Where 3D Makes a Difference
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3D echocardiography has revolutionized imaging in both operative and interventional settings. Three impact areas where 3D TEE imaging makes a difference include the mitral valve, challenging basic geometric assumptions, and guiding interventions in the EP and cath lab.

Mitral Valve
The 2012 EAE/ASE recommendations for image acquisition and display using 3D echo recognize that three-dimensional assessment of mitral valve pathology should be incorporated into routine clinical practice. The mitral valve is made to be imaged using 3D TEE. When the valve is closed in systole the leaflets are perpendicular to the echo beam providing optimal imaging and 3D reconstruction. One of the original papers written on 3D TEE imaging by Sugeng et al showed that the mitral valve was the best imaged valve in the heart including the ability to easily distinguish the various leaflet segments and commissures. In addition, the 3D findings correlated with surgical findings in 44 out of 46 patients. A more recent paper by Hien et al further confirmed that 3D imaging of the mitral valve increases accuracy of interpretation by facilitating spatial orientation. Not only does 3D imaging assist with determining the location of pathology but also gives a better understanding of how much of the valve is involved. In addition, lesions such as commissural prolapse and leaflet clefts are typically noted more clearly with 3D imaging compared to 2D imaging.

3D imaging of the mitral valve also makes communication of findings much easier. Rather than showing multiple 2D images to a surgeon or interventionalist, usually a single 3D image can provide the platform to have a complex discussion regarding mechanism and options for repair or intervention.

Unless the echocardiographer is meticulous in obtaining 2D images based on cardiac anatomy, determining exact locations of disease and extent and severity of mitral pathology can be fraught with errors. In addition, measuring annular dimensions and leaflet lengths may be off axis using 2D imaging alone. 3D echo increases the accuracy of measurements by assisting the echocardiographer in determining with certainty the leaflet or anatomic dimension being measured. This is typically done using multiplanar reconstruction (MPR) which is available on all 3D platforms.

3D imaging has changed how we look at the mitral annulus, which was not possible with 2D imaging. We now have a better understanding of the dynamic
function of the mitral annulus and the changes that occur with mitral valve pathology.

The normal mitral annulus demonstrates early systolic contraction followed by gradual annular area increase until end systole. The septolateral diameter narrows in early systole and then gradually increases. The transverse diameter remains relatively stable over systole. The annular height increases throughout systole. Because of these changes the saddle shape of the annulus become more pronounced throughout systole. The systolic saddle shape of the annulus is felt to reduce leaflet stress and assist in leaflet coaptation.

Patients with ischemic mitral regurgitation and myxomatous mitral regurgitation have enlarged and flatten annuli (reduced saddle shape). The ischemic annulus is typically dilated in the septolateral dimension with the transverse dimension relatively unchanged. Ischemic annular motion appears to be less dynamic than the normal mitral annulus. The annulus contracts less during systole with decreased shortening of the septolateral dimension and reduced increase in annular height. The annulus loses it ability to change shape as it continues to flatten and dilate. The myxomatous annulus is dilated in both the septolateral and transverse dimensions. Septolateral systolic contraction is reduced and delayed in myxomatous disease. Annular height increases but to a much lesser degree compared to normal hearts. Therefore the saddle shape is not as deep in patients with myxomatous disease. Below is a chart to summarize the changes seen:

### Mitral Annulus

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Myxomatous</th>
<th>Ischemic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septolateral Dimension</td>
<td>Normal</td>
<td>Enlarged</td>
<td>Enlarged</td>
</tr>
<tr>
<td>Transverse Dimension</td>
<td>Normal</td>
<td>Enlarged</td>
<td>Normal</td>
</tr>
<tr>
<td>Anterior Circumference</td>
<td>Normal</td>
<td>Larger</td>
<td>Normal</td>
</tr>
<tr>
<td>Posterior Circumference</td>
<td>Normal</td>
<td>Larger</td>
<td>Larger</td>
</tr>
<tr>
<td>Systolic Septolateral contraction</td>
<td>Early systolic annular contraction</td>
<td>Delayed with reduced contraction</td>
<td>Reduced</td>
</tr>
<tr>
<td>Systolic Annular Height</td>
<td>Increased</td>
<td>Reduced</td>
<td>Reduced</td>
</tr>
<tr>
<td>Systolic Saddle Shape</td>
<td>Increased</td>
<td>Reduced to Flat</td>
<td>Flat</td>
</tr>
</tbody>
</table>

Currently there is little consensus regarding the most appropriate annuloplasty ring design or support for use of one device over another. Most teaching states that for ischemic or functional mitral regurgitation the surgeon should use a rigid or semi-rigid complete ring and downsize the ring for what was measured. For myxomatous disease most surgeons will use either a partial or complete ring that is flexible and up size for what was measured especially is the leaflets are particularly long. This dogma is likely to be challenged in the future as we better
understand mitral annular dynamics and how ring selection changes these
dynamics, specifically the effect annuloplasty has on leaflet stress, strain, and
coopation. 3D imaging will likely play an important role in assisting with ring
selection in the future.

Challenging Assumptions
The impact of 3D imaging on our understanding of AV anatomy and how to
accurately measure the AV annulus for TAVR and surgical AVR is significant.
We now know that the AV basal virtual annulus is more likely an ellipse rather
than the assumed circle. In addition and importantly, the short axis of the
anatomic ellipse is typically measured with 2D imaging (ME AV LAX). The long
axis of the ellipse can only be measured accurately with 3D imaging. In addition,
AV annular area and perimeter are now the common measurements used to
make valve size decisions for TAVR. These measurements can only be
accurately measured using 3D imaging.

The elliptical shape of the AV annulus also extends to the shape of the LVOT.
Just like the AV annulus the LVOT is an ellipse and 2D imaging only measures
the short axis of the ellipse (ME AV LAX). This has important implications for
determining aortic valve area using the continuity equation. By measuring only
the short axis of the LVOT ellipse using 2D imaging and then assuming the
LVOT is a circle, the true area of the LVOT will be underestimated. Therefore,
the calculated area of the AV by the continuity equation will also be
underestimated (smaller than it actually is). Obviously this information is very
important when deciding whether replace a stenotic AV and have gradients and
aortic valve areas that don’t correlate.

EP and Cath Lab
The echocardiographer is now taking an active role in catheter-based
interventional procedures. “Interventional echocardiography” is when the
echocardiographer guides and assesses the progress and outcome of
interventions in a real-time, continuous, and stepwise fashion. 3D
echocardiography is an essential component to the interventional
echocardiographer.

The ability to guide the procedures using 3D imaging is changing how
interventions are performed. 3D imaging with its inherent improvement in spatial
anatomy guides atrial septal puncture, ASD/PFO closure, perivalve leak closure,
TAVR, and left atrial appendage occlusion with greater precision compared to 2D
imaging alone. The catheter based edge-to-edge mitral clip repair cannot be
performed without echo guidance and 3D imaging enhances the success of the
procedure. In addition, there are many case reports showing the positive impact
3D echocardiography has on the success of interventional procedures many of
which would not have been successful or possible without 3D imaging.
Recommended Reading (bold readings are top choices):


Sugeng et al. Live 3-dimensional transesophageal echocardiography. J Am Coll Cardiol 2008;52:446-9


Faletra et al. 3D TEE during catheter-based interventions. J Am Coll Cardiol Img 2014;7:292-308


Gross et al. TEE and Interventional Cardiology. J Am Soc Echocardiogr 2011 Jul;24(7):A22