Advanced Electrocardiography Identifies Left Ventricular Systolic Dysfunction in Non-Ischaemic Cardiomyopathy and Tracks Serial Change over Time

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Disclosures

• No conflicts of interest to declare
ECG - History

Matteucci recorded electrical activity from the heart of a frog

Waller recorded first electrical activity from a human heart

1842

1887

1893

1901

1908

1924

1934-1936

1942

1954

Photograph of a complete electrocardiograph. Showing the manner in which the electrodes are attached to the patient, in this case the hands and one foot being immersed in jars of salt solution.

Einthoven first used the term EKG

Einthoven built string galvanometer based 3 lead EKG machine

EKG entered the US.

Wilson invented the central terminal. Precordial leads are born.

Goldberg used the central terminal with augmentation. Augmented unipolar leads are born.

AHA standardized 12-Lead EKG as we know it now.

2014

• Miniaturisation, wireless
• Advanced signal processing
• Remote Cloud-based
• Advanced Analytics
• Pattern recognition, artificial intelligence
Background

Screening for left ventricular systolic dysfunction using GP-reported ECGs
Barclay M Goadie, Rob J Jervis, Peter T Dorman, Frank M Sullivan, Stuart D Pringle, Sunjay Keyesoles and Allan D Struthers

Figure 2. Mean ECG sensitivity and specificity (%) for left ventricular systolic dysfunction (LVSD) by GPs’ level of experience and confidence in detection.

Table 1—Electrocardiographic findings related to left ventricular systolic function. Figures are numbers of patients

<table>
<thead>
<tr>
<th>Electrocardiographic findings</th>
<th>Impaired left ventricular systolic function</th>
<th>Preserved left ventricular systolic function</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abnormal</td>
<td>90</td>
<td>169</td>
<td>259</td>
</tr>
<tr>
<td>Normal†</td>
<td>6</td>
<td>269</td>
<td>275</td>
</tr>
<tr>
<td>Total</td>
<td>96</td>
<td>438</td>
<td>534</td>
</tr>
</tbody>
</table>

Sensitivity 90/96=94%; specificity 269/438=61%; positive predictive value 90/259=35%; negative predictive value 269/275=98%.
†Normal or minor abnormality (atrial enlargement, bradycardia, tachycardia, broadening of QRS complex, poor R wave progression, right axis deviation, myocardial ischaemia, first degree atrio-ventricular block, nonspecific ST-T wave changes).

BMJ 1996;312:222
Advanced ECG

- WiFi based ECG
  - Standard 12L snap-shot

- Deconvolutes ECG components
  - ‘spectralised’ into multiple parameters

- Advanced pattern recognition
  - Artificial intelligence applied to resulting parameters
A-EKG

- Large software database of signal processed advanced ECG information

- Simple “A-EKG scores” generated from performing data mining on database, can apply to new patients whose cardiac status is unknown.

- Good accuracy to predict the presence or absence of several different cardiac diseases, that might otherwise remain “hidden” when clinicians only have conventional 12-lead ECG information.
Methods

• Aim:
  • Electronically stored echocardiographic and clinical information to evaluate the diagnostic accuracy of A-ECG for NICM.

• Retrospective case-controlled study
  • Referral stating “non-ischemic cardiomyopathy” or “NICM”
  • ≥2 serial echocardiograms
  • Controls were identified from same database - echocardiograms read as “normal”.

• ECGs before and after echocardiography
  • Converted
  • https://aecg.ch for A-ECG analyses
  • Applied a validated A-ECG score for LVSD to the stored digital 12L ECG recordings
Methods

- **A-ECG**
  - Presence vs absence of LVSD
  - LVSD followed by A-ECG over time

- Echocardiograms (GE Vivid 7)
  - Simpson biplanes estimates of ejection fraction were performed on all studies.
# Results

Table 1. Patient characteristics.

<table>
<thead>
<tr>
<th></th>
<th>Cases (n = 41)</th>
<th>Controls (n = 38)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean/SD)</td>
<td>57 (14)</td>
<td>44 (19)</td>
<td>0.76</td>
</tr>
<tr>
<td>Type 2 DM (%)</td>
<td>9 (22)</td>
<td>2 (5)</td>
<td>0.06</td>
</tr>
<tr>
<td>HTN (%)</td>
<td>18 (44)</td>
<td>9 (24)</td>
<td>0.1</td>
</tr>
<tr>
<td>Current Smoker (%)</td>
<td>7 (2)</td>
<td>6 (16)</td>
<td>0.07</td>
</tr>
<tr>
<td>Ex-smoker (%)</td>
<td>15 (37)</td>
<td>9 (24)</td>
<td>0.3</td>
</tr>
<tr>
<td>IHD (%)</td>
<td>2 (5)</td>
<td>2 (5)</td>
<td>0.6</td>
</tr>
<tr>
<td>Dyslipidaemia (%)</td>
<td>12 (29)</td>
<td>7 (18)</td>
<td>0.37</td>
</tr>
<tr>
<td>PVD (%)</td>
<td>1 (2)</td>
<td>-</td>
<td>0.81</td>
</tr>
<tr>
<td>CVA/TIA (%)</td>
<td>4 (10)</td>
<td>-</td>
<td>0.14</td>
</tr>
<tr>
<td>AF (%)</td>
<td>12 (29)</td>
<td>1 (3)</td>
<td>0.005</td>
</tr>
<tr>
<td>Alcohol excess (%)</td>
<td>3 (7)</td>
<td>-</td>
<td>0.29</td>
</tr>
<tr>
<td>Mental Health Dx (%)</td>
<td>3 (7)</td>
<td>3 (8)</td>
<td>0.8</td>
</tr>
<tr>
<td>Substance abuse (%)</td>
<td>2 (5)</td>
<td>-</td>
<td>0.49</td>
</tr>
<tr>
<td>Gout (%)</td>
<td>6 (15)</td>
<td>3 (8)</td>
<td>0.54</td>
</tr>
<tr>
<td>CKD (%)</td>
<td>2 (5)</td>
<td>2 (5)</td>
<td>0.6</td>
</tr>
<tr>
<td>Obesity (%)</td>
<td>21 (51)</td>
<td>11 (29)</td>
<td>0.08</td>
</tr>
</tbody>
</table>

DM: Diabetes, IHD: Ischemic heart disease, PVD: Peripheral vascular disease, CVA/TIA: Cerebrovascular accident/Transient ischemic attack, AF: Atrial fibrillation, Alcohol excess ≥ 21 standard drinks/week in a male or >14 in a female. CKD: Chronic kidney disease, Obesity = Body Mass Index > 30.
Table 2. Patient medication and left ventricular (LV) ejection fraction at each echocardiogram date.

<table>
<thead>
<tr>
<th>Ejection Fraction (mean/SD)</th>
<th>Echo 1 (n = 41)</th>
<th>Echo 2 (n = 41)</th>
<th>Echo 3 (n = 21)</th>
<th>Controls (n = 38)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25% (9)</td>
<td>31% * (11)</td>
<td>38% ¥ (13)</td>
<td>55%–60%</td>
</tr>
<tr>
<td>Drug Rx</td>
<td>Max dose</td>
<td>Drug Rx</td>
<td>Max dose</td>
<td>Drug Rx</td>
</tr>
<tr>
<td>Betablocker (%)</td>
<td>15 (37)</td>
<td>2 (5)</td>
<td>39 (95)</td>
<td>14 (34)</td>
</tr>
<tr>
<td>ACEI (%)</td>
<td>17 (41)</td>
<td>7 (7)</td>
<td>30 (73)</td>
<td>12 (29)</td>
</tr>
<tr>
<td>ARB (%)</td>
<td>4 (10)</td>
<td>2 (5)</td>
<td>10 (24)</td>
<td>2 (5)</td>
</tr>
<tr>
<td>CCHB (%)</td>
<td>5 (12)</td>
<td>1 (2)</td>
<td>2 (5)</td>
<td>-</td>
</tr>
<tr>
<td>Spironolactone (%)</td>
<td>9 (22)</td>
<td>7 (7)</td>
<td>24 (59)</td>
<td>19 (46)</td>
</tr>
<tr>
<td>Digoxin (%)</td>
<td>2 (5)</td>
<td>-</td>
<td>4 (10)</td>
<td>-</td>
</tr>
<tr>
<td>Loop Diuretic (%)</td>
<td>9 (22)</td>
<td>-</td>
<td>27 (66)</td>
<td>-</td>
</tr>
<tr>
<td>Thiazide diuretic (%)</td>
<td>2 (5)</td>
<td>2 (5)</td>
<td>1 (2)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Statin (%)</td>
<td>10 (24)</td>
<td>2 (5)</td>
<td>18 (44)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Aspirin (%)</td>
<td>13 (32)</td>
<td>12 (29)</td>
<td>12 (29)</td>
<td>12 (29)</td>
</tr>
<tr>
<td>Warfarin (%)</td>
<td>3 (7)</td>
<td>-</td>
<td>12 (29)</td>
<td>-</td>
</tr>
<tr>
<td>Dabigatran (%)</td>
<td>-</td>
<td>-</td>
<td>2 (5)</td>
<td>-</td>
</tr>
<tr>
<td>Dipyridamole (%)</td>
<td>1 (2)</td>
<td>1 (2)</td>
<td>1 (2)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Amiodarone (%)</td>
<td>1 (2)</td>
<td>-</td>
<td>3 (7)</td>
<td>-</td>
</tr>
<tr>
<td>Clopidogrel (%)</td>
<td>-</td>
<td>-</td>
<td>1 (2)</td>
<td>-</td>
</tr>
<tr>
<td>ISMN (%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* t test comparison between Echo 1 and Echo 2, *p = 0.004; and Echo 2 and Echo 3. ¥p = 0.01.
Results

- 11 NICM had LBBB therefore could not be fully analysed for A-ECG.

- In the remaining patients (N = 68 total: 29 patients with NICM and 39 controls), A-ECG had a sensitivity of 93% for LVSD and specificity of 95%.

- In the 29 NICM patients without LBBB who had serial ECGs, sensitivity of A-ECG also improved to 97% when all serial ECGs were considered.
Trajectories in the A-ECG score for LVSD demonstrated improvement, deterioration or no change in LVSD, which agreed with changes in echocardiographic LV ejection fraction, in 76% of cases (n = 25).

Correlation between A-ECG score for LVSD and the echocardiographic LVEF was $r = 0.32$ ($p = 0.01$) and between the change in the A-ECG score for LVSD and the change in the LVEF between echocardiograms and A-ECGs was $r = 0.35$ ($p = 0.01$).
Sub-study

Table 3. Diagnostic accuracy of cardiologists and general practitioners assessing for LVSD.

<table>
<thead>
<tr>
<th>Multiple Diagnoses</th>
<th>Cardiologists</th>
<th>General Practitioners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>25%</td>
<td>15%</td>
</tr>
<tr>
<td>Specificity</td>
<td>71%</td>
<td>42%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Binary Diagnosis (Normal/Abnormal)</th>
<th>Cardiologists</th>
<th>General Practitioners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>90%</td>
<td>85%</td>
</tr>
<tr>
<td>Specificity</td>
<td>63%</td>
<td>58%</td>
</tr>
</tbody>
</table>

Average sensitivity and specificity for two readers reporting on a random sample of 22 ECGs from the overall cohort.

Performance of the A-ECG score for LVSD was statistically significantly better than that of the clinical readers.
Limitations

• Limited number of patients/event rate

• Retrospective design:
  • Patient and control groups were not well matched
  • ECGs distant to the echocardiogram.

• Patients with ischaemic cardiomyopathy were excluded.
  • Although no scar was visible on most MRIs, only 26 patients underwent a coronary angiogram.

• Fully prospective application of this technology required to assess its utility and cost-effectiveness as both a diagnostic and screening tool.
Conclusions

• A-ECG scoring can detect LVSD due to NICM with high sensitivity (93%) and specificity (95%).

• Serial A-ECG score trajectories also represent an accurate method for inexpensively estimating changes in LVSD (76% correspondence).

• Population screening tool and method for triaging patients for noninvasive imaging.
  • High sensitivity and specificity of A-ECG and
  • Breadth of diagnostic ability
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