3D Echocardiography: 2011 update

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No disclosures
3D cardiac ultrasound imaging in 2011: Just pretty pictures or added value?
3D cardiac ultrasound imaging in 2011: Just pretty pictures or added value?

• A bit of both
Why 3D echo?

- Easier to understand 3D structure of the heart + relation of various structures to one another
  - No need to mentally reconstruct the 2D images
- Easier to demonstrate to those who are echo-challenged
- No need to rely on geometric assumptions when quantifying volumes, mass, function
- Potentially faster image acquisition
3D echo unique indications: 

valve disease

• 3D echo uniquely suited for imaging valves
  – Valves have
    • Non planar surfaces
      – Diagnosis of MVP
    • Complex spatial relationships of all components of the valve and surrounding structures
  • Complex Doppler color flow jets
3D echo reconstruction method

– Earliest approach in the 1970’s
– Requires precise location and timing of each image
– Time consuming
– Very accurate for quantitation

TEE - MV

LV volume

Handschumacher et al, JACC 1993;21:743-753
Siu et al, Circ 1993;88:1715-23

Courtesy of M. D’Ambra MD
3D echo volumetric method

– Required development of matrix array transducer
  • $30^\circ \times 50^\circ$ volume acquired / displayed in real time
  • $90^\circ \times 90^\circ$ full volume created from 1 beat or fusion of subvolumes from more than 1 beat (esp for color Doppler)

– Cropping required

– Potentially fast

– Transducer also allows multiple-plane 2D imaging
Real time 3D matrix array ultrasound transducers: acquire a volume of ultrasound rather than a single plane

> 3000 elements
Real time 3d TTE
Cropping 3D image set avoids foreshortening of the LV
Real time 3D matrix array ultrasound transducers allow imaging multiple 2D planes at same time

- Multi-planes over multiple cardiac cycles
- Multiple planes during the same cardiac cycle
- Leveraging the image quality of 2D
- Quantitation, on axis imaging, rapid image acquisition
Multi-plane 2D imaging from 3D transducer
Evidence based value of 3D echo quantitation

• LV volume, mass
• LA volume
• Valves
  – Stenosis
    • Planimetry of MVA, AVA
    • EROA of MR and AI
3D TTE for volume and EF

LV mass
<table>
<thead>
<tr>
<th>Ref</th>
<th>Parameter</th>
<th>Reference standard</th>
<th>r</th>
<th>Mean diff ± 1SD</th>
<th>Inter-obs variability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circ 2006;114:654-61</td>
<td>LV EDV</td>
<td>cMR</td>
<td>0.97</td>
<td>-5 ± 24 ml</td>
<td>11.2</td>
</tr>
<tr>
<td>Circ 2006;114:654-61</td>
<td>LV ESV</td>
<td>cMR</td>
<td>0.96</td>
<td>-6 ± 28 ml</td>
<td>14.2</td>
</tr>
<tr>
<td>JASE 2005;18:991-7</td>
<td>LV mass</td>
<td>cMR</td>
<td>0.95</td>
<td>-1.8 ± 19.9 g</td>
<td>12</td>
</tr>
<tr>
<td>JASE 2010;23:116-26</td>
<td>RV EDV</td>
<td>cMR</td>
<td>0.84</td>
<td>10.2 ± 20.8 ml</td>
<td></td>
</tr>
<tr>
<td>CV US 2009;7:16</td>
<td>LA volume</td>
<td>cMR</td>
<td>0.76</td>
<td>23.3 ± 9.6 ml/m²</td>
<td>5.1</td>
</tr>
</tbody>
</table>

3D TTE superior to 2D TTE for LV volume in patients with prior MI

Jenkins et al, Eur Heart J 2009;30:898-106
3D echo for valve disease: mitral stenosis

- Quantitation - Sometimes planimetry is better than Doppler PHT for MVA
  - Yet planimetry requires a precise image plane that is perpendicular to the long axis of the smallest MV orifice
    - MV orifice may be asymmetrically narrowed
    - Improper plane position results in overestimation of MV Area
3D view of MS
Selection for PMV

3D echo provides better assessment of degree and location of commissural fusion

View from LA

View from LV

View from LA
Alternative use of matrix transducer for MS: simultaneous multiplane imaging
3D TTE guided MV planimetry: excellent correlations with 2D but improved classification of disease severity and reduced measurement variability

Sebag et al, Am J Cardiol 2005;96;1151-6
Value of 3D TTE quantitation of MS

Zamorano et al, JACC 2004;43:2091-96
Sebag et al, Am J Cardiol 2005;96;1151-6

• More precise than 2D planimetry
  – Reduced measurement variability
• Better classification of disease severity
• Particular benefit for less-experienced personnel
  – Even experts will notice time savings

• Current Challenges:
  – AF with variable response
    • If integrating multiple cardiac cycles into 3D volume
Stitch artifact due to respiration
3D echo for valve disease: Mitral regurgitation

- Quantify severity of MR (Vena contracta, PISA)

- Delineate specific lesions responsible for MR
  - Degenerative, myxomatous, congenital, endocarditis

- Provide insights into mechanism of functional and ischemic MR

- By better understanding shape and anatomic relationships of surrounding structures, can assist in design of valve repair techniques and prosthetic supports (rings, etc)
Quantifying MR by vena contracta area

1. acquire full volume
2. crop to get best display of jet
3. Crop in plane orthogonal to orifice (parallel to leaflets)
4. Rotate and display en face the smallest color jet area in LA immediately behind orifice
5. Planimeter vena contracta
MR quantitation by RT3D

vena contracta area

Khanna et al, Echocardiogr 2005
RT3D of PISA for MR
Fluid dynamic theory predicts that as flow approaches a circular, finite orifice, it forms a series of concentric hemispheric shells with gradually decreasing area and increasing velocity.

By conservation of mass, the flow rate of each one of the isovelocity hemispheres should equal the flow rate at the regurgitant orifice.

Flow rate = Surface Area x Velocity

Is the hemispherical assumption for PFCR valid for the mitral valve?
A hemispherical PFCR by 2D (A, arrows) and by 3D (B, C) seen in this patient with functional MR.
A patient with dilated cardiomyopathy with a typical hemispherical PFCR by 2D (A, arrows); yet the PFCR contour is actually hemielliptical as shown by 3D (B, C).
2D proximal flow convergence region (PFCR) underestimated effective regurgitant orifice area (EROA) compared to the quantitative Doppler (Doppler Q) method.

Yosefy et al JASE 2007:20:389-96
2D misclassified 56% (14/25) as mild-to-moderate with nearly half of those (25% of the total) misclassified as mild–versus (1/25) 4% misclassified as mild-to-moderate by the simplified RT3D method.

Yosefy et al JASE 2007;20:389-96
3D echo for Aortic Stenosis
AV planimetry

Handke et al, Echocardiography 2002;19:45-53
AS quantitation: 3D TEE comparable to 2D

3D vs gorlin

2D vs gorlin

3D TEE vs 2D TEE

Rapid recognition of AS etiology

Viewed from aorta

Viewed from LV
3D echo for valve disease: aortic insufficiency

• Improved quantitation
  – PISA, Vena contracta as for MR

• Mechanism of AR

• Quantitation of structural relationships
  – Important for valve repair of AI
    • Sinotubular junction to coaptation, STJ to annulus, annulus to coaptation, annulus, STJ
Value of 3D echo: visualizing spatial relationships

• Accurate localization of redundant portion of MVP leaflet
• Localizing cardiac masses
• Complex regurgitant color jets
• Congenital heart disease
Identifying small membranous VSD
Rapid recognition of MR mechanisms

Prosthetic MV dehiscence

Sugeng et al, Echocardiography 2003;20:265-273
3D TEE of MVs viewed from LA

Bileaflet MVP

Johri et al, Br Hrt J. 2010;96;390-397

Posterior leaflet MVP
Comparative accuracy of 2D and 3D TTE and TEE in identifying MV pathology in patients undergoing MV repair

Zekry et al, JASE 2011;24;1079-85

All modalities equally reliable for functional MR. 2D TEE and 3D TEE comparable for diagnosis of MR mechanism but 3D TEE had advantage of better localizing lesions
3D echo for valve disease:
unique views of valves

• Localizing vegetations and other lesions
Value of 3D echo
real time guidance of catheter-based interventional procedures

• PFO / ASD closure
• Closure of Paravalvular leaks
• Deployment of left atrial appendage closure devices
• Percutaneous AV replacement and MV repairs
3D TEE provides more accurate depiction of ASD shape than 2D TEE and improves device selection and reduces residual leaks

Defect area and maximal dimensions underestimated by 2D TEE in the complex ASDs

Johri et al, JASE 2011;24:431-7
Real-time 3D TEE-guided catheter based repair of severe paraavalvular regurgitation in prosthetic valves

Left atrial appendage closure
Future uses of 3D echo

- RV volume
- Valvular heart disease
  - Quantitation of valve regurgitation
    - Vena contracta
    - PISA
    - Direct planimetry ROA
  - Quantitation of AVA
    - More accurate LVOT area
- Stress echo
- LV dyssynchrony
- Fusion imaging
3D stress echo
3D for CRT
Fusion imaging
3D LV volume and dysynchrony map integrated with 3D coronary venogram
Challenges remain

• Technology diffusion
  – Hands-on training

• Continued technologic enhancements
  – Higher frame (volume) rate acquisitions
    • Single beat full volumes
  – Image quality (TTE)
  – Processing time
    • Automated cropping
3D echocardiography 2011

• Clear uses today with advantageous over 2D
  – Visualizing spatial relationships between structures
  – Assessment of valvular heart disease
  – TTE
    • Quantitation of LV volume, EF, mass, LA volume
    • Improved quantitation of valve area, severity of regurgitation
  – TEE
    • MV morphology, improved visualization of pathologies
      – Enhanced communication with surgeons
    • Guiding interventional procedures
TEE 3D reconstructions to guide MV repair
Garcia-Orta et al, JASE 2007;20:4-12

1) 3D better than 2D TEE for:
A1 segment involvement,
Commissural involvement

2) No difference for:
A2, A3, P1, P2, P3,
Leaflet perforation,
annular dilation,
ruptured chords

3) 2D less accurate than 3D:
# of segments involved, two
leaflet prolapse, multi-segment
prolapse, commissural ds