Comprehensive 3D echocardiography assessment of mitro-aortic valvular physiology. Are we ready?

José Zamorano* and Covadonga Fernández-Golfín

University Hospital Ramon y Cajal, Madrid, Spain

Online publish-ahead-of-print 1 August 2013

Non-invasive mitral and aortic valve evaluation is important in clinical cardiology. Acquired pathology contributes to high morbidity and mortality. Technical developments, both in surgery and in interventional cardiology, have contributed to the increase in the type and number of treatment procedures. Older patients, sicker patients, and more complex abnormalities are now available for treatment. In this context, non-invasive imaging plays a crucial role not only in valvular heart disease diagnosis but also, and more important, in the selection of best therapeutic approach for each patient.

Aortic and mitral valve are anchored to the fibrous skeleton of the heart. They are in close proximity through the mitro-aortic continuity and share the left and right fibrous trigones. They both are conformed by the annulus, leaflets, and tendineous cords (mitral valve). The left ventricle (LV) plays a key role in the physiology of both valves that far from being passive elements have their own intrinsic function. Both the mitral annulus (MA) and the aortic annulus (AA) with a pre-determined shape undergo anatomical changes along the cardiac cycle that contributes to the function of the valve itself.

For years, research has focused on either aortic or mitral valve in isolation. However, the anatomic relationship between both valves should translate into an interdependence physiology. Early animal models showed synchronicity of aortic and mitral valve annular dynamics throughout the cardiac cycle based on the mitro-aortic continuity.1 Further animal studies confirmed the reciprocal annular behaviour with a change in significant area during the cardiac cycle.2 However, in contrast with previous works, this interdependence seemed to be related to dynamic annular contraction as seen under different haemodynamic conditions. The dynamic physiology of both annuluses during isotopic stimulation was reflected in both annular area change and mitro-aortic angle change.2

Technical issues have limited non-invasive imaging analysis of mitral and aortic annular physiology. Its complex shape and anatomy limited research with 2D echocardiography to either the mitral or aortic valve. Technical developments of 3D echocardiography overcome some of these limitations and, for the first time, non-invasive evaluation of the 3D structures of the both valves and its relation was possible. Further technological advances solved early limitations of 3D technology, making it possible to assess different cardiac structures with accurate spatial and temporal resolution.3

Using TEE 3D technology, Veronesi et al.4 described the mitro-aortic physiology and coupling in 24 patients with normal LV ejection fraction and normal mitral and aortic valves. For the first time, using custom software, no invasive mitro-aortic coupling (MAC) could be evaluated. As expected, annular mitral and aortic area changed reciprocally during the cardiac cycle (pusatility) as well as the mitro-aortic angle which decreased during systole, probably playing a significant role in cardiac performance. Further studies by the same group tested the impact of mitral valve surgical procedure (repair with ring implantation) in the MAC dynamics by assessing the influence of such a surgery on the normal aortic valve.5 Not surprisingly, mitral valve parameters showed significant differences after surgery, with lower pulsatility and area, but changes were also noted in the aortic valve and annulus where a reduced pulsatility was seen along with a decreased in the mitro-aortic angle.5

In the present study, Tsang et al.6 evaluated the impact of transcatheter aortic valve replacement (TAVR) in the MAC by analysing effects on MA dynamics after TAVR using the same technology. Again, the results of the study support the concept of MAC. First of all, the study shows the effect of calcified aortic stenosis in the anatomical configuration and dynamic behaviour of the MA showing reduced area, reduced displacement, and wider mitro-aortic angle. Secondly, these changes along with more spherical annular configuration were maintained after TAVR. Thirdly, mitro-aortic continuity grade of calcification affects final MA configuration. Thus, the presence of calcified aortic stenosis affects mitro-aortic anatomical configuration and MAC. It seems to be a consequence of the diseases that is maintained after TAVR which also affects the MA configuration. As the authors discuss, evaluation of MAC may influence TAVR development and new device designs and may be a part of the routine pre- and post-TAVR evaluation. Other implications of this findings regarding cardiac performance or clinical significance for the patients need to be further studied.
These results along with previous studies by the same group are relevant to the scientific community for several reasons. Three-dimensional echocardiography and software developments open a new field of research on cardiac physiology and pathological conditions previously limited to experimental animal models. Continuous development of new therapeutic surgical and interventional devices challenges non-invasive imaging techniques. This way, complete understanding of cardiac anatomy and physiology based on imaging, mainly echocardiography, plays a key role in the clinical arena. For the first time, non-invasive assessment of the MAC is feasible with reproducible and semiautomatic quantification of different parameters available. A first description of the MAC in the normal heart is performed as well as preliminary insight of its behaviour in valvular heart diseases and its change after intervention.

However, non-invasive MAC needs to be further evaluated in different cardiac conditions and different degrees of valvular heart diseases before and after intervention. This way, possible clinical applications, others than the physiological and anatomical evaluation, may be explored. Even though, TEE 3D echocardiography acquisition is straightforward, standardized software availability and expertise limits its applicability. In addition, this findings need to be reproduced by other groups before this type of analysis can be expanded to clinical decision-making.

References


**Aortic regurgitation during systolic-phase accompanied by mitral regurgitation in patients with continuous-flow left ventricular assist device**

Tomoko S. Kato*, Mathew S. Maurer, Fusako Sera, Shunichi Homma, and Donna Mancini

Division of Cardiology, Department of Medicine, Columbia University Medical Center, 622 West 168th Street, PH 9, Room 208, New York, NY 10032, USA

* Corresponding author. Tel: +1 212 342 4523; fax: +1 212 202 4018, Email: riniko@sannet.ne.jp

A 78-year-old male underwent continuous flow left ventricular assist device (LVAD) implantation due to ischaemic cardiomyopathy as a destination therapy. Routine echocardiogram performed 6 days after the surgery showed ‘systolic-phase’ aortic regurgitation (AR); the timing of regurgitation jet starting at the mid-systolic phase and ending at the early diastolic phase [Panel A, the colour Doppler M mode at the aortic valve (AV), white arrow]. The AR occurred slightly after the onset of mitral regurgitation (MR) [Panel B, the colour Doppler M mode at the mitral valve, yellow arrows], and both MR and AR timings were consistent with the systolic phase (See Supplementary data online, Videos S1 and S2). No remarkable AR jet was documented during the diastolic phase. The AV was mostly closed throughout the cycles, which opens once every 8–10 beats (Panel C). The mean pressure gradients of the trans-AV and trans-mitral valve based on the continuous wave Doppler measurements of AR (Panel D) and MR flow (Panel E) were 3.7 mmHg and 24.3 mmHg, respectively. The morphology of AV annulus changes through the cycles irrespective of the AV opening, with the AV annulus abnormally distorted and dilated during early mid-systole (Panel F), whereas the septum wall as well as the AV annulus edge slightly pushed towards the left ventricle during diastole (Panel G). The morphological change of the AV annulus during the systolic phase under LVAD support may result in impaired co-apptation of AV leaflets leading systolic-phase-limited AR in this patient. Imbalanced contraction between left and right ventricles under LVAD support may affect the abnormal distorsion of AV annulus during systole.

Supplementary data are available at *European Heart Journal – Cardiovascular Imaging* online.

Published on behalf of the European Society of Cardiology. All rights reserved. © The Author 2013. For permissions please email: journals.permissions@oup.com