Quantifying LV function – how good are we?

Professor Alan G Fraser
Wales Heart Research Institute
Cardiff University, U.K.

Support for research from Hitachi Aloka, & GE Ultrasound
Visual assessment of synchronicity
Computer-simulated regional delay

EQUALIS – Diagnosis of regional wall motion

Echocardiography Quality Control Project: Case #1

Independent reporting by 106 Swedish centres in 2008

Courtesy of Dr Odd Bech-Hansson
Inter-observer reproducibility of visual grading of regional wall motion – 11 experienced observers

Intra-class correlation coefficients (each observer vs others)

- Normal, hypokinetic, or akinetic: 0.79
- Normal, or abnormal: 0.71
- Hypokinetic, or not: 0.37
- Akinetic, or not: 0.37

180 segments from 105 studies

Blondheim DS et al, JASE 2010; 23: 258-64
Limitations of wall motion scoring

- Subjective interpretation of motion & thickening
- Learning curve, operator-dependent
- Sub-optimal reproducibility even in expert centres
- Insensitive for detecting single vessel disease
- Categorical outcomes, not a graded response
- Improved by LV opacification with echo contrast
- Remains a subjective diagnosis

So why is it still used in stress echocardiography?
EQUALIS
Echocardiography Project

Case #1

Courtesy of
Dr Odd Bech-Hansson
Case #1: Left ventricular ejection fraction

Simpson EF by 5 investigators: mean 34% (range 32-36%)
Expected normal value

Distribution

Cumulative frequency

N = 6,026

LVEDD

LVEF

Observer bias in visual estimation of LVEF

Berger AK et al, JACC 1999; 34: 1831
Visual assessment of LV ejection fraction
105 echo studies interpreted by 12 observers

Coefficient of variation 11%
Bias -8 to +4%

Blondheim DS et al, JASE 2010; 23: 258-64
End-diastole  End-systole

A4C

A2C

Modified Simpson’s method of discs

Biplane planimetry

LVEDV
LVESV
SV
EF
Systematic review of LV quantification by echo

<table>
<thead>
<tr>
<th>Author</th>
<th>Method</th>
<th>Interobserver variability (1.96SD of differences)</th>
<th>Intraobserver variability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior</td>
<td>Simpson’s rule</td>
<td>9%</td>
<td>6%</td>
</tr>
<tr>
<td>Jensen-Urstad</td>
<td>Simpson’s rule</td>
<td>16%</td>
<td>NR</td>
</tr>
<tr>
<td>Tsujita-Koroda</td>
<td>Simpson’s rule</td>
<td>21% (AQ)</td>
<td>13% (AQ)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11% (H + AQ)</td>
<td>6% (H + AQ)</td>
</tr>
<tr>
<td>Yu</td>
<td>Simpson’s rule</td>
<td>8% (echogenic)</td>
<td>11% (echogenic)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12% (H)</td>
<td>6% (H)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4% (C)</td>
<td>2% (C)</td>
</tr>
<tr>
<td>Berning</td>
<td>WMI</td>
<td>14%</td>
<td>NR</td>
</tr>
<tr>
<td>McGowan</td>
<td>WMI</td>
<td>20%</td>
<td>NR</td>
</tr>
<tr>
<td>van Royen</td>
<td>Subjective visual</td>
<td>17%</td>
<td>13%</td>
</tr>
<tr>
<td>Jensen-Urstad</td>
<td>Subjective visual</td>
<td>8%</td>
<td>NR</td>
</tr>
<tr>
<td>van’t Hof</td>
<td>Subjective visual</td>
<td>15%</td>
<td>11%</td>
</tr>
</tbody>
</table>
Contrast echo enhancement of LV borders

Recommended if <80% of endocardium not seen
Accuracy of contrast echo to quantify LV function, compared to magnetic resonance imaging (n 110)

Limits of agreement

-18% to +8%

-8% to +4%

Malm S et al et al, JACC 2004; 44: 1030-5
### Non-invasive measurement of global LV function

#### Comparison of imaging modalities

<table>
<thead>
<tr>
<th>Imaging Modality</th>
<th>End-diastolic volume (ml)</th>
<th>End-systolic volume (ml)</th>
<th>Ejection fraction (%)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cineventriculography, biplane</td>
<td>187 ± 105</td>
<td>90 ± 84</td>
<td>56.2 ± 18.3</td>
<td>100</td>
</tr>
<tr>
<td>Magnetic resonance imaging, SAX</td>
<td>174 ± 50</td>
<td>84 ± 45</td>
<td>54.1 ± 12.9</td>
<td>55</td>
</tr>
<tr>
<td>Unenhanced echocardiography</td>
<td>115 ± 53</td>
<td>62 ± 48</td>
<td>50.9 ± 15.3</td>
<td>115</td>
</tr>
<tr>
<td>Contrast-enhanced echocardiography</td>
<td>147 ± 60</td>
<td>73 ± 56</td>
<td>54.6 ± 16.8</td>
<td>115</td>
</tr>
</tbody>
</table>

*Hoffmann R et al, Eur Heart J 2005; 26: 607-16*
Three dimensional echocardiography

Real-time 3D echocardiography *avoids* foreshortening of the LV

Real-time 3D echocardiography *allows* automated quantification

*Courtesy of Luigi Badano*
Contrast echo to improve LV cavity opacification

Real-time 3D stress echocardiography

LA Brodin
### Utility of contrast for LV opacification

#### Real-time 3D stress echocardiography

<table>
<thead>
<tr>
<th></th>
<th>RT3D</th>
<th>+ LVO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segments analysable</td>
<td>76%</td>
<td>90%</td>
</tr>
<tr>
<td>Image quality index</td>
<td>2.2</td>
<td>3.1</td>
</tr>
<tr>
<td>Diagnosis of ischaemia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>by territory (n=108)</td>
<td>79%</td>
<td>88%</td>
</tr>
<tr>
<td>kappa</td>
<td>0.26</td>
<td>0.59</td>
</tr>
<tr>
<td>by patient (n=36)</td>
<td>72%</td>
<td>89%</td>
</tr>
<tr>
<td>kappa</td>
<td>0.43</td>
<td>0.77</td>
</tr>
</tbody>
</table>

*Nemes A et al, Am J Cardiol 2007; 99: 275-8*
Quantification of LV function: inter-machine comparison

Volumetric 3D (Philips iE33) vs speckle 3D (Toshiba Artida 4D)

"comparable & reproducible"    "interchangeable .. in daily clinical practice"

Kleijn SA et al, Am J Cardiol 2011; 108: 1038-44
Diagnostic imaging – the choice

- QUALITATIVE
  - Subjective
  - Insensitive
  - Imprecise
  - Variable
  - Categorical
  - Quick
Cognitive psychology – models of diagnostic reasoning

**Type 1**  
**Intuitive**  
- Heuristic  
- Reflexive  
- Fast  
- Vulnerable to bias  
- Prone to error

**Type 2**  
**Analytical**  
- Deductive  
- Deliberate  
- Slow  
- Consistent  
- Scientific

*Croskerry P et al, J Roy Coll Physicians Edin 2011; 41: 155-62*
Diagnostic imaging – the choice

- QUALITATIVE
  - Subjective
  - Insensitive
  - Imprecise
  - Variable
  - Categorical
  - Quick

- QUANTITATIVE
  - Objective
  - More sensitive
  - Precise
  - Reproducible
  - Continuous
  - Time-consuming
How could we improve diagnostic accuracy? 
.. by exploiting computing and information technology

- Normative databases
- Compare each patient to normal values that reflect age, gender, BMI, and risk factors
- Automated quantification / analysis
- Integrated clinical decision aids, algorithms
- Parametric visual displays of quantitative data
  - measurements, significance levels, z scores
A new concept for diagnosis: a statistical atlas

An average heart with population variability

Derived from fully automated 3D/4D analysis of velocity using tracking technique

Temporal display of mean velocities with variance, at a particular location

Duchateau N et al, Med Image Analysis 2011; 15: 316-28
Parametric displays of statistically abnormal myocardial motion

Local maps at fixed time \( t \)

- Red = large abnormality

Spatiotemporal maps of abnormality

- Blue = Inward (\( v_p < 0 \))
- Red = Outward (\( v_p > 0 \))

Duchateau N et al, Med Image Analysis 2011; 15: 316-28
The implications of reproducibility

The "reference change value"

Courtesy of Professor Frank Dunstan
<table>
<thead>
<tr>
<th>Number of subjects per sample</th>
<th>Coefficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2%</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>100</td>
<td>1</td>
</tr>
</tbody>
</table>
How good are we at quantifying LV function?

Each echo lab needs its own quality control.