the borders of that shape to the data. While determining the left ventricular cavity to trabecular myocardial border is not difficult, it is the location of the trabecular to compacted myocardial border that is difficult. This is difficult not only for humans, but also for computer algorithms, which not only rely on grayscale changes, but also search for certain myocardial features. There is variability between echocardiographic readers and laboratories regarding where the compacted-trabecular myocardial border is placed. For an algorithm to be trusted, it must place the borders where the interpreter is confident of the tracing. Thus, these algorithms offer default myocardial border settings that are consistent with the practice of individual echocardiography laboratories.

The authors examined the accuracy of three default settings:
• the 'standard' recommended border;
• a narrower border setting (closer to the left ventricular cavity);
• a wider border setting (further into the myocardium).

They found that the wider setting resulted in better agreement with cardiac magnetic resonance values, especially in those with larger ventricular volumes. However, it also resulted in 31.5% of patients with values greater than those reported on cardiac magnetic resonance imaging. With the narrower setting, there was a significant underestimation of volumes in 24% of patients.

This paper offers new information about how to use these default borders in a practical manner. For those using this program, the larger default border setting should be used to report on patients with a left ventricular ejection fraction < 50%. This would improve the accuracy of the reported volumes compared with cardiac magnetic resonance imaging.

Echocardiography remains the most readily available imaging modality for rapid assessment of left ventricular function worldwide. Ideally, the use of automated analysis programs will increase the accuracy of reported echocardiographic volumes, so that they are interchangeable with cardiac magnetic resonance imaging. This would perhaps create a world that is 'post-imaging modality', where the volumes are comparable whether they are obtained from echocardiography or cardiac magnetic resonance imaging or even cardiac computed tomography.

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Three-dimensional echocardiography-derived left ventricular volumes

Disclosure of interest

R.M.L. is a member of the speaker’s bureau and the Advisory board of Philips Healthcare. W.T. is a member of the speaker’s bureau of Philips Healthcare.

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