Basics of Real Time 3D Echocardiography

J.S. McGhie
W.B. Vletter
F. Meijboom
R. Frowijn
H. Van de Zwaan

No disclosures
Image acquisition and manipulation

Outline

- Introduction
- 3D imaging
- Data set manipulation
Image acquisition and manipulation

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Ultrasound imaging modalities in Cardiology
xMatrix X3-1 transducer

xMatrix array technology utilizes 2400 fully-sampled elements for 360-degree focusing and steering
RT3DE transducers iE33

Purewave technology – wider bandwidth, higher sensitivity

**X3-1**
- TTE adult
- >20 kg
- Footprint: 15 x 24mm

**X7-2**
- TTE pediatric
- <20 kg
- Footprint: 15 x 20mm

**X7-2t**
- TEE adult

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Erasmus MC
Image acquisition and manipulation

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- 3D imaging
- Data set manipulation
3D Echo Protocol – Imaging modes

LIVE 3D

- small sector - thin slice acquisition
- zoom mode (enlargement of a subsegment of this sector)
- xPlane (lateral tilt image)
3D Echo Protocol – Imaging modes

LIVE 3D

- small sector - thin slice acquisition
- zoom mode (enlargement of a sub segment of this sector)
- xPlane (lateral tilt image)
The current display format suffers from attempting to show 3D images on a 2D display.
Small sector – Thin slice mode

Real-time dataset (sector 30° x 60°)

Full-volume dataset not real-time (sector 101° x 104°)
3D Echo Protocol – Imaging modes

LIVE 3D

- small sector- thin slice acquisition
- zoom mode (enlargement of a subsegment of this sector)
- xPlane (lateral tilt image)
LIVE 3D – Zoom mode (TEE)
LIVE 3D – Zoom mode (TEE)
3D Echo Protocol – Imaging modes

LIVE 3D

- small sector- thin slice acquisition
- zoom mode (enlargement of a subsegment of this sector)
- xPlane (lateral tilt 2D image)
xPlane (a cross section and its orthogonal plane)
xPlane (a cross section and its orthogonal plane)

Lateral tilting
2D to 3D full volume
- not real-time
- multiple subvolumes are necessary because of limited maximal scan sector

Maximal pyramidal dimensions
- X7: 92° x 83°
- X4: 84° x 84°
- X3-1: 101° x 104°
3D Echo Protocol: Full Volume

Patient and machine preparation

1. Good ECG signal with clear R-wave
   *(3D Full volume triggering)*
2. Adjust machine settings (follow the rules as for 2D) for the best 3D resolution:
   - Harmonics – fundamental, adjust gain setting
     (clear blood-tissue border - minimize noise)
   - Region of interest between the dotted lines
   - Minimize sector (angle, depth, density)
   - Maximise number of subvolumes
   - *Increase overall gain before recording*
3D aquisition work flow
3D acquisition work flow: Gainsetting

Overall gain

TGC
3D Analysis

• Cardiac Function

• Cardiac morphology
Image optimisation for the LV and RV

Priority: Good quality 2D image

Frame rate as high as possible  - acquisition beats: 7
  - optimise depth setting

Complete ventricle in dataset  - optimise density setting

Extreem dilatation  - acquisition beats: 5 (wide angle)
  - notice: drop in frame rate
Frame Rate 3D Volume Data Set

Ultrasound speed: 1500 m/sec
Depth of 16cm: transmitting + receiving time: 220 micro sec
2D (90 scanlines) requires 19.8 msec → FR: 50 Hz
3D (2400 scanlines) requires 528 msec → FR: 1.9 Hz

How to improve the frame rate

- Receive multiple beams for each transmit event (parallel processing)
- Decrease image size either laterally or in depth
- Acquire data over multiple cardiac cycles (4 – 7) and build a composite volume data set
Depth: frame rate

Depth 13 cm

Depth 16 cm
Number of subvolumes – frame rate

20 Hz

35 Hz
Wide angle – frame rate

Wide angle
Subvolumes

Reasons to use less subvolumes

- Arrhythmias / severe bradycardia
- Breathhold problems
- Big heart: use wide angle / 5 subvolumes
Line density – frame rate

Low

High
Line density – sector size

High density

Low density
2D images within the 3D data set

Multiplane reconstruction
What do I trace?

Endocardial boarder detection using contrast
LV volume and ejection fraction

EDV = 212.7 ml
ESV = 146.7 ml
EF = 37.5 %
SV = 71.1 ml
Echo drop out in full volume data set

Sometimes unavoidable!
2D: RV view before RT3DE acquisition

Apical four-chamber view

Laterally modified apical four-chamber view
Full volume RT3DE RV: acquisition dataset

RV volumes and ejection fraction.
For the first time possible with echo!
What do I trace?

RV endocardial border detection using contrast
Real-time 3D echo: analyse
3D Analysis

• Cardiac Function

• Cardiac morphology
Dotted lines: ROI = mitral valve

90º Bi-plane view mitral valve
Normal Mitral Valve
Resolution: the best plane?

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial</td>
<td>Best</td>
</tr>
<tr>
<td>Lateral</td>
<td>Medium</td>
</tr>
<tr>
<td>Elevation</td>
<td>Least</td>
</tr>
</tbody>
</table>

~0.5 mm  ~3.0 mm
~2.5 mm
Ultrasound beam perpendicular to ROI
Full Volume – Colour

Parasternal LAX

Parasternal SAX
MV seen from the LA
3D Echo pitfalls: stitching artifact
3D Full volume data set

Multiple subvolumes
Increased chance of artefact

One - shot
3D Echo pitfalls: drop out

Enface view IAS: seen from LA
Drop-out Fossa Ovalis
Image acquisition and manipulation

Outline

- Introduction
- Tips and tricks for an optimal 3D data set
- Data set manipulation
3D Multiplane reconstruction: 4Fallot

- The ability to move through a 3D dataset in any 2D image plane
- Interrogate the data set on or off-line
- Allows precise identification and localization of abnormalities
- Allows quantification.
3D analysis – the crop-box
3D analysis – the crop-box
Crop till you Drop!!!
X5-1: the all in one transducer

2D imaging
2D colour Doppler
PW and CW Doppler

3D imaging
Live 3D imaging and colour
Live 3D zoom
Full volume imaging and colour
2D imaging

S5-1

X5-1

X3-1
3D imaging

X3-1

X5-1
Conclusions: Image acquisition and manipulation

- In 3D the cardiac structures are shown in relationship to each other in all three spacial dimensions.

- The cardiac structures can be rotated or viewed from different orientations.

- The ability to “move through” a 3D data set in any 2D image plane allows better appreciation of cardiac anatomy in complex structural heart disease.

- 3D images are more intuitive than 2D images allowing quicker appreciation of cardiac anatomy by other health care workers.

- The clinical role of 3D echocardiography will continue to evolve as technology advances.
Conclusions: Image acquisition and manipulation

But remember:

The limitations of 2D are also true for 3D echo

3D echo is not a stand-alone feature, but should be used next to / on top of other echo modalities.
Overall gain
Overall gain
Left A-V Valve

Source: SA of the Heart: Wilcock/Cook/Anderson
Bicuspid Ao Valve

Aortic valve en-face view from Aorta
Normal Tricuspid Valve

From RV
Normal Pulmonary Valve

- Only the closure line of PV is visible!
- Dynamic RVOT during the cardiac cycle
3D reconstruction: atrial septal defect

ASD enface view: a dynamic structure
3D reconstruction: VSD by 4Fallot (baby)

En face VSD from LV

En face VSD from RV
TEE: Enface view of the IAS

ASD II-SVC-Aorta

En face view LA: Device insitu