3D ECHOCARDIOGRAPHY basics and clinical use

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WHY SHOULD WE PERFORM 3D ECHOCARDIOGRAPHY?

- Highly dynamic organ with active and passive motion
- Complicated 3D anatomy and pathoanatomy
- Even more complicated 3D mechanical function and motion
- 3D diagnosis and quantification frequently more detailed, accurate, and precise
- New diagnostic opportunities ï rethink needs and concepts
- Superior communication of diagnostic information
LIVE 3D ECHO NEW STANDARD IN TTE AND TEE

- New physiological and pathophysiological knowledge
- Far more accurate and precise assessment of LV size and function
- Improved characterisation of valvular and other structural heart disease
- Superior communication of pathoanatomy and pathophysiology
- Platform for 3D deformation analysis (3D STE), e.g. in LV dyssynchrony
Implementation of Live 3D ECHO in routine TTE remains slow:

- Equipment availability
- Education and hands-on training
- Simplified and highly automated procedures
- Further improvement in spatial and temporal resolution
- One-beat Full Volume with adequate image quality and volume rate
- Easier integration into 2D examination
3D ECHOCARDIOGRAPHY

important basic rules

ÂDo not think in traditional 2D echocardiographic views

ÂDo not look at cut sides ï 2D echo is far better for that

ÂThink of 3D echo as a door to a room which you can enter with the purpose of studying the walls and the structural content from whatever angle you wish: think spatially ï think 3D !
3D ECHOCARDIOGRAPHY
important basic rules

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Think of 3D echo as a door to a room which you can enter with the purpose of studying the walls and the structural content from whatever angle you wish: think spatially — think 3D!

3D echo is subject to ultrasound physics just as 2D echo is
transducer position, frequency vs. penetration / resolution, reflection, resolution, dropouts, artefacts

Poor 2D image quality will result in poor 3D image quality

A good acoustic window is a prerequisite for reliable 3D echo
MILESTONES IN 3D ECHOCARDIOGRAPHY

1974: Offline 3D reconstruction – complicated, poor image quality

1990s: RT3D TTE, matrix transducer with 256 elements

Early 2000s: Second generation RT3D TTE – clinically useful
MILESTONES IN 3D ECHOCARDIOGRAPHY

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Fully integrated 2D / 3D Matrix transducers

Philips X5 -1, 3040 elements, PureWave
Philips X7-2, 2500 elements, PureWave
Philips X7-2t TEE, 2500 elements, PureWave
GE 4V-D, Ḟhousands of elements
GE 6VT-D TEE
**MILESTONES IN 3D ECHOCARDIOGRAPHY**

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**Fully integrated 2D / 3D Matrix transducers**
3D TTE AND TEE
acquisition of 3D data sets

Live 3D +/- Color

Live 3D zoom +/- Color
cropped

Full Volume
cropped

Full Volume Color
cropped
3D ECHOCARDIOGRAPHY

volume size, spatial resolution, temporal resolution

Volume size

Spatial resolution

Temporal resolution
3D ECHOCARDIOGRAPHY
volume size, spatial resolution, temporal resolution

**Volume Size unchanged:**

\[ \text{ Volume rate } \hat{y} \quad \rightarrow \quad \text{ Spatial resolution } \hat{z} \]

\[ \text{ Spatial resolution } \hat{y} \quad \rightarrow \quad \text{ Volume rate } \hat{z} \]

**Changing volume size:**

\[ \text{ Volume size } \hat{y} \quad \rightarrow \quad \text{ Volume rate } \hat{z} \quad \& \quad \text{ Spatial resolution } \hat{z} \]

\[ \text{ Volume size } \hat{z} \quad \rightarrow \quad \text{ Volume rate } \hat{y} \quad \& \quad \text{ Spatial resolution } \hat{y} \]

Adequate volume size

Adequate spatial resolution

\[ \text{ Adequate volume rate ? } \]

YES: acquire 3D data set

NO: stick to 2D
RT3D TTE OG TEE
problematic limitations

ÅInadequate volume rate (all RT3DE modalities)

ÅFV and FV Color data acquisition take a long time
- 4 respectively 6 subvolumes
- require breath hold for up to 9 respectively 11 cardiac cycles
- high risk of stitching artefacts

ÅSignificantly enlarged heart → large pyramid → low volume rate
RT3D TTE AND TEE

HVR mode (Vision 2012 software)

HVR = High Volume Rate
RT3D TTE AND TEE

HVR mode (Vision 2012 software)

HVR = High Volume Rate
RT3D TTE AND TEE

**HVR mode** (Vision 2012 software)

HVR = High Volume Rate

HVR is useful:
- in Live 3D and Live 3D Color with inadequate volume rate
- in Live 3D Zoom and Live 3D Zoom Color with inadequate volume rate
- as standard in FV and FV Color
RT3D TTE AND TEE

**xVR mode** (Vision 2012 software)

xVR = xtreme Volume Rate

xVR is useful:

- In FV and FV Color with inadequate volume rate
- In case of significant ventricular dilatation
RT3D ECHOCARDIOGRAPHY artefacts

Stitching artefacts (subvolumes, FV, and FV Color)
RT3D ECHOCARDIOGRAPHY

artefacts

• Stitching artefacts (subvolumes, FV, and FV Color)
• Dropouts
• Blooming or blurring
• Gain
CARDIAC ANATOMY

basic 3D TTE planes and viewing perspectives

frontal  transverse  longitudinal
MITRAL VALVE ANATOMY
3D echocardiography
RT3D ECHOCARDIOGRAPHY
clinical application

Anatomy and pathoanatomy

Volumetry and other 3D quantifications
RT3D ECHOCARDIOGRAPHY
left ventricular volumes and systolic function

2D
\(\text{LVID}_D, \text{LVID}_S, \text{FS}\)
\(\text{WMI}\)
\(\text{EF}_{\text{mod. Simpson}}\)

3D
\(\text{EDV}, \text{ESV}, \text{SV}, \text{EF}, \text{CO}\)
without mathematical assumptions
\(\text{Automatic LV segmentation}\)
2D and RT3DE vs. CMR imaging: EDV, ESV, EF
L. D. Jacobs et al.: Eur Heart J 2006;27(4):460-8

<table>
<thead>
<tr>
<th></th>
<th>2D r</th>
<th>3D r</th>
<th>2D SD</th>
<th>3D SD</th>
<th>2D bias</th>
<th>3D bias</th>
<th>2D intra / inter obs var</th>
<th>3D intra / inter obs var</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDV</td>
<td>0.89</td>
<td>0.96</td>
<td>29ml</td>
<td>17ml</td>
<td>-23ml</td>
<td>-14ml</td>
<td>23% / 26%</td>
<td>7.9% / 11%</td>
</tr>
<tr>
<td>ESV</td>
<td>0.92</td>
<td>0.97</td>
<td>24ml</td>
<td>16ml</td>
<td>-15ml</td>
<td>-6.5ml</td>
<td>26% / 31%</td>
<td>7.6% / 13%</td>
</tr>
<tr>
<td>EF</td>
<td>0.86</td>
<td>0.93</td>
<td>9.5%</td>
<td>6.4%</td>
<td>1%</td>
<td>1%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**RT3D ECHOCARDIOGRAPHY**  
left ventricular volumes and systolic function

2D and RT3DE vs. CMR imaging: EDV, ESV, EF  
Carly Jenkins et al.: JACC 2004;44:878-86

- 50 patients
- 2D and RT3D both performed as test-retest
- CMR

### Intraobserver variability

<table>
<thead>
<tr>
<th></th>
<th>RT-3DE</th>
<th>2DE</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-diastolic volume (ml)</td>
<td>r = 0.98*</td>
<td>-1 ± 6</td>
</tr>
<tr>
<td>End-systolic volume (ml)</td>
<td>r = 0.98*</td>
<td>-2 ± 6</td>
</tr>
<tr>
<td>Ejection fraction (%)</td>
<td>r = 0.97*</td>
<td>1 ± 2</td>
</tr>
<tr>
<td>LV mass (g)</td>
<td>r = 0.96*</td>
<td>-5 ± 8</td>
</tr>
</tbody>
</table>

### Interobserver variability

<table>
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<th>RT-3DE</th>
<th>2DE</th>
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<tr>
<td>End-diastolic volume (ml)</td>
<td>r = 0.95*</td>
<td>-3 ± 10</td>
</tr>
<tr>
<td>End-systolic volume (ml)</td>
<td>r = 0.97*</td>
<td>-2 ± 6</td>
</tr>
<tr>
<td>Ejection fraction (%)</td>
<td>r = 0.88*</td>
<td>0 ± 3</td>
</tr>
<tr>
<td>LV mass (g)</td>
<td>r = 0.96*</td>
<td>-1 ± 11</td>
</tr>
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</table>
RT3D ECHOCARDIOGRAPHY
left ventricular volumes and systolic function

**RT3DE:** LV volumetry

- Feasibility 60-80% (TTE, X5-1)
- Superior to 2D biplane planimetry
- More accurate and precise
- Systematic underestimation of volumes compared to CMR
- Trabeculae and papillary muscles should be included in LV volumes
- Optimise AP4CH and AP2CH in MPR!
RT3D ECHOCARDIOGRAPHY
left ventricular mass

\[
\text{2D } \tilde{\text{LVMI}}_{\text{ASE}} \quad \tilde{\text{LVMI}}_{\text{area-length}}
\]

\[
\text{3D } \tilde{\text{LVMI}}_{\text{double-Simpson}} \quad \tilde{\text{LVMI}}_{\text{3D volumetry}} \text{ no mathematical assumptions}
\]
M-Mode, 2D and RT3DE vs. CMR imaging: LVM
Masaaki Takeuchi et al.: J Am Soc Echocardiogr
2008;21:1001-1005

55 patients
RT3D and CMR
$LVM_{RT3D}$ vs. $LVM_{CRM}$: $r = 0.95$, bias -2g

150 patients
RT3D, 2D (Simpson) and M-Mode
$LVM_{RT3D}$ surface detection algorithm $LVM_{RT3D}$ surface detection algorithm $123 \pm 39$ g

LVM_{M-Mode} $175 \pm 64$ g, $r = 0.76$, bias 52 g
$LVM_{2D}$ biplane planimetry $125 \pm 42$ g, $r = 0.91$, bias 1.2 g
$LVM_{RT3D}$ biplane planimetry $119 \pm 36$ g, $r = 0.95$, bias -4.6 g
RT3D ECHOCARDIOGRAPHY
left ventricular dyssynchrony

- Standard criteria (clinical + ECG)
- CARE-HF criteria
- TDI
- RT3DE
- 2D speckle tracking
- 3D speckle tracking

SDI* = Systolic Dyssynchronicity Index
RT3DE: SDI
S Kapetanakis et al: Circulation 2005;112:992-1000

89 healthy and 174 unselected patients

Healthy: SDI 3.5 ± 1.8%
Normal EF: 4.5 ± 2.4%
Mildly reduced EF: 5.4 ± 0.83%
Moderately reduced EF: 10.0 ± 2%
Severely reduced EF: 15.6 ± 1%
Mod. / severely reduced EF & normal QRS: 14.7 ± 1.2%

RT3DE can quantify global LVMD in patients with and without QRS prolongation. RT3DE represents a novel technique to identify chronic heart failure patients who may otherwise not be considered for CRT.

SDI* = Systolic Dyssynchronicity Index
**RT3DE: SDI**
Carolin Sonne et al.: JACC Img 2009;2:802-812

- **135 healthy**
- **16 DCM + LBBB**
- **16 DCM – LBBB**
- **16 normal EF + LBBB**
- **Healthy**: SDI < 4.0 %
- **LBBB with normal EF doubles SDI**
- **All with DCM and EF < 35%** had high SDI
- **Effect of LBBB on SDI insignificant in DCM**

řě low signal-to-noise ratio in low-amplitude regional volume curves hampering accurate determination of regional ejection time.

**Low temporal resolution (low volume rate):**
Increased uncertainty in assessing Tmsv in low-amplitude regional volume curves

**SDI** = Systolic Dyssynchronicity Index
RT3DE: SDI predicts acute response to CRT

- 60 consecutive patients scheduled for CRT
- RT3D before and no later than 48 timer after CRT
- 4 patients excluded: poor apical views or artefacts
- Responders*: (35 eller 63%): baseline SDI 9.7 ± 4.1
- Nonresponders (21): baseline SDI 3.4 ± 1.8
- No differences in baseline characteristics

* Acute responders defined by an acute reduction in ESV ≥ 15 ml

SDI = Systolic Dyssynchronicity Index
**RT3DE:** SDI predicts acute response to CRT


- 60 consecutive patients scheduled for CRT
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- 4 patients excluded: poor apical views or artefacts

- **Responders** (35 eller 63%): baseline SDI 9,7 ± 4,1
- **Nonresponders** (21): baseline SDI 3,4 ± 1,8

**No differences in baseline characteristics**

- **Responders** post CRT: SDI 3,6 ± 1,8 %, P < 0,0001
- **Nonresponders** post CRT: SDI 3,1 ± 1,1 %, NS

* Acute responders defined by an acute reduction in ESV ≥ 15 ml

**SDI**

SDI = Systolic Dyssynchronicity Index
RT3D ECHOCARDIOGRAPHY
left ventricular dyssynchrony

- RT3DE: tracks endocardial motion
- Speckle tracking: myocardial deformation
- 2D ST: rotation / translation problematic

In future new modality integrating:
- RT3DE LV volumetry with automatic segmentation
- RT3D Speckle Tracking Echocardiography with automatic segmented deformation and timing analysis

SDI* = Systolic Dyssynchronicity Index
RT3D ECHOCARDIOGRAPHY
left atrial volumes and function

2D
- LA anteroposterior diameter
- LA area in AP4CH
- LA volumes – biplane planimetry

3D
- LA volumetry with no mathematical assumptions
- LA maximum and minimum volumes
- LA functional parameters
- RT3D TTE
- RT3D TEE rarely includes entire LA
RT3DE vs. CMR: LA volumes
Ramin Artang et al.: Cardiovascular Ultrasound 2009;7:16

27 consecutive patients referred to CMR

3D LA volume index: 56 ± 8 sek

2D LA volume index (biplane area-length): 135 ± 55 sek

\[
\begin{align*}
3DE & \quad \text{index ml/m}^2 \\
& \quad \text{vs.} \\
& \quad \text{MRI index ml/m}^2 \\
\end{align*}
\]

\[
\begin{align*}
3DE & \quad \text{index ml/m}^2 \\
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\end{align*}
\]

\[
\begin{align*}
\text{Diasstole} & \quad 3DE \text{ index ml/m}^2 \\
& \quad \text{MRI index ml/m}^2 \\
\end{align*}
\]

\[
\begin{align*}
\text{Systole} & \quad 3DE \text{ index ml/m}^2 \\
& \quad \text{MRI index ml/m}^2 \\
\end{align*}
\]

\[
\begin{align*}
\text{Atrial Ejection Fraction} & \quad 3DE \text{ index ml/m}^2 \\
& \quad \text{MRI} \\
\end{align*}
\]
RT3D ECHOCARDIOGRAPHY
right ventricular size and systolic function

2D
- RV short axis diameters and length
- RV planimetry
- TAPSE (M-mode or STE)

3D
- RV volumetry no mathematical assumptions?
Difficult due to complex geometric shape
Generally not very encouraging results of studies 1998-2004
Recently promising results, but a need for methodological development
Complicated and time-consuming, currently mainly suitable for research
2D and RT3DE vs. CMR: RV volumes and EF

89 patients with complex and/or surgically corrected congenital heart disease in sinus rhythm

RV group n = 62, LV group n = 27, control group n = 31

"3D echo improved quantitative RV size and function assessment compared with 2D echo in patients, as well as in healthy controls"

### Table 3  Correlation of echocardiographic measurements and cardiac magnetic resonance imaging

<table>
<thead>
<tr>
<th>CMR</th>
<th>Echo</th>
<th>All</th>
<th>RV group</th>
<th>LV group</th>
<th>Healthy controls</th>
<th>Mean difference</th>
<th>95% LOA</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-diastolic volume</td>
<td>PSAX RVOT 1</td>
<td>0.47</td>
<td>0.46</td>
<td>0.77</td>
<td>0.38</td>
<td>0.16</td>
<td>0.56</td>
<td></td>
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<tr>
<td></td>
<td>PSAX RVOT 2</td>
<td>0.32</td>
<td>0.47</td>
<td>0.20</td>
<td>0.11</td>
<td>0.09</td>
<td>0.092</td>
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<tr>
<td></td>
<td>AP4C inlet</td>
<td>0.46</td>
<td>0.33</td>
<td>0.47</td>
<td>0.47</td>
<td>0.67</td>
<td>1</td>
<td></td>
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<tr>
<td></td>
<td>AP4C long axis</td>
<td>0.65</td>
<td>0.71</td>
<td>0.55</td>
<td>0.76</td>
<td>0.64</td>
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<tr>
<td></td>
<td>Area ED</td>
<td>0.74</td>
<td>0.69</td>
<td>0.71</td>
<td>0.73</td>
<td>0.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EDV</td>
<td>0.97</td>
<td>0.97</td>
<td>0.96</td>
<td>0.93</td>
<td>–17</td>
<td>(–19.33)</td>
<td>0.065</td>
</tr>
<tr>
<td>End-systolic volume</td>
<td>Area ES</td>
<td>0.77</td>
<td>0.73</td>
<td>0.65</td>
<td>0.58</td>
<td>–3</td>
<td>(–25.32)</td>
<td>0.076</td>
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<tr>
<td></td>
<td>ESV</td>
<td>0.96</td>
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<td>0.91</td>
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<td>(–25.32)</td>
<td>0.076</td>
</tr>
<tr>
<td>Ejection fraction</td>
<td>FAC</td>
<td>0.37</td>
<td>0.35</td>
<td>0.35*</td>
<td>0.08*</td>
<td>–4</td>
<td>(–1.68)</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>TAPSE</td>
<td>0.40</td>
<td>0.29*</td>
<td>–</td>
<td>0.21</td>
<td>–3</td>
<td>(–9.16)</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>EF</td>
<td>0.71</td>
<td>0.71</td>
<td>0.52</td>
<td>0.63</td>
<td>–3</td>
<td>(–9.16)</td>
<td>0.54</td>
</tr>
</tbody>
</table>
RT3D ECHOCARDIOGRAPHY
right atrial volumes and function

RT3DE vs. CMR: RA volume

• 21 patients and healthy persons
• RA volume: 2D (MOD, areal-length), RT3DE
• CMR
  • 3D vs. CMR: $r = 0.91$  SEE = 8.8 ml  bias = 12.06 ml
  • 2D vs. CMR: $r = 0.87$  SEE = 10.23 ml  bias = 8.99 ml

Minimum RA volume
Maximum RA volume
RA functional parameters
Respiratory synchronous variation
RT3D ECHOCARDIOGRAPHY
mitral valve regurgitation diagnosis

- Primary versus functional and ischemic MR
- Degenerative, prolapse, chordal rupture, endocarditis, congenital

2D & 3D TTE / TEE: Identification of mitral valve pathology before mitral repair
Sagit Ben Zekry et al.: JASE 2011;241:1079-1085

- All modalities equally reliable in detection of functional MR
- 2D and 3D TEE comparable in detection of MR mechanism, but 3D TEE superior in localisation of pathological findings
- With current technique, 3D TTE is the least reliable in detection of mitral valve pathology
RT3D ECHOCARDIOGRAPHY quantification of mitral valve regurgitation

2D-Doppler
- ÅVC diameter
- ÅERO\textsubscript{hemispheric PISA}
- ÅRV\textsubscript{hemispheric PISA}

3D
- ÅVena Contracta Area (\textit{VCA}\textsubscript{RT3DE})
- ÅRV\textsubscript{RT3DE}

\textit{VCA}\textsubscript{RT3DE}
RT3D ECHOCARDIOGRAPHY
quantification of mitral valve regurgitation

**RT3DE:** ERO is rarely circular in MR

57 patients with MR

- Prolapse 20 (EF 54.7 ± 13.7)
- Degenerative without prolapse 16 (EF 55.2 ± 11.8)
- Functional 21 (EF 23.9 ± 9.0)

<table>
<thead>
<tr>
<th></th>
<th>asymmetry index*</th>
</tr>
</thead>
<tbody>
<tr>
<td>prolapse</td>
<td>1.58 ± 0.46</td>
</tr>
<tr>
<td>degenerative</td>
<td>1.18 ± 0.18</td>
</tr>
<tr>
<td>functional</td>
<td>2.87 ± 1.05</td>
</tr>
</tbody>
</table>

* asymmetry index = major VCW / minor VCW
**RT3DE in vitro:** Vena Contracta Area ($VCA_{RT3DE}$) in MR

- Experimental MR
- Different pulsatile flow rates
- 4 different orifice areas

**$VCA_{RT3DE}$ vs. known orifice area:** $r = 0.92$, $P < 0.001$

**2D VC diameter vs. known orifice area:** $r = 0.56$, $P = 0.01$
**RT3D ECHOCARDIOGRAPHY**

quantification of mitral valve regurgitation: \( \text{VCA}_{\text{RT3DE}} \)

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**RT3DE**: Vena Contracta Area (VCA\(_{\text{RT3DE}}\)) in MR
Philipp Kahlert et al.: J Am Soc Echocardiography
2008;21:912-922

- 57 patients with MR
- Prolapse 20 (EF 54.7 ± 13.7)
- Degenerative without prolapse 16 (EF 55.2 ± 11.8)
- Functional 21 (EF 23.9 ± 9.0)

\( \text{VCA}_{\text{RT3DE}} \) assessed in all patients: 2.6 ± 0.7 min

- \( \text{VCW-4CH vs. VCA}_{\text{RT3DE}} \): \( r = 0.77 \)
- \( \text{VCW-2CH vs. VCA}_{\text{RT3DE}} \): \( r = 0.80 \)

\( \text{EROA}_{\text{hemielliptic PISA vs. VCA}_{\text{RT3DE}}} \):
  \( r = 0.96 ± 0.14 \) mean error -0.09 ± 0.14 cm²

\( \text{EROA}_{\text{hemispheric PISA vs. VCA}_{\text{RT3DE}}} \): EROA\(_{\text{hemispheric PISA}}\) significantly underestimates noncircular regurgitant orifices
RT3D ECHOCARDIOGRAPHY
quantification of mitral valve regurgitation: $VCA_{RT3DE}$

RT3DE: Vena Contracta Area ($VCA_{RT3DE}$) in MR

- Simple and quick – even in TTE
- Feasible in the vast majority of patients
- Experimentally and clinically validated
- Severe MR all types: $VCA_{RT3DE} > 0.6 \text{ cm}^2$
- New standard method?
RT3DE: Regurgitant Volume (RV_{RT3DE}) in MR
Björn Plicht et al.: J Am Soc Echocardiography
2008;21:1337-1346

**Regurgitant flow rate (ml/s)**

\[
\text{Reg. flow rate} = \int_{VCA} \text{Area}_{\text{color pixel}} \cdot \text{Velocity}_{\text{color pixel}} \ + \ VCA \cdot v_Ny \cdot n_{\text{flashing}}
\]

**In vitro, flow rates 5-60 ml/s, orifice area 0.2-0.6 cm²**

**RT3DE flow rate vs. real flow rate:**

\[ r = 0.99, \text{ mean diff } 0.05 \pm 0.5 \text{ ml/s} \]

**23 patients with MR**

**MR-RV_{RT3DE} vs. MR-RV_{CMR}:**

\[ r = 0.91, \text{ mean diff } -1.8 \pm 7.1 \text{ ml, NS} \]

**MR-RV_{HS-PISA} vs. MR-RV_{CMR}:**

\[ r = 0.81, \text{ mean diff } -17.4 \pm 9.4 \text{ ml, } P<0.05 \]

**MR-RV_{HE-PISA} vs. MR-RV_{CMR}:**

\[ r = 0.89, \text{ mean diff } -11.7 \pm 9.4 \text{ ml, } P<0.05 \]
RT3D ECHOCARDIOGRAPHY
preoperative planning of mitral repair

3D guided quantitative 2D analysis
• Annular anteroposterior and lateromedial diameters
• Annular circumference and area in diastole and systole
• Intercommissural distance
• Prolapse width, height, and depth
RT3D ECHOCARDIOGRAPHY
preoperative planning of mitral repair

**MVQ: Mitral Valve Quantification**

Mitral Valve Anatomy Report

<table>
<thead>
<tr>
<th>Annulus</th>
<th>Leaflet</th>
<th>Aortic-Mitral</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAIPm 44.4 mm</td>
<td>L3D Ant 28.0 mm</td>
<td>0 138.3 mm *</td>
</tr>
<tr>
<td>DAP 36.8 mm</td>
<td>L3D Post 19.7 mm</td>
<td></td>
</tr>
<tr>
<td>H 5.4 mm</td>
<td>8 Ant 17.4 mm</td>
<td></td>
</tr>
<tr>
<td>CSD 136.1 mm</td>
<td>8 Post 16.3 mm</td>
<td></td>
</tr>
<tr>
<td>A2D 1382.2 mm</td>
<td>6 NPA 146.2 mm</td>
<td></td>
</tr>
<tr>
<td>A3D Post 817.6 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VTIent 0.8 mm</td>
<td></td>
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</tr>
<tr>
<td>VProl 1.4 mm</td>
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Coaptation

Papillary

Chordal

LChordPm 7.2 mm

LChordAl 6.2 mm

LChordM 3.4 mm
RT3D ECHOCARDIOGRAPHY
quantification of mitral valve stenosis

2D-Doppler
ÄMVA$_{2D}$ planimetry
ÄMVA$_{PHT}$
ÄMVA$_{CE}$ or MVA$_{PISA}$
ÄPG$_{mean}$

3D
ÄMVA$_{RT3DE}$
RT3DE vs. Gorlin: Mitral Valve Area (MVA) in MS
José Zamorano et al.: JACC 2004;431:2091-2096

21 patients with MS from 2 centers (Madrid, Chicago)

2D: MVA$_{2D}$, MVA$_{PHT}$, MVA$_{PISA}$

RT3D: 3D guided 2D planimetry of MVA (MVA$_{RT3DE}$)

Invasive: MVA$_{Gorlin}$

NOTE: Comparison of anatomical opening area and effective opening area!

Table 1. Linear Regression Coefficient and Intraclass Correlation Coefficient Between Noninvasive Methods (Averaged Value of Two Observers’ Measurements) and Gorlin Estimated MVA in Both Centers

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<tr>
<td></td>
<td>r</td>
<td>ICC</td>
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<td>PHT vs. Gorlin</td>
<td>0.84</td>
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MVA$_{RT3DE}$ best echo standard?

Easier to perform than MVA$_{2D}$ for less experienced echo staff
RT3DE vs. Gorlin: Mitral Valve Area (MVA) in MS
José Zamorano et al.: JACC 2004;431:2091-2096

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Now again available in 3DQ on Philips iE33 Vision 2012
Not yet available in QLAB
Also available on GE Vivid E9
RT3D ECHOCARDIOGRAPHY
g quantification of aortic valve stenosis

2D-Doppler
ÅAVA$_{2D}$, TEE
ÅAVA$_{CE}$
ÅPG$_{max}$ and PG$_{mean}$

3D
ÅAVA$_{3D}$ guided 2D planimetry
ÅAVA$_{3D-CW} = \frac{SV_{RT3DE}}{VTI_{AO}}$
RT3D ECHOCARDIOGRAPHY
quantification of aortic valve stenosis: 3D guided 2D planimetry

RT3DE vs. cath.: Aortic Valve Area (AVA)
Sorel Goland et al.: Heart 2007;93:801-807

33 patients with valvular AS

\[ AVA_{RT3DE} \text{ vs. } AVA_{cath}: \quad r = 0.86 \]

\[ AVA_{3D \text{ guided 2D planimetry}} \text{ vs. } AVA_{cath}: \quad r = 0.81 \]

\[ AVA_{TEE \text{ 2D planimetry}} \text{ vs. } AVA_{cath}: \quad r = 0.71 \]

**NOTE:** Comparison of anatomical opening area and effective opening area!

**Reproducibility:**
AVA$_{RT3DE}$ and AVA$_{3D \text{ guided 2D planimetry}}$ are superior to AVA$_{TEE \text{ 2D planimetry}}$

3DE vs 2DE: Aortic Valve Area (AVA)
Sorel Goland et al.: Heart 2007;93:801-807

AVA$_{3D \text{ guided 2D planimetry}}$: feasible in 95% of patients (56/59)
RT3D ECHOCARDIOGRAPHY
quantification of aortic valve stenosis: planimetry on 3D image

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Now again available in 3DQ on Philips iE33 Vision 2012
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RT3DE vs Gorlin: Aortic Valve Area (AVA\textsubscript{3D-CW})
Juan Luis Gutiérrez-Chico et al.: Eur Heart J
2008;29:1296-1306

- 41 patients with valvular AS
- \(\text{AVA}_{3D-CW}, \text{AVA}_{CE}, \text{AVA}_{\text{Simpson-CW}}, \text{AVA}_{\text{Gorlin}}, \text{AVA}_{\text{Hakki}}\)

- \(\text{AVA}_{3D-CW} \text{ vs. } \text{AVA}_{\text{Gorlin}}: r = 0.902\)
- \(\text{AVA}_{\text{Simpson-CW}} \text{ vs. } \text{AVA}_{\text{Gorlin}}: r = 0.627\)
- \(\text{AVA}_{CE} \text{ vs. } \text{AVA}_{\text{Gorlin}}: r = 0.646\)

- \(\text{AVA}_{3D-CW}\) slightly overestimates \(\text{AVA}\)

- Optimal cutoff for severe AS: \(\text{AVA}_{3D-CW} 1.06 \text{ cm}^2\)

- Need for further studies
RT3D ECHOCARDIOGRAPHY
quantification of aortic valve stenosis

$AVA_{3D}$ planimetry (TEE) and $AVA_{3D-CW}$ future “best echo standard”
RT3D ECHOCARDIOGRAPHY
quantification of aortic valve regurgitation

2D-Doppler
- Prevalvular flow acceleration
- Vena contracta diameter (VC)
- Visual assessment of AR-jet
- AR jet diameter / LVOT diameter
- AR jet area / LVOT area
- (AR jet PHT)
- Retrograde flow in aorta descendens

3D
- $\text{AVCA}_{\text{RT3DE}}$ : real value?
- $\text{ARV}_{\text{RT3DE}}$ : perhaps in near future?
RT3D ECHOCARDIOGRAPHY
quantification of aortic valve regurgitation: $VCA_{RT3DE}$

RT3DE: Vena Contracta Area ($VCA_{RT3DE}$) in AR
Ligang Fang et al.: Echocardiography
2005;22:775-781

- 56 consecutive patients with AR
- Aortic angiography (45 pt.), cardiac surgery (11 pt.)

- 2D TTE VCW$_{2D}$ vs. angiography and surgery: $r = 0.92$
- 3D TTE $VCA_{RT3DE}$ vs. angiography and surgery: $r = 0.95$

- $VCA_{RT3DE}$: good agreement with angiographic AR grading
RT3D ECHOCARDIOGRAPHY
evaluation of valvular prostheses and mitral annuloplasty ring

RT3DE: Valvular prostheses
Lissa Sugeng et al.: J Am Soc Echocardiogr
2008;21:1347-1354

40 patients with valvular prosthesis or mitral annuloplasty ring

RT3D TEE excellent in mitral prostheses and mitral annuloplasty rings

RT3D TEE less accurate in aortic and tricuspid prostheses
RT3D ECHOCARDIOGRAPHY
prosthetic paravalvular leak

**Mitral prosthetic paravalvular leak:** Reliable detection and localisation

**Aortic prosthetic paravalvular leak:** Useful for detection and localisation
- but not always feasible
RT3D ECHOCARDIOGRAPHY

echocardiography guided interventional procedures

- TAVI
- MitraClip
- Closure of prosthetic paravalvular leak
- Closure of LAA
- Closure of ASD / PFO
RT3D ECHOCARDIOGRAPHY
additional clinical applications

- Congenital heart disease
- Tricuspid and pulmonic valve disease
- Endocarditis
- Aortic dissection
- Intracardiac tumour, thrombus, vegetation
3D ECHOCARDIOGRAPHY

Difficult terrain
Many pitfalls

Worth the effort
Future standard