3D–stress echocardiography

Bernard Cosyns, MD, PhD

No Disclosure
Overview

- 2D stress echocardiography: main limitations
- 3D echocardiography: potential incremental value
- Accuracy of 3D stress echocardiography
- Which modalities of 3D – echo during stress
- Which modalities of stress during 3D – echo
- Do we have to throw the baby out with the bath water?
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Main limitations of 2D–stress echo

- Image quality during transthoracic scanning with insufficient visualization of left ventricle (LV) walls
- Probe positioning difficulties resulting in inadequate image planes
- Time-consuming serial acquisition of different image planes which has to be performed in a narrow time window during peak stress while wall motion abnormalities exist
- Data analysis: subjectivity of image interpretation still is the major problem, which leads to poor inter–observer agreement and causes a relevant examiner–dependency
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3D echocardiography: incremental value

- Avoid foreshortening
- More accurate evaluation of LV volumes and LVEF
- Time saving for acquisition
- LV dyssynchrony 3D stress map contraction
3DE to avoid foreshortening:
Reproducibility of the scan planes between stages

Mor-Avi et al  JACC 2008 and Circulation 2009
3D echocardiography: incremental value

- Avoid foreshortening
- More accurate evaluation of LV volumes and LVEF
- Time saving for acquisition
- LV dyssynchrony 3D stress map contraction
Evaluation of LV volumes and LVEF

Changes in ejection fraction and ventricular volume = stress-induced regional wall motion abnormalities for diagnosis of the extent of coronary disease and predictive of outcome

Arruda et al Am J Cardiol 2001;87:1069-73.

Chuah et al Circulation 1998;97:1474-80
Contractile reserve with 3DE

Wall motion and thickening

Rest

Low-dose dobutamine
Contractile reserve with 3DE

LV ejection fraction

Rest
LV EF = 36%

Low-dose dobutamine
LV EF = 45%
Need for accuracy and reproducibility

Agreement of 2D vs RT3D compared to MRI
RT3D improves reproducibility
Reproducibility in serial fup (1y)
3D echocardiography: incremental value

- Avoid foreshortening
- More accurate evaluation of LV volumes and LVEF
- Time saving for acquisition
- LV dyssynchrony 3D stress map contraction
Stress 3DE: Time saving

- No need to change the transducer position during apical scanning once the echo window is found.

- Acquisition easier and faster for both the beginner and the expert echocardiographer.

- The narrow time window at peak stress (especially in exercise stress echo) can be used much more effectively when acquiring two or even three image planes simultaneously.
Stress 3DE: Acquisition Time Saving

- A shorter time needed for scanning at peak stress
- More complete monitoring (more segments can be observed on-line during stress testing)
- Also reduces the potential risk of prolonged myocardial ischaemia for the individual patient.
3D echocardiography: incremental value

- Avoid foreshortening
- More accurate evaluation of LV volumes and LVEF
- Time saving for acquisition
- LV dyssynchrony 3D stress map contraction
Accurately localize and estimate the severity of stress-induced ischemia by identifying areas of delayed contraction.
Global longitudinal strain assessment

Rest GLS = -10%

LDD GLS = -12%
Global radial strain assessment

Rest GRS = 24%
LDD GRS = 30%
Overview

- 2D stress echocardiography: main limitations
- 3D echocardiography: potential incremental value
- **Accuracy of 3D stress echocardiography**
- Which modalities of 3D – echo during stress
- Which modalities of stress during 3D – echo
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Accuracy of 3D stress echocardiography

- **Sensitivity**: 73% (2D) vs. 78% (3D)
- **Specificity**: 93% (2D) vs. 89% (3D)
- **PPV**: 87% (2D) vs. 82% (3D)
- **NPV**: 85% (2D) vs. 87% (3D)
- **Accuracy**: 86% (2D) vs. 85% (3D)
Accuracy of Dipyridamole–3DE

![Graph showing the success rate of adequate image acquisition for different coronary artery territories.](image)

<table>
<thead>
<tr>
<th>Coronary artery territory</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
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<tbody>
<tr>
<td>All</td>
<td>80 78 NS</td>
<td>87 91 NS</td>
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<tr>
<td>Left anterior descending</td>
<td>87 78 .011</td>
<td>90 93 NS</td>
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<tr>
<td>Right</td>
<td>82 77 NS</td>
<td>85 88 NS</td>
</tr>
<tr>
<td>Left circumflex</td>
<td>65 63 NS</td>
<td>94 92 NS</td>
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</table>

**Notes:**
- NS: Not statistically significant.
Improved apical visualization
## Accuracy of 3D Stress Echo

<table>
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<td>Jenkins, 2009</td>
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<td>Treadmill exercise-3D</td>
<td>Coronary angiography</td>
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<tr>
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<td>Treadmill exercise-3D+CFM</td>
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Breath holding during stress
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Modalities of 3D echo during stress

**Conventional 2D stress**
- PLAX
- PSAX
- 4CV
- 2CV
- 3CV

**Biplane**
- PLAX
- PSAX
- 4CV
- 2CV
- 3CV

**Triplane**
- PLAX
- PSAX
- 4CV
- 2CV
- 3CV

**Full volume 3D**
- 4 heart cycles

Lang et al., EJCI 2012
Tri-plane 3D stress echo
Full 3D – stress echo
Contrast 3D stress echo
Contrast perfusion 3D stress echo

- Is feasible
- Low spatial resolution
- Lower frame rate (volume rate)
- No “flash destruction of bubbles”
- Only adenosine (lower heart rates)

Courtesy of I. Felekos
Perfusion Contrast 3D stress echo

A

<table>
<thead>
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<th></th>
<th>2D WM</th>
<th>3D WM</th>
<th>2D MP</th>
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<td>45</td>
<td>60</td>
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<td>specificity</td>
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<tr>
<td>accuracy</td>
<td>68</td>
<td>67</td>
<td>77</td>
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B

<table>
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<th>2D WM</th>
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<td>69</td>
<td>66</td>
<td>79</td>
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</tr>
<tr>
<td>specificity</td>
<td>81</td>
<td>77</td>
<td>81</td>
<td>87</td>
</tr>
<tr>
<td>accuracy</td>
<td>75</td>
<td>72</td>
<td>80</td>
<td>82</td>
</tr>
</tbody>
</table>

SVD

MVD
3D stress STI
3D stress STI vs Sonomicrometry

X = dobutamine infusion
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Which Stress?

Figure 2 Distribution of patients according to RT3D image quality separating the study group into pharmacological and exercise stress echo.

Figure 3 Agreement between two different observers for the evaluation of RT3D WMSI considering two different groups: exercise and pharmacological stress echo. In the graph the K value according to image quality and heart rate at peak stress is reported.
Stress 3D– Echocardiography

- **Advantages**
  - 1) better visualization of the LV apex, which is frequently foreshortened on standard 2DE apical images
  - 2) rapid acquisition of peak stress images before the heart rate declines in recovery
  - 3) evaluation of multiple segments from different planes from a single dataset.

- **Disadvantages**
  - 1) lower spatial resolution
  - 2) lower frame rates (tardokinesia can be missed)
  - 3) Learning curve required
  - 4) Automated algorythms not yet validated during stress
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Do we have to throw the baby out with the bath water?

EAE GUIDELINES

Stress echocardiography expert consensus statement

Real-time three-dimensional imaging

Technological advances in transducer and computer technology have led to the recent introduction of real-time 3D echocardiography. Similar to 2D echocardiography, contrast echocardiography can be used for enhancement of endocardial border definition and possibly for myocardial perfusion. Initial studies with 3D echocardiography during stress echocardiography have been encouraging, however, no data are available on the additional value of this technique over conventional wall motion interpretation. Matrix probes used for real-time 3D echocardiography offer the unique feature of recording all LV segments simultaneously, which may be advantageous for stress studies.
### Feasibility of 3D stress echo

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequate 3D echocardiographic imaging</td>
<td>84 (79%)</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>79 ± 13</td>
</tr>
<tr>
<td>Peak stress</td>
<td>115 ± 15</td>
</tr>
<tr>
<td>Blood pressure (mm Hg)</td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>131 ± 16</td>
</tr>
<tr>
<td>Peak stress</td>
<td>125 ± 34</td>
</tr>
<tr>
<td>Reason for test termination</td>
<td></td>
</tr>
<tr>
<td>End of the protocol</td>
<td>46 (55%)</td>
</tr>
<tr>
<td>New or worsening wall motion</td>
<td>38 (45%)</td>
</tr>
<tr>
<td>LV segments available for analysis</td>
<td>1428 x 2</td>
</tr>
<tr>
<td>Uninterpretable segments on 2DE</td>
<td>311</td>
</tr>
<tr>
<td>Baseline</td>
<td>197 (14%)</td>
</tr>
<tr>
<td>Peak stress</td>
<td>114 (8%)</td>
</tr>
<tr>
<td>Uninterpretable segments on 3DE</td>
<td>213 (P &lt; .001 vs 2DE)</td>
</tr>
<tr>
<td>Baseline</td>
<td>127 (9%) (P &lt; .03 vs 2DE)</td>
</tr>
<tr>
<td>Peak stress</td>
<td>81 (6%)</td>
</tr>
</tbody>
</table>

We excluded patients requiring contrast during 2D acquisitions. The impact of adding contrast to improve the feasibility of 3DE with DipSE and its effect on diagnostic accuracy remain to be determined.8,19,20
Prolonged Analysis Time?

<table>
<thead>
<tr>
<th></th>
<th>2D ECHO</th>
<th>3D ECHO</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition time</td>
<td>65 +/- 30</td>
<td>16 +/- 3</td>
<td>P&lt;0.0001</td>
</tr>
<tr>
<td>Analysis time</td>
<td>176 +/- 63</td>
<td>91 +/- 5</td>
<td>P&lt;0.0001</td>
</tr>
</tbody>
</table>
Additional value of 3D > 2D–stress echo

- Image quality during transthoracic scanning with insufficient visualization of left ventricle (LV) walls
- Probe positioning difficulties resulting in inadequate image planes
- Time-consuming serial acquisition of different image planes which has to be performed in a narrow time window during peak stress while wall motion abnormalities exist
- Data analysis: subjectivity of image interpretation still is the major problem, which leads to poor inter-observer agreement and causes a relevant examiner-dependency
Inconsistencies between softwares

Global = -18% (-14 to -26)
Global = -32% (-18 to -38)
Global = 15% (-20 to 43)
Global = -45% (-35 to -58)

Global Longitudinal strain %
Global Circumferential strain %
Global Radial strain (VolC) %
Global Area strain %

Global = -18% (-9 to -24)
Global = -23% (-13 to -32)
Global = 59% (33 to 88)
Global = -36% (-25 to -46)
Fully automated segmentation

Real-time segmentation → Real-time volume measurements!

Limitations still to overcome …

- 3D stress echo is still work in progress
- Further quality image improvement
- Higher Frame Rates, less stitching (tachycardia, arrhythmias)
- More well validated automated algorithms
- Side by side analysis and synchronization (different stages)
- Implementation and validation of other echo- modalities (STI)
- Validation in various indications and non selected patients
The Pro–Technology bias

A coffee is a coffee, is a coffee, is a coffee...

Cardiologists have to be aware that due to the pro-technology bias of modern medicine, we, as physicians, are encouraged to trust, to use (and to buy) technologies far before their clinical incremental value has been shown.
Challenges for 3D speckle tracking

- Increased FOV at the cost of both spatial and temporal resolution
- Speckle pattern has less details and de-correlation between subsequent volumes is high
- 3D strain normal values depending on the method used (block matching vs elastic registration)
- Same information 2D in less time