
Table of Contents

-
1. Accuracy of AF Algorithm: KardiaBand
 2. Accuracy of AF Algorithm: KardiaMobile
 3. Arrhythmia Assessment
 4. Managing Patients with AF: Post-Ablation
 5. Managing Patients with AF: Post-Cardioversion
 6. Managing Patients with AF: Monitor Symptoms and Rhythm
 7. Diagnosing AF Early in High Risk Patients: Post-Cardiac Surgery
 8. Diagnosing AF Early in High Risk Patients: Cryptogenic Stroke/TIA
 9. Diagnosing AF Early in High Risk Patients: Screening
 10. Investigational Use: As-Needed Anticoagulation for AF*
 11. Investigational Use: HRV*
 12. Investigational Use: Pediatrics*
 13. Investigational Use: Potassium*
 14. Investigational Use: QT Interval*
 15. Investigational Use: ST Elevation*
 16. Patient Management of Cardiac Risk Factors (Supporting Literature)
 17. Other Supporting Literature

* The research labeled "Investigational Use" was conducted using AliveCor devices in an investigational manner and explore potential future devices and configurations. The devices and configurations used in this research are not commercially available today. AliveCor may make these available in the future after pursuing the appropriate regulatory process. CAUTION: The devices used in the research labeled "Investigational Use" are for investigational use. Restricted by federal (US) law for investigational use only.

1. Accuracy of AF

Algorithm:
KardiaBand

Automated atrial fibrillation detection algorithm using smartwatch technology.

This study evaluated the accuracy of KardiaBand ECG and the automated AF algorithm. 100 patients (mean age 68 ± 11 yrs) with AF presenting for cardioversion (CV) were enrolled and received simultaneous 12-lead ECG and KardiaBand ECG before the procedure; if the CV was performed a post CV 12-lead ECG was then obtained along with another KardiaBand ECG. CV was canceled in 8 patients due to presentation in sinus rhythm. There were 169 simultaneous 12-lead ECG and KardiaBand ECGs. Compared to 12-lead ECG, the automated algorithm detected AF with 93% sensitivity, 84% specificity and K coefficient 0.77. Physician-interpretation of KardiaBand ECGs demonstrated 99% sensitivity, 83% specificity and K coefficient 0.83. The automated AF algorithm on KardiaBand, when supported by physician review, can accurately differentiate AF from sinus rhythm. This technology can help screen patients prior to elective CV and avoid unnecessary procedures.

Bumgarner JM, Lambert CT, Hussein AA, Cantillon DJ, Baranowski B, Wolski K, et al. JACC. March 2018. DOI:10.1016/j.jacc.2018.03.003

2. Accuracy of AF

Algorithm:
KardiaMobile

Assessing the accuracy of an automated atrial fibrillation detection algorithm using smartphone technology: The iREAD Study.

The accuracy of the KardiaMobile AF algorithm was evaluated in 52 patients admitted for antiarrhythmic drug initiation for AF. Patients performed KardiaMobile recordings immediately following twice daily 12-lead ECGs. There were 225 paired KardiaMobile and 12-lead ECG recordings. The algorithm interpretation was missing or labeled as non-interpretable in 62 (27.5%) of recordings for multiple reasons (truncated recording, noise, slow heart rate, other). When the algorithm did not provide a diagnosis, blinded electrophysiologists were able to provide interpretation in 92% of these recordings. After exclusion of non-interpretable recordings, the KardiaMobile AF algorithm had very good accuracy, with a sensitivity of 96.6% and specificity of 94% for the detection of AF when compared to physician interpreted ECGs, and a coefficient of 0.89. The majority of patients (93.6%) found KardiaMobile easy to use, and 59.6% noted that use lessened AF-diagnosis related anxiety. 63.8% of survey respondents preferred continued use of KardiaMobile for AF detection.

William AD, Kanbour M, Callahan T, Bhargava M, Varma N, Rickard J, et al. Heart Rhythm. August 2018. doi: 10.1016/j.hrthm.2018.06.037

Detection of atrial fibrillation with a smartphone camera: first prospective, international, two-centre, clinical validation study (DETECT AF PRO).

In this prospective study of 672 patients with AF or sinus rhythm at two university hospitals in Switzerland and Germany, physician review of KardiaMobile was used as the reference for evaluation of the accuracy of a photoplethysmography (PPG) heart rhythm analysis from a smartphone camera. Less than 3% of patients had KardiaMobile recordings with poor signal quality. Additionally, the study tested the accuracy of the KardiaMobile algorithms. 18.8% of KardiaMobile recordings were labeled "unclassified," but cardiologists were able to identify the cardiac rhythm in all of these cases. The KardiaMobile AF algorithm had a sensitivity of 99.6% (95% CI 97.9-100%) and a specificity of 97.8% (95.3-99.2%).

Brasier N, Raichle CJ, Dorr M, Becke A, Nohturfft V, Weber S, et al. Europace. 2018. doi:10.1093/europace/euy176

Clinical validation of heart rate apps: mixed-methods evaluation study.

Heart rate (HR) detection from a smartphone-based photoplethysmography (PPG) app (FibriCheck) was compared with the KardiaMobile ECG and the Nonin pulse oximeter. The HR (BPM, beats per minute) of 88 random subjects consecutively measured for 10 seconds with the 3 devices showed a moderate-to-strong correlation coefficient of 0.834 between FibriCheck and Nonin, 0.88 between FibriCheck and AliveCor, and 0.897 between Nonin and AliveCor. The mean HR for FibriCheck was 71 BPM, for Nonin 69 BPM, and for AliveCor 69 BPM. A single way analysis of variance showed no significant differences between the HRs as measured by the 3 devices ($p=0.61$). This study reports the potential utility and limitations in use of the smartphone-based PPG signal for HR detection.

Vandenberk T, Stans J, Van Schelvergem G, Pelckmans C, Smeets CJ, Lanssens D, et al. JMIR Mhealth Uhealth. 2017;5(8):e129.

Screening for atrial fibrillation during influenza vaccinations by primary care nurses using a smartphone electrocardiograph (iECG): a feasibility study.

KardiaMobile was used to identify asymptomatic AF at the time of influenza vaccination in 5 practices in Sydney, Australia. Nurses used the automated algorithm to screen 973 patients aged ≥ 65 years between April-June 2015. Screening took on average 5 minutes (range 1.5 -10 minutes); abnormal recordings required additional time. Newly identified AF was found in 0.8% (8) of patients, and the overall prevalence of AF was 3.8% (37). The sensitivity and specificity of the automated algorithm for detecting AF was 95% and 99%, respectively. Screening by practice nurses was well accepted by practice staff. Key enablers were the confidence and competence of nurses and a 'designated champion' to lead screening at the practice. Barriers were practice specific, and mainly related to staff time and funding.

Orchard J, Lowres N, Freedman SB, Ladak L, Lee W, Zwar N et al. Eur J Prev Cardiol. 2016; 23(2S):13-20.

Feasibility and cost-effectiveness of stroke prevention through community screening for atrial fibrillation using iPhone ECG in pharmacies. The SEARCH-AF study.

One thousand pharmacy customers (mean age 76 ± 7 years, 44% male) were screened with KardiaMobile. Newly identified AF was found in 1.5% (95% CI, 0.8-2.5%), and AF prevalence was 6.7%. The automated algorithm showed 98.5% sensitivity and 91.4% specificity for detecting AF. Using cost and outcome data from a United Kingdom study for AF screening, the incremental cost-effectiveness ratio of extending screening into the community with KardiaMobile, based on 55% warfarin prescription adherence, would be \$USD4,066 per quality-adjusted life-year gained, and \$USD20,695 for preventing one stroke. In summary, screening for AF with KardiaMobile is feasible and cost-effective.

Lowres N, Neubeck L, Salkeld G, Krass I, McLachlan AJ, Redfern J, et al. Thromb Haemost. 2014;111(6):1167-76.

iPhone ECG application for community screening to detect silent atrial fibrillation: a novel technology to prevent stroke.

KardiaMobile was used in a community screening of 109 patients (70 in sinus rhythm and 39 in AF) soon after a 12-lead ECG had been performed. The ECGs were interpreted by two cardiologists blinded to the rhythm diagnosis, and were processed to provide an automated diagnosis of sinus rhythm or AF. Results were compared with the 12-lead ECG diagnosis by a third cardiologist. An optimized algorithm performed extremely well in the validation set with high sensitivity, specificity, overall accuracy and Kappa (95% CI) of 98% (89%–100%), 97% (93%–99%), 97% (94%–99%) and 0.92 (0.86–0.98) respectively. This study concluded that KardiaMobile can be used to simply and rapidly record a high quality single-lead ECG to accurately detect AF, making it an ideal technology for community screening programs to detect silent AF.

*Lau JK, Lowres N, Neubeck L, Brieger DB, Sy RW, Galloway CD, et al.
Int J Cardiol. 2013;165(1):193-4.*

**3. Arrhythmia
Assessment**

Modified positioning of a smartphone based single-lead electrocardiogram device improves detection of atrial flutter.

This study evaluated the use KardiaMobile in the lead II position (right hand to left leg) to improve visualization of flutter waves and clinician diagnosis of atrial flutter (AFL), compared to traditional lead-I tracings. Fifty patients were recruited (25 in sinus rhythm, 14 in AF, 11 in AFL). Lead-I AFL sensitivity was 27% for both electrophysiologists (EP), which individually improved to 73% and 55% in lead-II. KardiaMobile appropriately diagnosed lead-I AFL as unclassified in 18% of cases, compared to 55% in lead-II. Overall clinician agreement (AF, sinus rhythm and AFL) was modest utilizing lead-I position (EP1: $\kappa=0.71$, EP2: $\kappa=0.73$, $p<0.001$), which improved with lead-II tracings (EP1: $\kappa=0.87$, EP2: $\kappa=0.83$, both $p<0.001$). In summary, lead II position of KardiaMobile improves clinician diagnosis of atrial flutter.

*Rajakariar K, Koshy AN, Sajeev JK, Nair S, Roberts L, Teh AW.
J Electrocardiol. 2018. 51(5): 884-88.*

Diagnostic utility of real-time smartphone ECG in the initial investigation of palpitations.

148 patients (mean age 41 years) with intermittent palpitations were asked to use KardiaMobile and record an ECG when symptomatic. Over a median period of use of 244 days, 113 patients (76.4%) made 516 symptomatic recordings. A symptom-rhythm correlation was possible for all patients who submitted recordings. Diagnoses were: sinus rhythm $n=47$ (41.6%), sinus tachycardia $n=21$ (18.6%), supraventricular/ventricular ectopics $n=31$ (27.4%), atrial fibrillation $n=8$ (7.1%), and supraventricular tachycardia $n=6$ (5.3%). Median time to diagnosis was nine days (range 1–287 days). In conclusion, KardiaMobile diagnosed the cause of intermittent palpitations in the majority of patients referred for evaluation.

*Dimarco AD, Onwordi EN, Murphy CF, Walters EJ, Willis L, Mullan NJ, et al.
Brit J Cardio. March 2018. doi:10.5837/bjc.2018.006*

Validation of a smartphone-based event recorder for arrhythmia detection.

This trial evaluated the diagnostic yield of KardiaMobile versus a 14-30 day external loop recorder (ELR). 38 patients were instructed to transmit ECGs via KardiaMobile and activate the ELR whenever they had symptoms. More patients had a potential diagnosis for their symptoms (i.e., at least one symptomatic recording during the entire monitoring period) with KardiaMobile than with the ELR (KardiaMobile= 34 (89.5%) vs ELR = 26 (68.4%); $\chi^2 = 5.1$, $p = 0.024$). In the per-protocol analysis, all 33 patients (100%) had a potential diagnosis using the KardiaMobile device, which was significantly higher compared to 24 patients (72.2%) using the ELR ($\chi^2 = 10.4$, $p = 0.001$). In summary, KardiaMobile is non-inferior to an ELR for detecting arrhythmias in the outpatient setting. The ease of use and portability of this device make it an attractive option for the detection of symptomatic arrhythmias.

*Narasimha D, Hanna N, Beck H, Chaskes M, Glover R, Gatewood R et al.
Pacing Clin Electrophysiol. March 2018. doi:10.1111/pace.13317*

Monitoring patients with implantable cardioverter defibrillators using mobile phone electrocardiogram: case study.

Three patients with implantable cardioverter defibrillators (ICD) used KardiaMobile; device usage and satisfaction, patient engagement, quality of life (QoL), and cardiac anxiety were assessed. Each patient used the technology approximately daily or every other day as prescribed. At the 30-day follow-up, participants recorded an average of 32 ECGs per month. At 90-day follow-up, participants recorded an average of 34 ECGs per month. Two of the three participants self-reported a significant improvement in their physical QoL from baseline to completion, while simultaneously self-reporting a significant decrease in their mental QoL. All three participants reported high levels of device acceptance and technology satisfaction.

*Kropp C, Ellis J, Nekkanti B, Sears S.
JMIR Cardio 2018;2(1):e5*

Using smart technology to improve outcomes in myocardial infarction patients: rationale and design of a protocol for a randomized controlled trial, The Box.

The aim of this randomized controlled trial is to investigate the clinical effectiveness and patient satisfaction of a smart technology intervention in patients admitted with ST elevation myocardial infarction (STEMI) or non-ST acute coronary syndrome (NST-ACS). Patients will be followed up to one year after the index event. The intervention group will take daily measurements with KardiaMobile, as well as a blood pressure monitor, weight scale, and activity tracker. Furthermore, two of four outpatient clinic visits will be replaced by electronic visits (1 and 6 months after index event). The control group will receive regular care, consisting of four outpatient clinic visits (1, 3, 6, and 12 months after index event). All patients will be asked to fill in validated questionnaires about patient satisfaction, quality of life, propensity of medication adherence, and physical activity. The primary outcome of this trial will be percentage of patients with controlled BP. In summary, this trial will investigate whether usage of smart technology can improve clinical- and cost-effectiveness of care.

*Treskes RW, van Winden LA, van Keulen N, Atsma DE, van der Velde ET, van den Akker-van Marle E, et al.
JMIR Res Protoc. 2017;6(9):e186*

Alcohol consumption, sinus tachycardia, and cardiac arrhythmias at the Munich Oktoberfest: results from the Munich Beer Related Electrocardiogram Workup Study (MunichBREW)

This study prospectively associated acute alcohol consumption with cardiac arrhythmias using KardiaMobile. At the 2015 Munich Oktoberfest, 3028 volunteers received a KardiaMobile ECG and breath alcohol concentration (BAC) measurements. ECGs were analyzed for cardiac arrhythmias (sinus tachycardia, sinus arrhythmia, premature atrial/ventricular complexes, atrial fibrillation/flutter) and respiratory sinus arrhythmia. Mean BAC was 0.85 +/- 0.54 g/kg. Cardiac arrhythmias occurred in 30.5% (sinus tachycardia 25.9%; other arrhythmia subtypes 5.4%). Breath alcohol concentration was significantly associated with cardiac arrhythmias overall (odds ratio (OR) per 1-unit change 1.75, 95% confidence interval (CI) 1.50-2.05; P < 0.001) and sinus tachycardia in particular (OR 1.96, 95%CI 1.66-2.31; P < 0.001). Respiratory sinus arrhythmia measuring autonomic tone was significantly reduced under the influence of alcohol.

*Brunner S, Herbel R, Droblesch C, Peters A, Massberg S, Kaab S, et al.
Eur Heart J. 2017. 38(35): 2641-43.*

Supraventricular tachycardia diagnosed by smartphone ECG.

This is a case report of paroxysmal supraventricular tachycardia, unable to be diagnosed through typical evaluation with an event monitor despite several years of symptoms. Here, the patient diagnosed himself through purchase of KardiaMobile, capturing an atypical atrioventricular node re-entrant tachycardia (AVNRT). He emailed his cardiologist the tracing, which eventually led to an electrophysiology study and successful ablation procedure.

*Tabing A, Harrell TE, Romero S, Francisco G.
BMJ Case Rep.; published online 11 September 2017.*

A randomized trial of pocket-echocardiography integrated mobile health device assessments in modern structural heart disease clinics.

Mobile health (mHealth) devices were used as clinical decision support tools in resource-limited areas to investigate the impact on long-term outcomes among patients with rheumatic and structural heart diseases. Patients randomized to the mHealth clinics (n=139) received, among other mHealth devices, point-of-care ECG using KardiaMobile. An initial mHealth assessment was associated with a shorter time to referral for valvuloplasty and/or valve replacement and was associated with an increased probability for valvuloplasty/valve replacement compared to standard care. Patients randomized to mHealth were associated with a lower risk of a hospitalization and/or death on follow-up (15% vs. 28%, adjusted hazard ratio: 0.41; 95% CI: 0.21 to 0.83; p = 0.013).

*Bhavnani SP, Sola S, Adams D, Venkateshvaran A, Dash PK, Sengupta PP, et al.
JACC Cardiovasc Imaging. Available online September 2017.*

2017 ISHNE-HRS expert consensus statement on ambulatory ECG and external cardiac monitoring/telemetry.

This consensus document by the Heart Rhythm Society describes the evolution and advancement of ambulatory ECG technology and its impact on clinical decision-making and practice. It includes a section devoted to smartphone-based ECG recording systems, highlighting the vast literature on KardiaMobile. The document describes the benefits and challenges of KardiaMobile, blurring the traditional models of prescribed device and physician interpretation, and also definitions of patient versus consumer.

*Steinberg JS, Varma N, Cygankiewicz I, Aziz P, Balsam P, Baranchuk A, et al.
Heart Rhythm. 2017;14(7):e55-e96.*

Crowd-sourcing syncope diagnosis: mobile smartphone ECG apps.

This case report documents a 76-year-old gentleman with witnessed syncope. When he regained consciousness, a bystander cardiologist used KardiaMobile on the patient, which showed sinus tachycardia with complete heart block and a narrow complex escape rhythm. The patient later underwent pacemaker implantation. Although KardiaMobile is patient triggered, it can be used in syncope if applied by bystanders. The authors conclude there is a potential for widespread use of KardiaMobile to usher in a new era of democratized, crowd-sourced, syncope diagnostic capability.

Nyotowidjojo I, Erickson RP, Lee KS.

Am J Med. 2016;129(4):e17-8.

Smartphone ECG aids real time diagnosis of palpitations in the competitive college athlete.

Six college athletes presented to their athletic trainers complaining of palpitations during exercise. A single lead ECG was performed using KardiaMobile and sent wirelessly to the team cardiologist who confirmed an absence of dangerous arrhythmia. KardiaMobile has the potential to enhance evaluation of symptomatic athletes by allowing trainers and team physicians to make diagnoses in real-time and facilitate faster return to play.

Peritz DC, Howard A, Ciocca M, Chung EH.

J Electrocardiol. 2015;48(5):896-9.

Diagnosing symptomatic arrhythmia via mobile phone.

This is a case study of a 22-year old admitted to the hospital for an episode of tachycardia at a rate of 150 BPM. Upon discharge from the hospital, the patient had an exercise ECG test in attempt to provoke the arrhythmia, then wore a 24-hour ambulatory ECG, and finally was issued a patient-activated event recorder for two weeks. None of these methods captured abnormalities despite symptoms recurring approximately every three months. The patient then purchased KardiaMobile and used this device to record when symptomatic. A consultant cardiologist reviewed recordings to diagnose probable atrioventricular nodal re-entrant tachycardia. Treatment reviewed.

Richley D, Graham A.

Br J Cardiac Nurs. 2015;10(3):130.

Living with the handheld ECG.

This review paper discusses the evolution of the ECG and highlights the rise of digital health devices and wearable technologies. It identifies KardiaMobile as a useful tool to reduce clinic visits and lower the cost of monitoring while increasing the speed and accuracy of diagnoses. Clinical usability of KardiaMobile is described for narrow complex tachycardia in a patient with palpitations, complete heart block in a patient with intermittent giddiness, arrhythmia in a patient following catheter ablation, and AF in an asymptomatic individual.

Mitchell AR, Le Page P.

BMJ Innov. 2015;0:1-3.

Wide complex tachycardia recorded with a smartphone cardiac rhythm monitor.

This case report discusses the use of KardiaMobile to diagnose RVOT ventricular tachycardia in diagnosis of a 62-year old man experiencing frequent, sudden episodes of exertional near-syncope and syncope with monomorphic RVOT VT. KardiaMobile may improve diagnostic yield in patients with symptoms of palpitations, light-headedness, or near-syncope. However, the lack of adhesive electrodes and variable contact between the patient and the device can lead to superimposed noise and artifact that may, in some cases, obscure the correct electrocardiographic diagnosis. Further, the device records cardiac rhythms only upon proper activation.

*Waks JW, Fein AS, Das S.
JAMA Intern Med. 2015;175(3):437-9.*

Ubiquitous wireless ECG recording: a powerful tool physicians should embrace.

Fifty-three attendees at a computing conference (mean age 43 ±11 years, 77% male) transmitted KardiaMobile recordings weekly for eight weeks. Transmission interpretation was normal sinus rhythm (68%); sinus bradycardia or tachycardia (16%); extra atrial or ventricular systoles (2%); QRS delay (1%); and noise (13%). Symptomatic ventricular tachycardia and asymptomatic ST segment depression were detected in two participants, suggesting that early detection of abnormalities provides a window of diagnostic and therapeutic opportunity for intervention to prevent significant cardiac events. The majority of participants (82%) reported that the device was beneficial, 33% felt that they were more health conscious after participating in the study, and 88% thought that the device was transmitting accurate information. Use of the device caused 24% of subjects to reach out to see a physician for a consultation.

*Saxon LA.
J Cardiovasc Electrophysiol. 2013;24(4):480-3.*

4. Managing Patients with AF: Post-Ablation

2017 HRS/EHRA/ECAS/APHS/SOLAECE expert consensus statement on catheter and surgical ablation of atrial fibrillation.

This document, written by an international task force of electrophysiologists, provides updated definitions, mechanisms, and rationale for AF ablation and consensus recommendations concerning indications, strategies, techniques, and endpoints, technology and tools, and follow-up considerations for AF ablation. Specifically, it references the iTransmit study featuring KardiaMobile as an example of the use of smartphone-based ECG monitors that can be helpful for long-term intermittent surveillance after AF ablation.

*Calkins H, Hindricks G, Cappato R, Kim YH, Saad EB, Aguinaga L, et al.
Heart Rhythm. 2017;14(10):e275-e444.*

Using a novel wireless system for monitoring patients after the atrial fibrillation ablation procedure: the iTransmit study.

Fifty-five patients (mean age 60 ± 12 years) with AF undergoing ablation recorded their rhythm using KardiaMobile and a traditional transtelephonic monitor (TTM) whenever they had symptoms, or at least once a week, for 3-4 months following ablation. All were interpreted by electrophysiologists. There were 831 KardiaMobile recordings, and 7 were noninterpretable. Of the 389 simultaneous recordings with KardiaMobile and TTM, there was excellent agreement (K statistic 0.82). KardiaMobile detected sinus rhythm 97% of the time and correctly detected AF and atrial flutter 100% of the time, with 3% false-positive results. For manual review of KardiaMobile versus TTM for detection of AF, KardiaMobile had 97% specificity and 100% sensitivity. P waves could be difficult to discern, and occasionally this resulted in mislabeling sinus rhythm with atrial ectopy as AF. KardiaMobile is an alternative method for monitoring patients after AF ablation, with patients agreeing on ease of use.

*Tarakji KG, Wazni OM, Callahan T, Kanj M, Hakim AH, Wolski K, et al.
Heart Rhythm. 2015;12(3):554-9.*

5. Managing Patients with AF: Post-Cardioversion

Detection of recurrent atrial fibrillation using novel technology.

This is a case study of a 58-year-old patient with AF with multiple cardiac risk factors who failed to remain in normal sinus rhythm after two ablations and one cardioversion. Following a second cardioversion, the patient was given KardiaMobile for mobile monitoring of any symptomatic events. Within days, the patient began feeling symptomatic again and used his device to transmit an ECG to his healthcare provider. The novel technology led to more timely detection of recurrent AF. Since approximately one-third of patients with AF are asymptomatic, a daily ECG transmission in those who have undergone a prior cardioversion or AF ablation may prove useful in detecting silent AF.

Hickey KT, Dizon J, Frulla A. JAFIB. 2013;6(4):50-1.

6. Managing Patients with AF: Monitor Symptoms and Rhythm

Rationale and design of the Atrial Fibrillation health Literacy Information Technology Trial: (AF-LITT).

This randomized clinical trial will implement a novel, smartphone-based intervention to address the patient experience of AF. One hundred eighty patients with AF who are receiving anticoagulation for stroke prevention will be randomized to 30 days of an embodied conversational agent and KardiaMobile, or to usual care, which includes a symptom and adherence journal. The primary endpoints are improvement in health related quality of life, and self-reported adherence to anticoagulation.

Guhl EN, Schlusser CL, Henault LE, Bickmore TW, Kimani E, Paasche-Orlow MK, et al. Contemp Clin Trials. 2017;62:153-8.

Evaluating the utility of mHealth ECG heart monitoring for the detection and management of atrial fibrillation and flutter in clinical practice.

A pilot cohort from within the larger ongoing NIH randomized trial, iPhone Helping Evaluate Atrial Fibrillation Rhythm through Technology (iHEART), was evaluated to determine differences in AF/AFL recurrence rates (after undergoing treatment to restore normal rhythm) and quality-of-life over a 6-month follow-up period among 23 patients utilizing KardiaMobile on a daily basis, and 23 control patients. In the KardiaMobile group, 61% had recurrent AF/AFL versus 30% of controls (hazard ratio 2.55, 95% CI 1.06-6.11, $p=0.04$). Among the 13 patients with baseline and 6 month QoL assessments, significant improvements were observed in the physical functioning ($p = 0.009$), role physical ($p = 0.007$), vitality ($p = 0.03$), and mental health domains ($p = 0.02$). In summary, self-monitoring of AF is feasible using KardiaMobile, and improves self-reported quality-of-life.

Hickey K, Biviano AB, Garan H, Sciacca RR, Riga T, Warren K, et al. J Atr Fibrillation. 2017;9(5):1546.

A single-center randomized, controlled trial investigating the efficacy of a mHealth ECG technology intervention to improve the detection of atrial fibrillation: the iHEART study protocol.

The iHEART study is a single center, prospective, randomized controlled trial. A total of 300 participants with a recent history of atrial fibrillation will be enrolled. Participants will be randomized 1:1 to receive the iHEART intervention, receiving an iPhone® equipped with a KardiaMobile and behavioral altering motivational text messages or usual cardiac care for 6 months. This will be the first study to investigate the utility of a mobile health intervention in a "real world" setting. This study will assess the impact of KardiaMobile on clinical outcomes, quality of life, quality-adjusted life-years and disease-specific knowledge.

Hickey KT, Hauser NR, Valente LE, Riga TC, Frulla AP, Masterson Creber R, et al. BMC Cardiovasc Disord. 2016;16:152.

7. Diagnosing AF Early in High Risk Patients: Post-Cardiac Surgery

Self-monitoring for atrial fibrillation recurrence in the discharge period post-cardiac surgery using an iPhone electrocardiogram.

This study aimed to determine the feasibility of patients self-monitoring with KardiaMobile to identify recurrence of post-operative AF (POAF) in the post-discharge period following cardiac surgery. Forty-two participants with no prior history of AF, and discharged home in stable sinus rhythm, used KardiaMobile 4 times per day for 4 weeks post-discharge. Self-monitoring for POAF recurrence using KardiaMobile was feasible and acceptable, and participants felt empowered. Self-monitoring identified 24% (95% CI 12–39%) with an AF recurrence within 17 days of hospital discharge. 80% of patients with recurrence were at high enough stroke risk to warrant consideration of anticoagulation. The study concluded that KardiaMobile is a non-invasive, inexpensive, convenient and feasible way to monitor for AF recurrence in post-cardiac surgery patients. It also provides a mechanism to provide knowledge about the condition and also potentially reduces anxiety.

Lowres N, Mulcahy G, Gallagher R, Freedman B, Marshman D, Kirkness A, et al. Eur J Cardiothorac Surg. 2016;50(1):44-51.

8. Diagnosing AF Early in High Risk Patients: Cryptogenic Stroke/TIA

Mobile phones in cryptogenic stroke patients Bringing single Lead ECGs for Atrial Fibrillation detection (MOBILE-AF): study protocol for a randomised controlled trial.

This multicenter randomized clinical trial will investigate the effectiveness of prolonged ECG monitoring with KardiaMobile for AF detection in patients with cryptogenic stroke or transient ischemic attack (TIA). One hundred patients in the intervention group will use KardiaMobile to record their ECG twice daily; 100 patients in the control group will complete a 7-day Holter monitor. The primary outcome of this study is the percentage of patients in which AF is detected in the first year after the index ischaemic stroke or TIA. Secondary outcomes include markers for AF prediction, orally administered anticoagulation therapy changes, as well as the incidence of recurrent stroke and major bleeds.

Treskes RW, Gielen W, Wermer MJ, Grauss RW, van Alem AP, Dehnavi RA, et al. Trials. 2017;18(1):402.

Smartphone electrographic monitoring for atrial fibrillation in acute ischemic stroke and transient ischemic attack.

The aim of this study is to use KardiaMobile to identify AF in patients admitted to the hospital with stroke/transient ischemic attack, compared with 12-lead ECG, 24-h Holter monitoring and cardiac telemetry. KardiaMobile ECGs will be administered by nursing staff at the same frequency as the vital observations of pulse and blood pressure until discharge, in addition to the standard testing paradigm of each participating stroke unit to detect paroxysmal AF.

Tu HT, Chen Z, Swift C, Churilov L, Guo R, Liu X, et al. Int J Stroke. 2017;12(7):786-9.

9. Diagnosing AF Early in High Risk Patients: Screening

Effectiveness of a nongovernmental organization-led large-scale community atrial fibrillation screening program using the smartphone electrocardiogram: An observational cohort study.

Between November 2015 to September 2016, 11,574 Hong Kong citizens voluntarily participated in the AFinder Program, a nongovernmental organization (NGO)-led community-based AF screening program using KardiaMobile. A total of 118 screening sessions in 108 community centers was carried out by 84 trained layperson volunteers older than 50 years. Citizens with AF were contacted by telephone for completing the baseline and 9-month follow-up questionnaires. The ECG reports were mailed to those participants with AF, and they were advised to seek medical attention. Participants who had uninterpretable ECGs were advised to seek medical attention and undergo conventional ECG tests. Among all participants (9236 female citizens [79.8%]; mean age 78.6 years), KardiaMobile ECGs were interpretable in 10,735 citizens (92.8%). 244 (2.3%) had AF; a new diagnosis of AF was found in 74 participants (0.69%), with a mean CHA2DS2-VASc score of 3.9 +/- 1.5. 36 of the 74 were asymptomatic. Of 72 participants with newly diagnosed AF and indicated for oral anticoagulation, 47 sought medical attention and 17 (23.6%; 95% CI 13.8-33.4%) received oral anticoagulants. This NGO-led community-based AF screening program was effective in identifying citizens with newly diagnosed AF. However, the effectiveness of the program in subsequently leading them to receive appropriate oral anticoagulation therapy was weakened by the lack of a more structured downstream management pathway.

Chan NY, Choy CC, Chan CK, Siu CW. Heart Rhythm. 2018;15(9):1306-11.

Screening for atrial fibrillation is feasible in US managed care outpatient facilities.

The purpose of this study was to evaluate the utility of screening for AF in patients presenting to Kaiser Permanente ambulatory clinics for routine care using KardiaMobile during intake. A total of 2286 patients 65 years and older were screened; mean age of the patients was 80 ± 11 years (range 65-96), 60% were males and 40% were females. AF was detected in 117 (5.1%) patients, 81 of whom had a history of AF (3.5% of the total screened). There were 36 (1.6%) patients who had undiagnosed AF, and only 236 (6%) were on anticoagulant therapy. In summary, up to 1.6% of patients 65 years and older presenting to an ambulatory clinic may have undiagnosed AF, most of whom are at significant risk of stroke (CHADsVAsC score of ≥2), and would benefit from screening and treatment for AF to prevent stroke.

Keen W, Martin J, Lopez C, Pena-Ruiz M, Antons K, Longson S, et al. American Heart Association's Scientific Sessions (2017). Abstract.

Assessment of remote heart rhythm sampling using the AliveCor heart monitor to screen for atrial fibrillation: the REHEARSE-AF study.

This is the first prospective randomized trial of AF screening using a remote, handheld ECG device over an extended period of time (1 year). 1001 adults ≥ 65 years of age with a CHADS₂-VASc score ≥2 (mean score 3.0) were randomized to AF screening using KardiaMobile or usual care. Patients randomized to KardiaMobile acquired ECGs twice weekly over 12 months (plus additional ECGs if symptomatic). 19500 (3.8%) patients in the KardiaMobile group were diagnosed with AF, versus 5501 (1.0%) in the usual care group (hazard ratio, 3.9; 95% confidence interval=1.4-10.4; P=0.007) at a cost per AF diagnosis of \$10,780 (£8255). There was a statistically similar number of stroke/transient ischemic attack/systemic embolic events. The majority of KardiaMobile patients were satisfied with the device, finding it easy to use without restricting activities or causing anxiety. This trial found that extended AF screening with KardiaMobile is significantly more likely to identify incident AF than usual care.

Halcox JPJ, Wareham K, Cardew A, Gilmore M, Barry JP, Phillips C, et al. Circulation. 2017;136(19):1784-94.

Feasibility of using mobile ECG recording technology to detect atrial fibrillation in low-resource settings.

This study used KardiaMobile to screen 50 adults in Kenya (mean age 54 years, 66% women) attending Kijabe Hospital outpatient internal medicine or diabetes clinics; 44% had hypertension, 32% had diabetes, and 4% had stroke. ECG tracings in 4 of the 50 patients (8%) showed AF, and none had been previously diagnosed with AF. The authors concluded that KardiaMobile can be used to screen for AF in low-resource settings.

Evans GF, Shirk A, Muturi P, Soliman EZ.

Glob Heart. Published online first: 13 Mar 2017. doi:10.1016/j.ghheart.2016.12.003.

Opportunistic screening to detect atrial fibrillation in Aboriginal adults in Australia.

This protocol is for a mixed methods study that will recruit and train Aboriginal health workers to use KardiaMobile to consecutively screen 1500 Aboriginal people aged 45 years and older. The study will quantify the proportion of people who presented for follow-up assessment and/or treatment following a non-normal screening and then estimate the prevalence and age distribution of AF of the Australian Aboriginal population.

Gwynne K, Flaskas Y, O'Brien C, Jeffries TL, McCowen D, Finlayson H, et al.

BMJ Open. 2016;6(11):e013576.

Screening for atrial fibrillation during influenza vaccinations by primary care nurses using a smartphone electrocardiograph (iECG): a feasibility study.

KardiaMobile was used to identify asymptomatic AF at the time of influenza vaccination in 5 practices in Sydney, Australia. Nurses used the automated algorithm to screen 973 patients aged ≥ 65 years between April-June 2015. Screening took on average 5 minutes (range 1.5 -10 minutes); abnormal recordings required additional time. Newly identified AF was found in 0.8% (8) of patients, and the overall prevalence of AF was 3.8% (37). The sensitivity and specificity of the automated algorithm for detecting AF was 95% and 99%, respectively. Screening by practice nurses was well accepted by practice staff. Key enablers were the confidence and competence of nurses and a 'designated champion' to lead screening at the practice. Barriers were practice specific, and mainly related to staff time and funding.

Orchard J, Lowres N, Freedman SB, Ladak L, Lee W, Zwar N et al.

Eur J Prev Cardiol. 2016; 23(2S):13-20.

High burden of unrecognized atrial fibrillation in rural India: an innovative community-based cross-sectional screening program.

Residents from 6 villages in Gujarat, India, were screened for AF using KardiaMobile. A total of 235 participants aged 50 years and older (half female) used KardiaMobile for 2 minutes on 5 consecutive days. Community health workers helped to screen participants. The prevalence of AF increased by the number of screenings, from 3.0% with 1 screening to 5.1% with 5 screenings.

Soni A, Earon A, Handorf A, Fahey N, Talati K, Bostrom J, et al.

JMIR Public Health Surveill. 2016;2(2):e159.

Screening for atrial fibrillation in 13,122 Hong Kong citizens with smartphone electrocardiogram.

From May 1, 2014, to April 30, 2015, adults aged 18 and above were informed by media promotion for a community-wide AF screening program in Hong Kong. A group of non-medical volunteers used KardiaMobile to screen 13,122 Hong Kong citizens (mean age 65.5 ± 13.3 years). All recordings were overread by a cardiologist within 1 month of the recording, and all participants with AF detected were referred for medical consultation. Fifty-six (0.4%) out of 13,122 KardiaMobile recordings were uninterpretable. Newly diagnosed AF was discovered in 101 (0.8%) participants. The overall prevalence for AF was 1.8% (239/13,122, 95% CI 1.6-2%). Systematic population-based ECG screening for AF with KardiaMobile was feasible and identified a proportion of Hong Kong citizens with AF that was comparable with that of contemporary US and European populations.

*Chan NY, Choy CC.
Heart. 2017;103(1):24-31.*

The effectiveness of a mobile ECG device in identifying AF: sensitivity, specificity, and predictive value.

Ninety-five patients, 29 with AF and 66 in sinus rhythm, were assessed with KardiaMobile and a standard 12-lead EKG by two physicians in clinic. For one practitioner's review, the sensitivity of KardiaMobile was 90% and the specificity was 86%; for the other practitioner, the sensitivity was 93% and the specificity was 76%. The high sensitivity of KardiaMobile suggests this test is a good 'rule-out' for AF. A positive test should be combined with a 12-lead EKG to confirm the diagnosis of AF.

*Williams, J, Pearce K, Benett I.
Br J Cardiol. 2015;22:70-2.*

The efficacy of a smartphone ECG application for cardiac screening in an unselected island population.

KardiaMobile was used to screen 954 participants aged 12-99. There were 54 (5.6%) people noted to have a potential abnormality (conduction defect, increased voltage, rhythm abnormality); of these 23 (43%) were abnormal with two confirming AF and 2 showing atrial flutter. Other abnormalities detected included atrial and ventricular ectopy, bundle branch block, and left ventricular hypertrophy. One patient with increased voltages was later diagnosed with hypertrophic cardiomyopathy. In conclusion, KardiaMobile was quick and easy to use and led to new diagnoses of arrhythmia, bundle branch block, left ventricular hypertrophy and cardiomyopathy.

*Le Page P, McLachlan H, Anderson L, Penn L, Moss A, Mitchell A.
Br J Cardiol. 2015;22:31-3.*

Pharmacy-based screening for atrial fibrillation in high-risk Maori and Pacific populations

One hundred twenty-one Maori and Pacific people age ≥ 55 years were screened for AF with KardiaMobile in New Zealand community pharmacies; if the automatic algorithm was positive, participants were referred to primary care for confirmatory 12-lead ECG. Two of the 121 participants screened had a new diagnosis of AF (1.7%), and two known AF cases appeared to not be receiving warfarin, giving a total of four people (3%) that could benefit from initiation of anticoagulation. There were 2 false positives, which were thought to occur due to incorrect handling of the device, which was corrected through further training of the pharmacists. The study determined that KardiaMobile is highly acceptable to patient populations as well as health professionals in this environment.

*Walker N, Doughty R, Parag V, Harrison J, Bennett M, Freedman B.
N Z Med J. 2014;127(1398):128-31.*

iPhone ECG screening by practice nurses and receptionists for atrial fibrillation in general practice: the GP-SEARCH qualitative pilot study.

Receptionists and practice nurses screened patients aged ≥ 65 years using KardiaMobile. General practitioner (GP) review was then provided during the patient's consultation. Eighty-eight patients (51% male; mean age 74.8 ± 8.8 years) were screened: 17 patients (19%) were in AF (all previously diagnosed). KardiaMobile was well accepted by GPs, nurses and patients. Receptionists were reluctant, whereas nurses were confident in using the device to explain and provide screening.

*Orchard J, Freedman SB, Lowres N, Peiris D, Neubeck L.
Aust Fam Physician. 2014;43(5):315-9.*

Feasibility and cost-effectiveness of stroke prevention through community screening for atrial fibrillation using iPhone ECG in pharmacies. The SEARCH-AF study.

One thousand pharmacy customers (mean age 76 ± 7 years, 44% male) were screened with KardiaMobile. Newly identified AF was found in 1.5% (95% CI, 0.8-2.5%), and AF prevalence was 6.7%. The automated algorithm showed 98.5% sensitivity and 91.4% specificity for detecting AF. Using cost and outcome data from a United Kingdom study for AF screening, the incremental cost-effectiveness ratio of extending screening into the community with KardiaMobile, based on 55% warfarin prescription adherence, would be \$USD4,066 per quality-adjusted life-year gained, and \$USD20,695 for preventing one stroke. In summary, screening for AF with KardiaMobile is feasible and cost-effective.

*Lowres N, Neubeck L, Salkeld G, Krass I, McLachlan AJ, Redfern J, et al.
Thromb Haemost. 2014;111(6):1167-76.*

iPhone ECG application for community screening to detect silent atrial fibrillation: a novel technology to prevent stroke.

KardiaMobile was used in a community screening of 109 patients (70 in sinus rhythm and 39 in AF) soon after a 12-lead ECG had been performed. The ECGs were interpreted by two cardiologists blinded to the rhythm diagnosis, and were processed to provide an automated diagnosis of sinus rhythm or AF. Results were compared with the 12-lead ECG diagnosis by a third cardiologist. An optimized algorithm performed extremely well in the validation set with high sensitivity, specificity, overall accuracy and Kappa (95% CI) of 98% (89%–100%), 97% (93%–99%), 97% (94%–99%) and 0.92 (0.86–0.98) respectively. This study concluded that KardiaMobile can be used to simply and rapidly record a high quality single-lead ECG to accurately detect AF, making it an ideal technology for community screening programs to detect silent AF.

*Lau JK, Lowres N, Neubeck L, Brieger DB, Sy RW, Galloway CD, et al.
Int J Cardiol. 2013;165(1):193-4.*

10. Investigational Use: As-Needed Anticoagulation for AF*

Intermittent versus continuous anticoagulation therapy in patients with atrial fibrillation (ICARE-AF), a pilot study.

Fifty-eight patients with paroxysmal AF and CHADS₂ < 3 were randomized to intermittent anticoagulation based on daily KardiaMobile monitoring (n=29), or continuous anticoagulation with a new oral anticoagulation medication (n=29). Over a median 20 months, 20 patients in the intermittent arm failed to submit a daily ECG at least once (median 3 failed submissions). 10 patients (35%) crossed over to continuous anticoagulation, either for failure to submit an ECG for 3 days, or for progression to persistent AF. Rates of death or stroke were not different between the groups (3 vs. 1, p=0.65). Major bleeding was not different. Gastrointestinal bleeding was more frequent in the continuous group.

Stavrakis S, Stoner JA, Kardokus J, Garabelli PJ, Po SS, Lazzara R. J Interv Card Electrophysiol. 2017;48(1):51-60.

11. Investigational Use: HRV*

Impact of heart rate variability, a marker for cardiac health, on lupus disease activity.

Decreased heart rate variability (HRV) is associated with adverse outcomes in cardiovascular diseases and has been observed in patients with systemic lupus erythematosus (SLE). This study assessed HRV in 53 SLE patients with a 5-minute KardiaMobile ECG. Baseline HRV (RMSSD, pNN50, HF power, LF/HF ratio) was inversely related to disease activity, as measured by clinical assessment and plasma cytokine levels. Changes in RMSSD between visits were inversely related to changes in the Systemic Lupus Erythematosus Disease Activity Index (p=0.007). Changes in the LF/HF ratio between visits were also associated with plasma cytokine changes. Impaired HRV, particularly the LF/HF ratio, is associated with lupus disease activity and several cytokines related to IFN type II and TNF pathways.

Thanou A, Stavrakis S, Dyer JW, Munroe ME, James JA, Merrill JT. Arthritis Res Ther. 2016;18:197.

Heart rate variability in concussed athletes: a case report using the smartphone electrocardiogram.

This case report describes assessment of heart rate variability in a concussed 18-year-old male collegiate football player, using KardiaMobile. Five days after his concussion, and while still symptomatic, a 5-minute ECG was obtained using KardiaMobile, at rest and after exercise on a stationary bike. The assessment was repeated 2 weeks post injury when he was symptom free. HRV analysis was performed using Kubios HRV version 2.2 (Biosignal Analytics and Medical Imaging Group, Kuopio, Finland). Exercise induces an overall decrease in HRV due to an increase in sympathetic activity and decrease in parasympathetic activity. There were expected post-exercise decreases in HRV 2 weeks post-injury, and some deviation from the expected pattern when the athlete was symptomatic 5 days post injury, suggesting some dysfunction in autonomic cardiovascular regulation when the athlete was concussed. HRV may be a promising tool, especially via wearable technologies, for the sideline assessment of concussion..

Lai E, Boyd K, Albert D, Ciocca M, Chung EH. HeartRhythm Case Rep. 2017;3(11):S23-6.

12. Investigational Use: Pediatrics*

Comparison of a smartphone-based ECG recording system with a standard cardiac event monitor in the investigation of palpitations in children.

The use of KardiaMobile in 80 children with palpitations was compared to a pediatric practice's most recent 100 conventional patient-activated event monitors. Median patient age was 11 years in KardiaMobile group, compared with 10 years in the conventional group. Seventy-nine of 80 (98%) patients with a smartphone monitor sent an ECG recorded during symptoms, compared with 62/100 (62%) from the conventional group. A total of 836 ECG recordings were sent from the smartphone monitors compared with 752 from the conventional group. Eight per cent of ECG recordings in each group were of inadequate quality for analysis. Twenty of 80 (25%) patients with a smartphone monitor had documented tachyarrhythmia compared with 6/100 (6%) patients with the conventional monitor ($p < 0.001$). On comparison with the conventional approach, the smartphone monitor outperformed with respect to diagnostic yield and patient satisfaction. The authors conclude that KardiaMobile allows simple, effective, long-term ECG event monitoring in children that is highly acceptable to the patient and parent.

Macinnes M, Martin N, Fulton H, McLeod KA.

Arch Dis Child. Published Online First: 02 June 2018. doi:10.1136/archdischild-2018-314901.

An unusual cause of lone atrial fibrillation in a young female subject due to a rapid-cycling focal atrial trigger.

A 13-year-old female was diagnosed with lone atrial fibrillation with recurrence despite multiple cardioversions and antiarrhythmic medications. She underwent EP testing and had radiofrequency ablation of a rapidly cycling focal atrial trigger in the region of the ligament of Marshall. Catheter ablation was successful. KardiaMobile was used throughout her treatment to document recurrent atrial fibrillation and tachycardia, as well as normal sinus rhythm once the atrial focus was ablated.

Baskar S, Attari M, Czosek RJ, Jais P, Anderson JB, Spar DS.

HeartRhythm Case Rep. 2018;4(6):204-8.

SPEAR Trial: Smartphone Pediatric ElectroCARDiogram Trial.

This study aimed to assess the usefulness of pediatric ECG tracings generated by KardiaMobile. Over a year, 20 patients with documented paroxysmal arrhythmia used KardiaMobile, generating a total of 238 tracings. 96% of tracings were of diagnostic quality for sinus rhythm, sinus tachycardia, supraventricular tachycardia, and AF. 126 patient satisfaction surveys (64% from parents) were completed. 98% of the survey responses indicated that it was easy to obtain tracings, 93% found it easy to transmit the tracings, 98% showed added comfort in managing arrhythmia by having the device, and 93% showed interest in continued use of the device after the study period ended. In summary, KardiaMobile generates tracings of diagnostic quality in children. User satisfaction was extremely positive.

Nguyen HH, Van Hare GF, Rudokas M, Bowman T, Silva JN.

PLoS ONE 10(8):e0136256. Available online 2015 August.

A smartphone application to diagnose the mechanism of pediatric supraventricular tachycardia.

The utility of KardiaMobile to record supraventricular tachycardia (SVT) and to distinguish atrioventricular reentrant tachycardia (AVRT) from atrioventricular nodal reentrant tachycardia (AVNRT) in pediatric patients was ascertained. Tracings were obtained by placing the smartphone in three different positions on the chest. Two blinded pediatric electrophysiologists jointly analyzed a pair of sinus and tachycardia tracings in each position. 37 patients (mean age 13.7 years) were enrolled. 128 pairs of tracings were obtained, and the correct diagnosis was made in 59-73% with the three-lead positions. KardiaMobile can successfully record SVT in pediatric patients and can predict the SVT mechanism at least as well as previously published reports of Holter monitors.

Ferdman DJ, Liberman L, Silver, ES.

Pediatr Cardiol. 2015;36(7):1452-7.

13. Investigational Use: Potassium*

Noninvasive blood potassium measurement using signal-processed, single-lead ECG acquired from a handheld smartphone.

The single lead ECG from KardiaMobile was used to estimate blood potassium levels in 21 patients during hemodialysis sessions. Individualized potassium estimation models were generated for each patient. ECG-calculated potassium values were compared to blood potassium results at subsequent visits to evaluate the accuracy of the potassium estimation models. The mean absolute error between the estimated potassium and blood potassium was 0.38 ± 0.32 mEq/L (9% of average potassium level) decreasing to 0.6 mEq/L using predictors of poor signal.

*Yasin OZ, Attia Z, Dillon JJ, DeSimone CV, Sapir Y, Dugan J, et al.
J Electrocardiol. 2017;50(5):620-5.*

14. Investigational Use: QT Interval*

Artificial intelligence and deep neural networks can identify patients with electrocardiographically concealed long QT syndrome from the surface 12-lead electrocardiogram.

Long QT syndrome (LQTS) is characterized by prolongation of the QT interval and is associated with increased risk of sudden cardiac death, especially if the QTc exceeds 500 ms. However, approximately 25% of patients with genetically confirmed LQTS have a normal QTc at rest. Distinguishing LQTS patients from normal is of utmost importance to correctly diagnose disease, implement simple preventative measures, and initiate prophylactic therapy if necessary. All ECGs from patients seen at Mayo Clinic's Genetic Heart Rhythm Clinic were analyzed retrospectively. Patients were included if they a) had a definitive diagnosis of LQTS (n=1048) or b) were seen because of an initial suspicion for LQTS but dismissed as normal (n=1010). A multi-layer convolutional recurrent neural network (CRNN) was used to classify patients based on a 10 second ECG using Lead I alone. The CRNN was trained using 72% of the patients and validated in the remaining 28%. When looking only at LQTS patients with a normal resting QTc value (QTc < 450ms), the QTc alone distinguished LQTS from normal with an AUC of 0.67. Here, the CRNN increased this discrimination to an AUC of 0.83. Deep neural networks were able to successfully distinguish patients with electrocardiographically concealed LQTS from those dismissed as normal. As these tools are further developed, deep neural networks and artificial intelligence could aid in the early detection and diagnosis of patients with LQTS.

*Bos JM, Attia ZI, Thome T, Albert D, Friedman PA, Ackerman MJ.
Heart Rhythm Scientific Sessions (2018). Abstract.*

Comparison of QT interval readings in normal sinus rhythm between a smartphone heart monitor and a 12-lead ECG for healthy volunteers and inpatients receiving sotalol or dofetilide.

This study sought to evaluate the accuracy of KardiaMobile for assessing the QTc. Across 99 healthy volunteers and 25 hospitalized patients in sinus rhythm being loaded on dofetilide or sotalol, KardiaMobile QTc had good agreement with the 12-lead ECG QTc. For patients receiving QT prolonging antiarrhythmics, KardiaMobile is capable of detecting QTc prolongation, and lead I is most accurate in measuring the QTc if < 500 milliseconds.

*Garabelli P, Stavrakis S, Albert M, Koomson E, Parwani P, Chohan J, et al.
J Cardiovasc Electrophysiol. 2016;27(7): 827-32.*

QTc intervals can be assessed with the AliveCor heart monitor in patients on dofetilide for atrial fibrillation.

The feasibility of KardiaMobile tracings for QTc assessment in 5 patients receiving dofetilide was assessed. There was no significant difference between KardiaMobile QTc and standard ECG-QTc (all ± 20 msec). None of the patients required a dosage adjustment due to QT prolongation during their stay. KardiaMobile can be used to monitor the QTc in patients receiving dofetilide for AF.

*Chung EH, Guise KD.
J Electrocardiol. 2015;48(1):8-9.*

15. Investigational Use: ST Elevation*

Smartphone ECG for evaluation of ST-segment elevation myocardial infarction (STEMI): Design of the ST LEUIS International Multicenter Study.

This multicenter, international prospective study aims to validate an investigational KardiaMobile attachment that provides all 12 leads of a standard ECG system, and its ability to accurately assess the presence or absence of ST-elevation myocardial infarction (STEMI) in patients presenting with chest pain. The aim is to support the diagnostic utility of smartphone technology which can improve the availability of a 12-lead ECG in the diagnosis of STEMI. The study will take place over 12 months at five institutions. Approximately 60 patients will be enrolled per institution, for a total recruitment of 300 patients.

Barbagelata A, Bethea CF, Severance HW, Mentz RJ, Albert D, Barsness GW, et al. J Electrocardiol. Available online 19 October 2017.

Mobile digital health devices and the diagnosis in real-time of myocardial ischaemia.

This case report describes the use of KardiaMobile during episodes of chest pain at rest in a 61-year-old man. The single-lead ECG demonstrated ST-segment elevation with intermittent ectopy, which resolved following the administration of sublingual nitroglycerin. He underwent coronary angiography which did not show significant coronary obstructive disease, so he was diagnosed with coronary artery spasm and treated with vasodilators. This case provides a demonstration of how mobile health devices can provide new insights into previously difficult to establish diagnoses.

Joseph JP, Redwood SR. QJM. 2017;110(5):309-10.

Smartphone ECG for evaluation of STEMI: results of the ST LEUIS Pilot Study.

In this pilot study, a 12-lead ECG generated from electrodes attached to KardiaMobile was compared to the 12-lead ECG in evaluation of in-hospital cardiac ischemia. Six patients for whom the hospital ST elevation myocardial infarction (STEMI) was activated were evaluated. All tracings were taken prior to catheterization or immediately after revascularization while still in the catheterization laboratory. The 12-lead ECG generated from KardiaMobile had excellent correlation with the gold standard 12-lead ECG in all patients. Four out of six tracings were judged to meet STEMI criteria on both modalities as determined by three experienced cardiologists, and in the remaining two, consensus indicated a non-STEMI ECG diagnosis. This study confirmed the potential of KardiaMobile for evaluation of acute ischemia.

Muhlestein JB, Le V, Albert D, Moreno FL, Anderson JL, Yanowitz F, et al. J Electrocardiol. 2015;48(2):249-59.

16. Patient Management of Cardiac Risk Factors (Supporting Literature)

Effect of weight reduction and cardiometabolic risk factor management on symptom burden and severity in patients with atrial fibrillation: a randomized clinical trial.

In this partially blinded study, 150 patients with symptomatic AF were randomized to weight management or general lifestyle advice to determine the effect of weight reduction on AF burden. For the intervention, participants were prescribed meal replacements for 2 of their daily meals, an exercise program, and face-to-face clinic visits every 3 months. Participants were required to maintain a diet, activity, and blood pressure diary. Over 15 months, the intervention group showed a significantly greater reduction in weight (14.3 and 3.6 kg, respectively; $p < 0.001$), blood pressure (3 mmHg and 1 mmHg; $p < 0.001$), AF symptom burden and severity scores, and in cumulative duration as measured by 7-day Holter recordings. These findings support therapy directed at weight and risk factors in the management of AF.

Abed HS, Wirt GA, Leong DP, Shirazi MG, Bahrami B, Middeldorp ME, et al. JAMA. 2013;310(19):2050-60

17. Other Supporting Literature

Defining a mobile health roadmap for cardiovascular health and disease.

This review outlines specific opportunities for mobile health, potential challenges to the development and adoption of solutions, and a framework for developing safe, effective, and evidence-based mobile health solutions for cardiovascular disease.

Eapen ZJ, Turakhia MP, McConnell MV, Graham G, Dunn P, Tiner C, et al. J Am Heart Assoc. 2016;5(7).

Mobile technology and the digitization of healthcare.

This review assesses current literature of mobile health and provides a framework for the advances in mobile health by understanding the various device, patient, and clinical factors as they relate to digital health, from device designs and patient engagement, to clinical workflow and device regulation.

Bhavnani SP, Narula J, Sengupta PP. Eur Heart J. 2016;37(18):1428-38.

* The research labeled "Investigational Use" was conducted using AliveCor devices in an investigational manner and explore potential future devices and configurations. The devices and configurations used in this research are not commercially available today. AliveCor may make these available in the future after pursuing the appropriate regulatory process. CAUTION: The devices used in the research labeled "Investigational Use" are for investigational use. Restricted by federal (US) law for investigational use only.