Regurgitant mitral valve and 3D echocardiography—meant for each other?

The requirements for echocardiography to assess the morphology and function of the regurgitant mitral valve have largely been dependent on the available treatment options. In the era of mitral valve replacement, the most important question for the echocardiographer was to determine the severity of regurgitation and to estimate if further delay of operation would worsen the prognosis.

With the development and widespread use of advanced techniques for surgical valve reconstruction, which have shown to improve survival compared to valve replacement, the demands of echocardiography have increased considerably. Apart from assessing the severity of regurgitation using Doppler techniques, the major goal of echocardiography is now to assess the feasibility of valve repair before operation. To determine the feasibility of mitral valve repair and to plan the optimal surgical technique as much details of mitral valve pathomorphology as possible need to be obtained. Complex valve pathology such as commissural involvement and bi-leaflet prolapse may result in significant difficulties for the surgeon. Thus, there is a need for a reliable and reproducible method for the comprehensive assessment of mitral valve pathomorphology which is crucial for planning and outcome of the operation.

Today’s gold standard for the evaluation of mitral valve pathomorphology is transesophageal Doppler echocardiography owing to the optimal image quality and the possibility to achieve a nearly unrestricted view onto the valve. Excellent agreement between 2D TEE findings (in the hands of experienced observers) and intraoperative morphology has been shown convincingly.

Nevertheless, two-dimensional techniques still may be insufficient to demonstrate exact spatial localization of pathological structures especially in the commissural zones and the subvalvular apparatus. One explanation for this limitation of 2D TEE is the need for mental reconstruction of the three-dimensional valve anatomy by the examiner.

Fortunately, the advances in surgery were paralleled by the development of new echocardiographic modalities allowing a more comprehensive and complete evaluation even of complex cardiac structures—such as the mitral valve apparatus. Since its first steps, a major potential of three-dimensional (3D) echocardiography has been a better spatial orientation and the ability to more comprehensively describe and measure cardiac structures.

Correspondingly, there is a long common history of 3D echocardiography and the mitral valve. It started with insights about the non-planarity of the mitral annulus using custom-made software based on multiplanar TEE images. With the development of easier and faster acquisition hard- and software, several studies demonstrated the value of transesophageal 3D echocardiography to better describe leaflet and subvalvular morphology. Salustri et al. used a scoring system to semi-quantitatively measure the value of reconstructive 3D echo in comparison to 2D echo. Three-dimensional echo turned out to be superior to 2D echo for the localization of pathological structures, for the visualization of the commissures and for the analysis of mitral valve opening patterns. Other groups found a high correlation between planimetry of the regurgitant orifice in 3D rendered images and the 2D echo PISA-based calculation of the effective regurgitant orifice. There have also been elegant experimental studies demonstrating new insights into the pathophysiology of ischemic mitral regurgitation and changes of the complex subvalvular apparatus that could not have been analysed without using 3D echocardiography. The recognition of an
increasing lateral displacement of the posterior papillary muscle tip after inferolateral myocardial infarction led to the development and the experimental testing of modified surgical techniques (LV plication) which were also controlled by 3D echocardiographic techniques.  

Additionally, first studies of transthoracic 3D echocardiography have been performed either using reconstructive techniques or the newly developed real-time 3D approach. However, transthoracic image quality will always remain limited in a substantial portion of patients. Thus, transthoracic 3D approaches—to our opinion—will not be superior to 2D TEE in the precise evaluation of mitral valve pathology. Another addition to 3D echocardiography is the combination with color Doppler information. Although first studies demonstrated a good correlation between conventional techniques for the quantitative evaluation of mitral regurgitation, limited color 3D image quality will prevent from superior sensitivity and specificity.

In this issue of the Journal Macnab et al. describe the value of transesophageal reconstructive 3D echocardiography for the assessment of mitral valve pathology in the preoperative evaluation of mitral regurgitation. Moreover, they compared results of 3D echocardiography to those obtained by conventional 2D TEE using surgical findings as gold standard. They included a relatively large number of 75 patients and performed a well-planned and structured analysis of both the 2D as well as the 3D data. Three-dimensional TEE was superior in the description of all different forms of valve pathology except the "simple" and isolated middle scallop prolapse. Three-dimensional reconstruction was particularly helpful in complex valve disease with the involvement of several scallops and especially the commissural segments. Two-dimensional imaging in these regions clearly failed because of difficulties to conceptualize a complex morphology in 2D image planes. A very important point is the fact that 3D was able to identify and detect normality: 3D TEE revealed to have a higher negative predictive value than 2D TEE. If a valve leaflet or a leaflet segment was assessed as normal using 3D echocardiography, it was very likely that this finding was confirmed at surgery. Both, the high sensitivity of identifying pathomorphology correctly and detecting normality clearly will have an impact on clinical decision-making, planning of surgical strategy, and most likely the duration of operation. In this respect, the work of Macnab et al. represents a valuable contribution in the field of clinical use of 3D echocardiography.

There are two other recent studies that—similar to the one presented by Macnab et al. in this issue of the Journal—evaluated 3D TEE in comparison to surgical findings and 2D TEE or to surgical findings alone. Both studies used a limited semi-quantitative approach in a smaller number of patients but also demonstrated a clinically relevant value of 3D in mitral regurgitation.

Finally, some limitations of 3D reconstruction of TEE images have to be mentioned. The serial acquisition of image planes and the resulting duration of acquisition lead to artefacts in the 3D data set especially in atrial fibrillation or in not ventilated patients. Thus, the ultimate goal for future would be—similar to TTE—"real-time 3D TEE".

There is no doubt that the close connection of 3D echocardiography and the mitral valve leads to one of the first clinically established indications for 3D echocardiography: 3D echo and mitral valve are really meant for each other!

References


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