Prediction of Left Ventricular Ejection Fraction Using Wall Motion Score Index

Validation in a Large Patient Population in Clinical Practice

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IHS 60th Annual Scientific Meeting
Apr 22 2013, Jerusalem
Disclosure

No conflicts of interest (all co-authors)
Background

- Left ventricular ejection fraction (LVEF) is an important clinical and prognostic factor in pts with cardiovascular disease
- Echocardiography is the most common clinical imaging technique used to evaluate LVEF
  - Several quantitative techniques for measuring LVEF
  - LVEF – commonly assessed qualitatively (visual estimation)
    Visual estimation of LVEF – highly observer-dependent
- Wall motion score index (WMSI) – represents LV segmental Fx
  - WMSI = \( \Sigma \) wall motion scores / # of scores segments (16 segments)
  - Correlation between WMSI & LVEF – intuitive
    Not assessed in large pt populations in routine clinical practice
Objectives

• To evaluate the relation between WMSI and LVEF in a large pt population undergoing echocardiography in routine clinical practice
• To examine whether any additional echocardiographic parameters modify this relation
• To develop a formula that predicts LVEF according to:
  - WMSI
  - Additional interacting factors
• To validate this formula in a large pt population
Methods
Data Collection

- Computerized database – echocardiographic laboratory
- 2000 consecutive pts with Dx: “LV segmental wall motion abnormality”
- Collection of relevant data from echocardiographic reports
  - Demographics / body size
  - Heart rate / rhythm
  - Left ventricle
    - Size / wall thickness / remodeling
    - Coronary artery territory (LAD, non-LAD, multiple territories)
  - Valve dysfunction (> moderate)
Statistical Analysis

- Total population (n = 2000)
  - Correlation: WMSI ↔ LVEF
  - Modifiers of WMSI ↔ LVEF relationship (interactions)

- Test group (1st 1000)
  - Predictors of LVEF (WMSI + other predictors)
  - Multivariate linear regression analysis → regression equation

- Validation group (2nd 1000)
  - Calculation of “predicted LVEF” using regression equation
  - Relationship between predicted LVEF ↔ LVEF (original)
    - Correlation & Bland-Altman analysis

- ROC analysis
  - WMSI → LV dysfunction (ASE categories of LV dysfunction)
Results
Total Study Population (n=2000)

- Age (yrs) 67±13
- Male 74%
- LV dilatation (qualitative)
  - Mild 24.6%
  - Moderate-severe 13.8%
- LVEDd (cm) 5.4±0.7
- LVH (qualitative) 24.2%
- HR (min⁻¹) 72±15
- Irregular heart rhythm 13.1%
- Coronary artery territory
  - LAD 9.4%
  - Non-LAD (RCA / LCx) 62.8%
  - Multiple territories 27.8%
- MR > moderate 7.8%
Results

WMSI vs. LVEF

$$r = -0.92$$  
$$P < 0.001$$  
(n=2000)
# Linear Regression Analysis

## Univariate Predictors of LVEF – Test Group (n=1000)

<table>
<thead>
<tr>
<th>Predictor</th>
<th>$R^2$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMSI*</td>
<td>0.84</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LV size (cat)*†</td>
<td>0.42</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LVEDd*</td>
<td>0.37</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Territory**‡</td>
<td>0.29</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>RWT</td>
<td>0.19</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LV mass</td>
<td>0.11</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HR*</td>
<td>0.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MR &gt; moderate*</td>
<td>0.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>IV septum, PW</td>
<td>0.01</td>
<td>0.002</td>
</tr>
<tr>
<td>Male*</td>
<td>0.01</td>
<td>0.002</td>
</tr>
<tr>
<td>BMI</td>
<td>0.006</td>
<td>0.03</td>
</tr>
</tbody>
</table>

- **Non-significant**
  - Age, BSA
  - Regular rhythm
  - LV wall thickness (qual)
  - AR > moderate

* Negative associations
† 1 = normal LV size; 2 = mildly dilated; 3 = mod-severely dilated (visual assess.)
‡ 1 = LAD; 2 = non-LAD; 3 = multiple territories
## Results

**Multivariate Predictors of LVEF**

**Test Group (n=1000)**

- Significant independent predictors ($\Delta R^2 > 0.01$):

<table>
<thead>
<tr>
<th>Stand. coefficient ($\beta$)</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMSI</td>
<td>-0.85</td>
</tr>
<tr>
<td>LV size (category)</td>
<td>-0.11</td>
</tr>
</tbody>
</table>

**Regression equation**

\[
LVEF = 95.1 - 26.9 \times \text{WMSI} - 2.0 \times \text{LV size (cat)}^*
\]

* 1 = normal LV size; 2 = mildly dilated; 3 = mod.-severely dilated (eyeballing)
Results

LV size $\rightarrow$ WMSI $\leftrightarrow$ LVEF Relationship

LV size (categorical)
1=normal, 2=mild↑, 3=mod+↑
Results

**Prediction of LVEF (Regression Equation)**

Validation Group (2\textsuperscript{nd} n=1000)

- **Correlation**
  - $R^2 = 0.85$
  - $P < 0.001$

- **Bland-Altman analysis**
  - Mean $\Delta$LVEF (%) = 0.4 (95% CI -9.8-10.1)
  - Mean absolute $\Delta$LVEF (%) = 4.0 (0.1-11.5)
Results

Prediction of Qualitative LV Dysfunction – WMSI

- **Mild+ LV dysfunction**
  - LVEF <54%
  - AUC = 0.95 (0.94-0.96)
  - \( P < 0.001 \)
  - WMSI \( \geq 1.47 \)
  - Sensitivity = 0.88
  - Specificity = 0.88

- **Moderate+ LV dysfunction**
  - LVEF <44%
  - AUC = 0.97 (0.96-0.98)
  - \( P < 0.001 \)
  - WMSI \( \geq 1.70 \)
  - Sensitivity = 0.89
  - Specificity = 0.92

- **Severe LV dysfunction**
  - LVEF <30% (severe LVDFx)
  - AUC = 0.98 (0.97-0.98)
  - \( P < 0.001 \)
  - WMSI \( \geq 2.16 \)
  - Sensitivity = 0.92
  - Specificity = 0.93
Summary

• WMSI correlates strongly with LVEF
  - This correlation – modified by LV size
• LVEF can be predicted using a regression equation
  - Combining WMSI & estimated LV size
• Regression equation – high accuracy
  - Validation in a large group of pts
• LV dysfunction (categories) can be predicted using WMSI cutoffs
A new tool for estimating left ventricular ejection fraction derived from wall motion score index.

- 243 TTE and radionuclide angiography (RNA) performed
- First 150 patients established a correlation between LV WMSI and RNA EF.
  Regression equation (RNA LVEF=92.8-25.8 x WMSI)
- Correlated well with RNA EF (r=0.86) in 93 pts.

Novel wall motion score-based method for estimating global left ventricular ejection fraction: validation by real-time 3D echocardiography and global longitudinal strain

Vittorio Palmieri¹*, Cesare Russo², Antonietta Buonomo¹, Emiliano A. Palmieri¹, and Aldo Celentano¹

- EF of 63% if all segments were normal, 49% if all were mildly hypokinetic, 35% if all were moderately hypokinetic and 21% if all were severely hypokinetic.
- 40 random patients

Table 3  Reliability analysis and regression equations

<table>
<thead>
<tr>
<th>Items</th>
<th>Intraclass correlation coefficients</th>
<th>95% confidence interval</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMSI-EF vs. 3D based EF</td>
<td>0.94</td>
<td>0.89–0.97</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>WMSI-EF vs. Biplane EF</td>
<td>0.94</td>
<td>0.89–0.97</td>
<td></td>
</tr>
<tr>
<td>Biplane EF vs. 3D-EF</td>
<td>0.94</td>
<td>0.88–0.97</td>
<td></td>
</tr>
<tr>
<td>Regression equations</td>
<td>B (β)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>r²; standard error of estimates (%)</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>WMSI-EF predicting 3D-EF</td>
<td>0.86 (0.95)</td>
<td>0.89; 6.2</td>
<td>6</td>
</tr>
<tr>
<td>WMSI-EF predicting 2D-EF</td>
<td>0.84 (0.96)</td>
<td>0.91; 5.4</td>
<td>9</td>
</tr>
<tr>
<td>Biplane EF predicting 3D-EF</td>
<td>0.98 (0.95)</td>
<td>0.90; 6.1</td>
<td>−1</td>
</tr>
</tbody>
</table>
Prognostic implications of ejection fraction from linear echocardiographic dimensions: The Strong Heart Study

Richard B. Devereux, MD, a Mary J. Roman, MD, a Vittorio Palmieri, MD, a Jennifer E. Liu, MD, a
Elisa T. Lee, PhD, b Lyle G. Best, MD, c Richard R. Fabsitz, MA, d Richard J. Rodheffer, MD, c and
Barbara V. Howard, PhD f New York, NY, Timber Lake, SD, Bethesda, Md, Washington, DC, and Rochester, Minn

- EF of 63% if all segments were normal, 49% if all were mildly hypokinetic, 35% if all were moderately hypokinetic and 21% if all were severely hypokinetic.

Freedom from cardiovascular death (vertical axis), adjusted for covariates described in the text, is similarly lower in SHS participants with mildly reduced EF (40%-54%) or severely reduced EF (<40%) compared to those with normal EF from 2-D echocardiographic wall motion scores.
A prospective comparison of echocardiographic wall motion score index and radionuclide ejection fraction in predicting outcome following acute myocardial infarction

G I W Galasko, S Basu, A Lahiri, R Senior

• 120 consecutive patients treated with thrombolysis following AMI

• Confirmed the very close correlation between WMSI and RNV EF

Heart (British Cardiac Society) 2001; 86(3):271–6.
Rapid Estimation of Left Ventricular Ejection Fraction in Acute Myocardial Infarction by Echocardiographic Wall Motion Analysis

Berning J. · Nielsen J.R. · et al

• Using radionuclide ventriculography (RNV) and contrast ventriculography measurements of LVEF for comparison.

• ECHO-LVEF from 41 patients correlated well with the reference methods \(y = 1.5x - 14.7, r = 0.93\); linear regression analysis; 95% confidence limit for a single determination of ECHO-LVEF was 17.2.

Cardiology 1992;80:257–266
Usefulness of the severity and extent of wall motion abnormalities as prognostic markers of an adverse outcome after a first myocardial infarction treated with thrombolytic therapy.
Carluccio E, Tommasi S, et al

- Most powerful predictor of a subsequent event was a resting WMSI \( \geq 1.50 \) before discharge.
- In patients with a first AMI who underwent thrombolysis wall motion abnormalities are important independent predictors of cardiac events.

Determinants of $\Delta$LVEF

- Logistic regression – predictor(s) of absolute $\Delta$LVEF > 10%:
  - Single significant predictor – LVEF
    \[ OR = 0.75 \text{ per 10\% LVEF} \]
    \[ (95\% CI 0.61-0.93; \ P < 0.01) \]
Study Limitations

- Retrospective analysis using a prospectively collected database
- Referral bias – pts undergoing echocardiography in a tertiary medical center
- Comparison of 2 qualitative techniques (visual assessment)
  - WMSI ↔ LVEF
  - Reflects common clinical practice
- Additional qualitative parameters analyzed (LV size / wall thickness)
  - Secondary analyses using quantitative LV parameters (LVEDd, LVM)
- Relatively small subgroups of pts with pure involvement of LAD territory
Conclusions

- WMSI can be used to predict visually-estimated LVEF in routine clinical practice
- Calculation of LVEF via WMSI may be used for “cross-checking” of standard visual assessment of LVEF
  - A method for quality-control of visual LVEF assessment?