Smartphone ECG Application

Chan-Hee LEE
Notice

- Nothing to declare
- Cardiologist perspective
1. Introduction for ECG Apps
   - Education
   - Interpretation
   - Recording / Analysis

2. Photoplethysmography (PPG)
   - AF detection algorithm

3. AliveCor™
   - Clinical applications

4. Summary
Education

- Summary / Case review / Training

[Images of various ECG-related apps and resources]
Interpretation

ECG tools™

Bazett’s formula

Point added.

Need help? Click here.

App Store on Google Play and iTunes
Interpretation

Doctor ECG™

Scan ECG in real time

Automatic Measurements

App Store on Google Play and iTunes
Recording

• HeartCall™
Recording

- **Cardio-Spirograph**
- **Sleep apnea, Sinus arrhythmia**

After touching the START button, after 5 seconds will automatically start research. Lie down horizontally and place on the navel mobile phone. Breathe normally. The first beep - the beginning, second - the end of the study.

Normal rhythm. Bradycardia. Heart rate=57
Pulse signal recording application

- **myPulse™**
- **Heart Rate™**
- **Cardiograph™**
- **iCare Health Monitor™**

**Instructions**

Gently place your finger over the camera lens. Do not press hard as that will stop the blood circulation on your finger. Keep your hand steady and let the app take a reading.

After the measuring process is 100% complete you can continue to hold your finger for a continuous reading.

View your pulse wave, add tags, and add notes.

Available on App Store on Google Play and iTunes
Cardiac diagnosis ™

● HRV?

Caution (주의)
- 백행이 감지되었습니다. 병원에서 정밀검사를 받아보세요.
  Pulse rate: 146

Caution (주의)
- 백행이 감지되었습니다. 병원에서 정밀검사를 받아보세요.
  Pulse rate: 56

Danger (위험)
- 부상이 감지되었습니다. 병원에서 정밀검사를 받아보세요.
  Pulse rate: 63

Heart rate: 81
HRV: 0.210

App Store on Google Play and iTunes
Cardiac diagnosis ™

● Sinus rhythm vs. AF

Heart rate: 70
HRV: 0.198

Heart rate: 73
HRV: 0.259

Heart rate: 83
HRV: 0.551

App Store on Google Play and iTunes
Cardiio™

- Finger & Face
- Life expectancy?

Scientifically Validated Technology. Born at HR.

Look ahead at the front camera. Cardiio will measure your heart rate by analyzing the light reflected from your face.

Gently cover the rear camera with your finger to measure your heart rate.

Gain Insight. See How You Stack Up, Compete with Your Friends.

YOUR LIFE EXPECTANCY
Based on your average heart rate, here's your potential life expectancy.

You: 86 yrs
Kangaroo: 9 yrs

HOW YOU STACK UP
Your heart rate is 19% lower than the average person in USA.

62 77 38
You USA Michael Phelps

ENDURANCE SCORE (VO2 MAX)
43.5 ml/min/kg
ABOVE AVERAGE

PEER GROUP AVERAGE: 38-41
MICHAEL PHELPS: 76

Complexity
Variability
Periodicity
27.3% AVG 9.0% AVG 90.2% AVG
Rhythm: REGULAR  Likelihood: 100%

Complexity
Variability
Periodicity
59.9% HIGH 24.2% AVG 28.5% LOW
Rhythm: IRREGULAR  Likelihood: 96.4%
1. Introduction for ECG app
   - Education
   - Interpretation
   - Recording / Analysis

2. Photoplethysmography (PPG)
   - AF detection algorithm

3. AliveCor™
   - Clinical applications

4. Summary
PPG (Photoplethysmography) technology

- Detect blood **vol. changes** in microvascular bed of tissue
- **Pulsatile signals by illuminating fingertip** using iPhone lamp
- Recording video signal (30 frames/s) for 30sec~2min
- Bandpass filter: 0.5 to 7 Hz
PPG (Photoplethysmography) technology

- [AC] Pulsatile physiological waveform
  - Each heart beat
  - Synchronous changes in blood volume

- [DC] Slowly varying baseline
  - Various lower frequency components
  - Respiration, sympathetic nervous system activity and thermoregulation

- Has been used for O2 saturation, BP and Cardiac output, assessing Autonomic function and detecting Peripheral vascular disease.
Pulse waveform analysis

- Pulse to Pulse = QRS to QRS intervals
- RR intervals
Clinical aspects

- Irregular pulse
- Premature beats (PAC/PVC)
- Atrial fibrillation
AF detection algorithm(1): RMSSD, ShE

A novel application for the detection of an irregular pulse using an iPhone 4S in patients with atrial fibrillation

David D. McManus, MD, ScM, FACC, FHRS, Jinseok Lee, PhD, Oscar Maitas, MD, Nada Esa, MD, Rahul Pidikiti, MD, Alex Carlucci, BS, Josephine Harrington, BS, Eric Mick, PhD, Ki H. Chon, PhD

- **RR variability**: nRMSSD (root mean square of successive RR difference)

  \[
  \text{Normalized RMSSD} = \sqrt{\frac{1}{l-1} \sum_{j=1}^{l-1} [a(j+1) - a(j)]^2} \frac{1}{\sum_{j=1}^{l} a(j)}
  \]

- **RR complexity/uncertainty**: ShE (Shannon entropy)

  \[
  SE = - \sum_{i=1}^{N} p(i) \frac{\log(p(i))}{\log \left( \frac{1}{N} \right)}, \quad p(i) = \frac{N(i)}{l}
  \]
AF detection algorithm(1): RMSSD, ShE

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSSD/mean</td>
<td>0.9818</td>
<td>0.9150</td>
<td>0.9533</td>
</tr>
<tr>
<td>Shannon entropy</td>
<td>0.9750</td>
<td>0.8218</td>
<td>0.9097</td>
</tr>
<tr>
<td>RMSSD/mean + Shannon entropy</td>
<td>0.9619</td>
<td>0.9752</td>
<td>0.9676</td>
</tr>
</tbody>
</table>
AF detection algorithm(2)

- Poincaré plots
  - SD1/SD2

![Diagram of Poincaré plots A and B](image-url)
AF detection algorithm (2)

- Sinus rhythm vs. AF

AUC for the combination of SD1/SD2 and nRMSSD

AUC = 0.931
1. Introduction for ECG app
   - Education
   - Interpretation
   - Recording / Analysis

2. Photoplethysmography (PPG)
   - AF detection algorithm

3. AliveCor™
   - Clinical applications

4. Summary
AliveCor Kardia Mobile ECG

- David Albert, San Francisco, CA
- FDA (2012), $199 AUD, OTC sales
- Latest 4th generation
- AliveInsights™, iOS/Android

www.alivetec.com/alivecor-heart-monitor
AliveCor Kardia

- Just start App and place fingers on the metal sensors
- Single-channel (Lead I)
- Frequency Response: 0.5-40Hz
- Heart Rate Range: 30-300 bpm

- Automated AF detection
  - Criteria of P-wave absence and R-R interval irregularity
    - Sen 98%, Spe 97%, Accuracy 97%

- Share PDF, E-MAIL
- Import EMRs

www.alivetec.com/alivecor-heart-monitor, IJC 2013
AliveCor Kardia

- AliveInsights™
- Additional fee for cardiologist’s interpretation
AliveCor in Korea

- Veterinary AliveECG (iPhone)
AF screening

Feasibility and cost-effectiveness of stroke prevention through community screening for atrial fibrillation using iPhone ECG in pharmacies

The SEARCH-AF study

- 1,000 pharmacy customers ≥ 65 yo
- Previously unknown AF detection: 1.5%
ECG morphology

“Accuracy and Novelty of an Inexpensive iPhone-based Event Recorder”

- **Lead I**: Pacemaker (placed directly on chest, V3-4)
- R amplitudes(mV): 0.77±0.24 vs. 0.78±0.24 (AliveCor)
- Pacing spike artifacts clearly identified
- **Similar QRS morphology**
QTC intervals can be assessed with the AliveCor heart monitor in patients on dofetilide for atrial fibrillation

Eugene H. Chung, MD, FACC, FAHA, FHRS,* Kimberly D. Guise, MSN, ANP

Division of Cardiology, Cardiac Electrophysiology, UNC School of Medicine, 160 Dental Circle, CB 7075, Chapel Hill, NC 27599 USA

Abstract
We assessed the feasibility of AliveCor tracings for QTC assessment in patients receiving dofetilide. Five patients with persistent AF underwent the two-handed measurement (mimicks Lead I). On the ECG, Lead I or II was used. There was no significant difference between the AliveCor-QTC and ECG-QTC (all ± 20 msec). The AliveCor device can be used to monitor the QTC in these patients.

Keywords: Atrial fibrillation; QT interval; QTC; ECG; AliveCor

<table>
<thead>
<tr>
<th>Patient</th>
<th>AliveCor</th>
<th>Lead I</th>
<th>Lead II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>470</td>
<td>460</td>
<td>460</td>
</tr>
<tr>
<td>2</td>
<td>440</td>
<td>440</td>
<td>440</td>
</tr>
<tr>
<td>3</td>
<td>440</td>
<td>430</td>
<td>430</td>
</tr>
<tr>
<td>4</td>
<td>400</td>
<td>390</td>
<td>390</td>
</tr>
<tr>
<td>5</td>
<td>430</td>
<td>430</td>
<td>420</td>
</tr>
</tbody>
</table>

* Corresponding author.
Surface 12 lead electrocardiogram recordings using smart phone technology

Giselle A. Baquero, MD, a Javier E. Banchs, MD, b Shameer Ahmed, MD, a
Gerald V. Naccarelli, MD, a Jerry C. Luck, MD a,*

a Penn State Hershey Heart & Vascular Institute, Division of Cardiology, Department of Medicine, Penn State College of Medicine, Penn State University, Hershey, PA
b Texas A & M College of Medicine, Baylor Scott & White Health, Temple, TX
Patient #2 standard 12 lead (Top) vs AliveCor lead comparisons (Bottom)
Smartphone ECG for evaluation of STEMI: Results of the ST LEUIS Pilot Study
62/M, Near-syncope

- PMVT or VF?
- Consider ICD??

- EPS: RVOT VT
- Artifact d/t inconsistent contact electrodes
- Irregularity: Artifact + Variability in tachycardia CL

JAMA Internal medicine 2015
**Limitation**

- **False Positive**: small P waves or multiple atrial ectopies. 
  
  *IJC* 2013;165:193-194

- **2.5%** of 1000 AliveCor recordings: **non-diagnostic**
  

- **13%** of 1768 AliveCor recordings: **uninterpretable**
  

- **Short symptoms or Rapid onset syncope**: prefer to **LINQ** (1.2cm$^3$; 44.5 x 7.2 x 4.0 mm)

*Thromb Haemost 2014; 112: 1167–1176*
1. Introduction for ECG app
   - Education
   - Interpretation
   - Recording / Analysis

2. Photoplethysmography (PPG)

3. AliveCor™

4. Summary
Summary

● **PPG technology**
  - Pulse waveform analysis
  - **Pros:** Not require additional hardware, AF detection
  - **Cons:** Touch power, frequent ectopy, AT/AFL
  - Asymptomatic, *When ‘light up?’*

● **AliveCor™**
  - Single lead ECG recording (Lead I)
  - **Pros:** QT prolongation, Silent AF, postRFA monitor
  - **Cons:** ACS setting, short run tachy, dizzy/syncope
  - False positive issue
Needs for Apps

- Simple
- User-friendly
- Inexpensive
- Real time realizable
- Reproducible
- **Exact**: Hospital-Quality ECG

- Smartwatch implementation
- Legal issue: Telemedicine