Past, Present & Future of Ambulatory ECG Monitoring

OHI Heart Rhythm Symposium
David E. Albert, MD
Chief Medical Officer
AliveCor, Inc.
Disclosure Statement of Financial Interest

Within the past 12 months, I or my spouse/partner have had a financial interest/arrangement or affiliation with the organization(s) listed below.

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<th>Affiliation/Financial Relationship</th>
<th>Company</th>
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<td>• Major Stock Shareholder/Equity</td>
<td>• AliveCor, Inc.</td>
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<td>• Ownership/Founder</td>
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As Payment Moves From Traditional Fee-For-Service to Bundles & Pay-For-Performance Models, Who Pays for Monitoring & How Much They Pay Are Bound to Change!
The Evolution of Cardiac Ambulatory Monitoring
Time Of Monitoring Is KEY To Diagnostic Yield

1. Holter: 1 to 12-leads for 24/48/72 hours
2. Cardiac Post Event Recorders: 1 lead (up to 30 days)
3. Looping Cardiac Event Recorders: 1-3 leads, Automatic & Patient Activated (up to 30 days)
4. Mobile Cardiac Telemetry: 1-3 leads (up to 30 days)
5. Implantable Event Recorders (Reveal & Linq): 1-Lead (Up to 3 years)
6. iRhythm™ Patch-type Continuous Recorder: 1-lead (up to 14 days)
7. Smartphone ECG: 1-lead (Long-Term/Lifetime Cardiac Post Event Recorder)

The Time Limits for a Given Monitoring Method are Reimbursement-Determined Not Technology-Determined
Observational Studies Show Greater AF Detection with Longer Monitoring

- 24-72h Holter Monitor 5-10% Diagnostic Yield
- 4-7d Monitoring Additional 6-8%
- 10-30d Monitoring Additional 5-20%
- Implantable (up to 3 yrs.) Max Yield
Focus on Atrial Fibrillation

Suneet Mittal, MD,* Colin Movsowitz, MBC°B,† Jonathan S. Steinberg, MD*

New York, New York; and Wynnewood, Pennsylvania
A. Holter monitoring
- Patient wears monitor (typically 24-48 hours)
- Patient keeps diary of symptoms and times when they occur
- Patient returns monitor to technician to be scanned after recording period
- Technician gives physician final report

B. Event monitoring
- Patient carries monitor (typically 30 days)
- Patient places monitor on chest to record during symptom
- Patient transmits data over telephone to monitoring station
- Monitoring station sends data to physician

C. Loop monitoring
- Patient wears monitor (typically 30 days)
- Patient activates monitor during symptom (some devices auto-trigger if arrhythmia is detected and alert patient)
- Patient transmits data over telephone to monitoring station
- Monitoring station sends data to physician

A. Patch-Type Extended Holter monitoring
- Patient wears monitor patch (up to 7-14 days)
- Patch monitor records all ECG data during period
- Patient mails back monitor after recording period to central receiving station
- The handheld device transmits ECG data to a central monitoring station
- Technician reviews data and sends report to physician

B. Ambulatory Telemetry monitoring - (Non-Real Time)
- Patient wears monitor (up to 30 days)
- Monitor sends all ECG data to a handheld device
- Patient can also log onto secure web server at any time to view real time ECG data

C. Ambulatory Telemetry monitoring - (Real Time)
- Patient wears monitor (up to 30 days)
- Monitor sends all ECG data continuously to central monitoring station
- Physicians are notified by technician if significant arrhythmia is detected

Source: Mittal et al, JACC, 2011
iRhythm™ (14d) Has Demonstrated Superior Arrhythmia Diagnostic Yield to Conventional Holter (24h)

Additionally, the Patch Solution is Far Preferred Over Holter by Patients!
Comparison of 24-hour Holter Monitoring with 14-day Novel Adhesive Patch Electrocardiographic Monitoring

Paddy M. Barrett, MB, BCh, BAO, a Ravi Komatireddy, MD, a Sharon Haaser, RN, BSN, CCRC, a Sarah Topol, RN, BSN, BA, a Judith Sheard, MPH, a Jackie Encinas, MS, a Angela J. Fought, MS, b Eric J. Topol, MD a,c

aScripps Translational Science Institute, La Jolla, Calif; bFought Statistical Consulting, Chicago, Ill; cScripps Health, La Jolla, Calif.
“CONCLUSIONS: Over the total wear time of both devices, the adhesive patch monitor detected more events than the Holter monitor. Prolonged duration monitoring for detection of arrhythmia events using single-lead, less-obtrusive, adhesive-patch monitoring platforms could replace conventional Holter monitoring in patients referred for ambulatory ECG monitoring.”

Source: Barrett et al, AJM, 2014
Finding atrial fibrillation in stroke - randomised evaluation of enhanced and prolonged Holter-ECG (NCT01855035)

Rolf Wachter, MD\textsuperscript{1,2}, Klaus Gröschel, MD\textsuperscript{3}, Götz Gelbrich, PhD\textsuperscript{4,5}, Gerhard F. Hamann, MD\textsuperscript{6}, Pawel Kermer, MD\textsuperscript{7}, Jan Liman, MD\textsuperscript{8}, Joachim Seegers, MD\textsuperscript{9}, Katrin Wasser, MD\textsuperscript{8}, Anna Schulte\textsuperscript{1}, Falko Jürries\textsuperscript{1}, Anna Messerschmidt\textsuperscript{1}, Nico Behnke\textsuperscript{2}, Sonja Gröschel, MD\textsuperscript{3}, Timo Uphaus, MD\textsuperscript{3}, Anne Grings, MD\textsuperscript{3}, Tugba Ibis, MD\textsuperscript{3}, Sven Klimpe, MD\textsuperscript{10}, Michaela Wagner- Heck, MD\textsuperscript{10}, Magdalena Arnold, MD\textsuperscript{7}, Evgeny Protsenko, MD\textsuperscript{7}, Peter U. Heuschmann, PhD\textsuperscript{4}, David Conen, MD MPH\textsuperscript{11}, Mark Weber-Krüger, MD\textsuperscript{1} on behalf of the Find-AF\textsubscript{randomised} Investigators and Coordinators
Primary Objective

We aimed to determine whether enhanced and prolonged monitoring (3 x 10-day Holter ECG) for atrial fibrillation / atrial flutter (AF) in stroke patients aged 60 years and above results in a higher detection rate of AF (before recurrent stroke) compared to standard-of-care procedures (including at least 24 hours of continuous heart rhythm monitoring)
Primary Endpoint:
AF after 6 months (before rec. stroke)

AF detected (% of patients)

Months since Randomisation

EPM 13.5%
Control 4.5%

Difference 9.0% (CI: 3.5; 14.6%)
P = 0.002

Number needed to screen 11
Secondary Endpoint:
Recurrent stroke after 12 months

All recurrent strokes were ischemic

p = 0.28

Control: 4.5%
EPM: 2.5%

Days from randomization

Incidence of recurrent stroke [%]
Patch-based Continuous ECG Monitors are Proliferating and will Eclipse Traditional Multi-lead Holters!

What is Clear With Patch, MCT and Implantable Monitors:
Time is More Important Than Number of Leads For Diagnostic Yield!
SEEQ™ MCT Transmitter

- Relays sensor data continuously via cellular signals to monitoring center
- Battery life is 12 hours
- Must be within 30 feet of the transmitter for successful data transmission
Implantable ECG Monitoring is The Current Gold Standard For Arrhythmia Diagnosis!

Compliance & Time Of Monitoring Are The Main Advantages of Implants Cost? Not So Much!
The Medtronic *Linq™* is the First $1 Billion Revenue in the First Year Cardiac Electrodiagnostic Product

Today, *it is the Global Standard of Care for >30d ECG Monitoring*  
**What Do You Think the Payers are Thinking?**
The Smartphone Will Be The World’s Personal Healthcare Portal

Trends: The Promise of Mobile Technologies for Health

Here Comes the “Uberfication” of Healthcare!

- Hospital Beds: 20
- Computers: 1,000
- Mobile Phones: 5,000
- Population: 6,892

AliveCor™
But You CAN Detect AFib With A Daily ECG

- Daily ECG second only to implants
- Detect AFib ASAP
- Adjust treatment
- (Re)Ablate sooner

AliveCor® Smartphone Cardiac Event Monitor

- ECGs Stored Securely In the Cloud
- ECGs Accessed Via Secure Login
- ECGs Stored Locally
- Stored ECGs Read Directly

ANYWHERE IN THE WORLD
Wireless technologies enable transmission of high quality ECG recordings without the need for leads. A device incorporating electrodes into an Apple iPhone case allows for wireless recording of 30-second rhythm strips (LEAD I) to the cloud (AliveCor, Okla. City, Ok.). ECGs can be downloaded for immediate interpretation using any browser.

**Objectives**

To determine use cases for and assess usage of wireless, single lead EKG iPhone cases.

**Results**

Use of the device and ECG information caused 24% of subjects to reach out to their private physicians for a consultation and 16% felt that they discovered a health condition unknown to them with the device. The majority of participants (78%) wanted to continue to use the device after the 8 week study period.

The majority of ECGs were recorded from study subjects but 61% also handed their phones to others to enable them to record ECGs.

Transmission interpretation of the 1768 EKGs was normal sinus rhythm (68%); sinus brady or tachy (16%); extra atrial or ventricular systoles (3%); QRS delay (1%); and noise (13%). Symptomatic ventricular tachycardia and asymptomatic ST segment depression were detected in 2 participants, the latter in Mumbai, India (Figure 1 A,B).

**Conclusion**

Anytime ECG monitoring, as an adjunct to a smart phone, is intuitive and allows users to learn about and characterize their heart rates and rhythms. It provides global identification of arrhythmias at any time. The implications of this technology for improving public awareness of health metrics and for the early diagnosis of arrhythmias in large patient populations are enormous.

**Methods**

iPhone-owning attendees of a Body Computing Conference at USC participated in an 8 week study to determine how they utilize the device. ECG recordings were reviewed daily by the principal investigator, a board certified electrophysiologist.

54 participants (43±11 yrs, 77% male, 15% physicians, 61% business, 13% media/entertainment, 11% engineers) transmitted 365±30-second recordings weekly (range: 3-298) for 8 weeks. Without training, subjects used the case to record ECG’s on themselves and others (61%).

Subjects reported using the device and under many different conditions. A total of 81% used the device casually and while alone, to determine their heart rate during varying emotional and physical conditions. Most (88%) used the device in social situations to show others. Symptoms such as rapid heart rate or a sensation of an irregular heart beat prompted at least one transmission in 87% of subjects. ECG’s were recorded at work in 64% of subjects.

**References**

Leading Cardiologists Use Smartphone ECG For AFib Detection

• “Antman prescribed a heart-rhythm monitoring device so the patient could take readings using an attachment to his smartphone case and email the results to Antman. He quickly diagnosed him with atrial fibrillation and formulated a treatment plan.” (Source: AHA Scientific Session Daily Article on President’s Keynote, 2014)

• **Elliott Antman, MD FACC FAHA: Brigham & Women’s Hospital, Harvard Medical School & President of American Heart Association**
“I probably have 20 patients in my practice who have this AliveCor device as part of their iPhone or Android. Is every cardiac Patient going to have their own ECG monitor with their iPhone; is that where we’re going? It has HUGE RAMIFICATIONS (emphasis added).”

Dr. John D. Day
President, Heart Rhythm Society
Source: theHeart.org
Detection of Recurrent Atrial Fibrillation Utilizing Novel Technology

Kathleen T. Hickey EdD, FNP-BC, ANP-BC, FAHA, FAAN\textsuperscript{1}, Jose Dizon, MD\textsuperscript{2}, Ashton Frulla, BS\textsuperscript{3}

\textsuperscript{1}Assistant Professor of Nursing, Columbia University School of Nursing, Columbia University Medical Center, New York, NY, USA. \textsuperscript{2}Associate Professor of Clinical Medicine, Department of Cardiac Electrophysiology, Columbia University Medical Center, New York, NY. \textsuperscript{3}Clinical Research Coordinator, Department of Cardiac Electrophysiology, Columbia University Medical Center, New York, NY.

Abstract

The true prevalence of AF is likely underestimated because episodes are often sporadic and challenging to detect in a “real world” setting. This case report will describe a 58-year-old atrial fibrillation patient with multiple cardiac risk factors. After two ablations and one cardioversion, the patient failed to remain in normal sinus rhythm. Shortly after AF returned, the decision was made to perform a second cardioversion. Post-procedure, the patient was given a novel FDA-approved, wireless ECG monitoring device compatible with the iPhone\textsuperscript{e}. This device has the capability of recording and transmitting a single-channel ECG. Within days, the patient began feeling symptomatic again and used his device to transmit an ECG to his healthcare provider. Recurrent AF was detected and the patient was directed to seek further evaluation.

The success of this novel device to detect recurrent AF highlights the “real world” applicability of using mHealth technology more readily in patient care.
The Smartphone ECG is Well Received By >90% Patients!
Feasibility and cost effectiveness of stroke prevention through community screening for atrial fibrillation using iPhone ECG in pharmacies

The SEARCH-AF study

Nicole Lowres1,2; Els Neubeck4; Glenn Saikoff1; Ines Krooss1; Andrew J. Mclachlan2,8; Julie Redfearn1,4; Alexandra A. Bennett3,1; Tom Briffa1; Adrian Bauman1; Carlos Martinez10; Christopher Wallenhorst10; Jerrett K. Lau1; David B. Brier1,1; Raymond W. Sy1,2,1; S. Ben Freedman1,1,4

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The Smartphone ECG Can Screen For Undiagnosed AFib!

Summary

Atrial fibrillation (AF) causes a third of all strokes, but often goes undetected before stroke. Identification of unknown AF in the community and subsequent antithrombotic treatment could reduce stroke burden. We investigated community screening for unknown AF using an iPhone electrocardiogram (iECG) in pharmacies, and determined the cost-effectiveness of this strategy. Pharmacists performed pulse palpation and iECG recordings, with cardiologist iECG over-reading. General practitioner review/12-lead ECG was facilitated for suspected new AF. An automated AF algorithm was retrospectively applied to collected iECGs. Cost-effectiveness analysis incorporated costs of iECG screening and treatment. Retrospective data from a United Kingdom cohort of 3,553 patients with incidentally detected asymptomatic AF. A total of 1,000 pharmacy customers aged ≥65 years (mean 76 ± 7 years; 44% male) were screened. Novelly identified AF was found in 1.5% (95% CI, 0.8–2.5%); mean age 76 ± 6 years; all had CHA2DS2-VASc score ≥2. AF prevalence was 6.7% (67/1,000). The automated iECG algorithm showed 98.5% (CI, 92–100%) sensitivity for AF detection and 91.4% (CI 89–93%) specificity. The incremental cost-effectiveness ratio of extending iECG screening into the community, based on a 55% variance in prescription adherence, would be $AUD5,988 ($3,142; $USD4,666) per Quality Adjusted Life Year gained and $AUD30,481 ($15,993; $USD16,695) for preventing one stroke. Sensitivity analysis indicated cost-effectiveness improved with increased treatment adherence. Screening with iECG in pharmacies with an automated algorithm is both feasible and cost-effective. The high and largely preventable stroke/thromboembolism risk of those with newly identified AF highlights the likely benefits of community AF screening. Guideline recommendation of community iECG AF screening should be considered.

Keywords

Atrial fibrillation, screening, stroke prevention, cost-effectiveness, anticoagulation

Thrombosis and Haemostasis 111/6/2014

AliveCor™
What AliveCor Does Every Day

Wayne @Toaster_Pastry • 12h
Case: When he showed me his @AliveCor ECG, we thought for sure it was an SVT with normal heart. It wasn't.
What It Means & Why It Matters

AliveCor Enabled the Patient to “DRIVE” the diagnosis of his serious arrhythmia!
For Many Patients, AFib is a Disease for Life So It Must Be Chronically Managed: Smartphone ECG Is Becoming a Part of that Management

• Anti-arrhythmic & Anticoagulation Medication Management as well as lifestyle modification- rhythm & symptom tracking are key

• Post-ablation monitoring is LONG-TERM to detect recurrence (we have a proven technology*)

• Daily Monitoring of therapeutic results is key to optimize therapy & engage patients in their own care!

* iTransmit Study, Heart Rhythm, Jan, 2015 (Cleveland Clinic)
CardioNet Report With AF Burden Graph

Detecting Asymptomatic AFib (~40%) & AFib Burden Requires Continuous Monitoring!
The Smartphone ECG is **NOT** a Continuous Monitor So it **CANNOT** Detect Asymptomatic Arrhythmias or Quantify AFib Burden.

The Ubiquity of Smartphones, Patient Device Preference & Low Cost are **NO SUBSTITUTES** for This Valuable Clinical Data.

Is there **ANYTHING** that we can do to bring Patient-Focused Smartphone Solutions To Provide Long-term Continuous Cardiac Monitoring?

Can We Do **MORE** For **LESS**?
Atrial Fibrillation Detected By Step Increases in Heart Rate

The red area of the Heart Rate (HR) Graph shows the minutes of AFib rhythm. Note the increase in HR during the AFib run. The 1-minute ECG verifies the AFib.

The Increase in Heart Rate is confirmed as AFib by looking at the RR Variability in the ECG.
**iRhythm™ Report Shows This Increased HR During AFib**

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<th>6am</th>
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<td><strong>HR (bpm)</strong></td>
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**Days 1 & 2**

- **Max/Min**: [Max/Min]
- **Avg**: [Avg]

Note: Heart rates are calculated using a sliding window of 5 beat intervals.

- **5** Patient diary events
- **8** Patient triggered
- **0** PVT, VF, TdP
- **0** VT
- **0** SVT
- **26** Pauses
- **55** % AF burden
- **0** AV Block
- **Y** SVE/PACs
- **Y** VE/PVCs
- **▼** Unanalyzable ECG
Zoom Into PAF Episode- Step Increase in HR & HRV

Increased HR

Increased HRV
So What Else Do I Have Up My Sleeve Now?
The Latest “FAD” in Consumer Technology is Wearables & in this we may find the “consumerized” solution to patient-friendly, low-cost & long-term, continuous Cardiac Monitoring!

You Cannot Go Anywhere Without Hearing About The Apple Watch!
Wrist-Worn Continuous Heart Rate/Activity Monitors Are Proliferating From the World’s Largest Tech Companies
Virtually All of these HR Monitors Use the Absorption of Green LED Light by Blood to Track Pulse Rate
Can Smartwatches Plus The Smartphone ECG Match Continuous ECG Monitoring?

Days 3 & 4

iRhythm™ AFib Burden Report
Smartwatches Continuously Monitor Both Activity & HR/HRV
HR/HRV-Activity **Discordance** Monitoring Enables Alerts to Take an ECG To Confirm AFib & Other Arrhythmias

Smartwatches Plus Smartphone ECGs May Well Provide Low-Cost, Patient-Friendly & Long-Term Cardiac Monitoring? **Clinical Validation Required!**
How About An All-In-One Solution?
Mobile, Personal, Continuous & Intelligent:
AliveCor Apple Watch Band ECG

Long-Term, Continuous, Noninvasive, Contextualized Cardiac Monitoring
Thank You!

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