OXFORD UNIVERSITY GLOBAL SURGERY GROUP

Smartphone-based ECG Systems in Resource-limited Settings

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Background

The rise in global smartphone penetrance - topping 3 billion users in 2018 (Newzoo) - has presented mobile health providers with unique opportunities to address unmet clinical need worldwide. One source of this, namely cardiovascular disease, constitutes a large and growing burden for Low and Middle Income countries (LMICs). These countries often face chronic shortages of health professionals, particularly in rural areas, and addressing this remains a challenge.

In recent years, various single– and multi-lead smartphone-based electrocardiographs (ECGs), such as the £50, FDA-approved AliveCor™ Kardia device (Figure 1) have become commercially available. These devices can remotely send ECGs via smartphone to doctors elsewhere for diagnosis ('tele-ECG'), or perform automated diagnosis. Quick, cost-effective, and easy-to-use in virtually any environment, smartphone-based ECG systems (iECG) may play a pivotal role in optimising access and affordability of specialist healthcare in low-resource settings. Here, I conduct a structured literature review of iECG devices., a schema of which is shown on the right, identifying several key themes, including:

- **Remote cardiac monitoring**
- **Detection of arrhythmias, e.g. atrial fibrillation (AF)**
- **Rapid diagnosis of ST-elevated Myocardial Infarction (STEMI)**

These applications are discussed here, with a focus on LMIC healthcare systems.

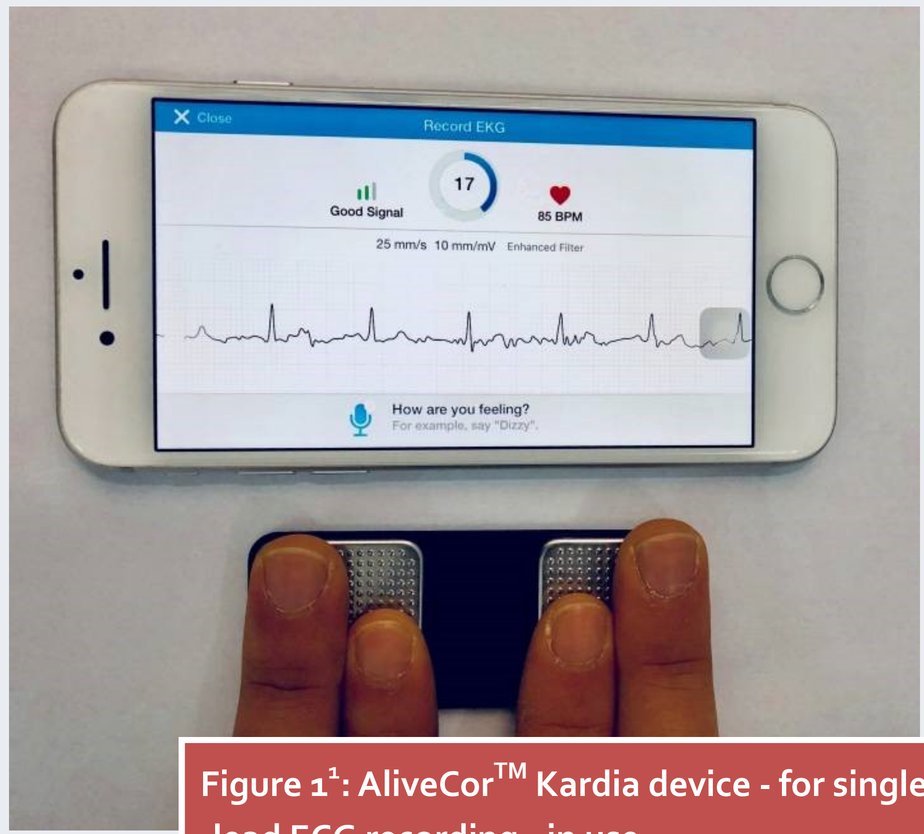


Figure 1[1]: AliveCor™ Kardia device - for single-lead ECG recording - in use.

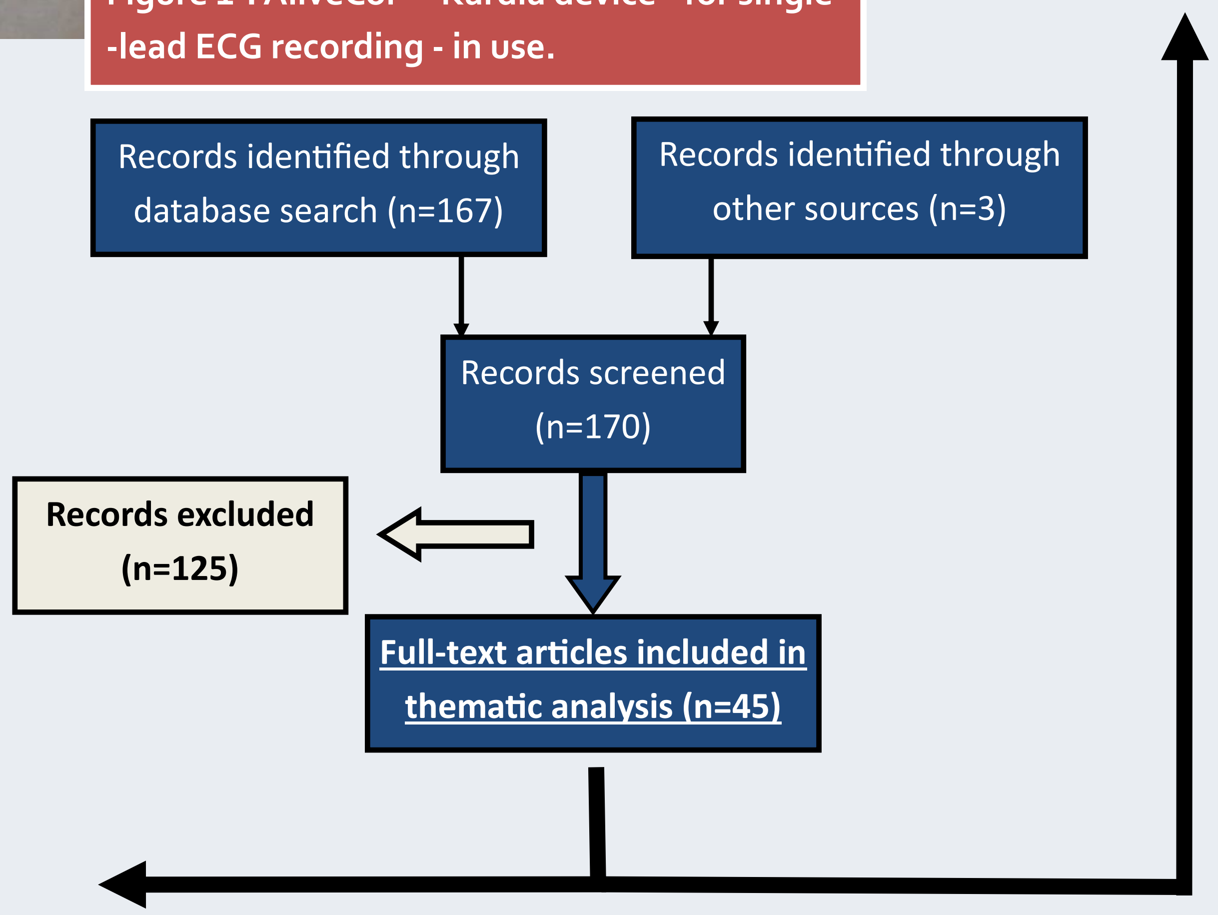
"The rate-limiting step in STEMI diagnosis is the availability and performance of a 12-lead ECG"[5]

'Time is muscle' when it comes to Acute Coronary Syndrome: the ischaemic window is the principal factor affecting mortality/morbidity and prognosis. Earlier diagnosis and treatment is vital to improve outcomes; in recent years great strides have been made in reducing in-hospital 'door-to-balloon' time, but time-to-admission and time-to-treatment, particularly in LMICs, remain prolonged.

Extending the availability of ECG services, via tele/iECG in the pre-hospital setting, e.g. community health centres, is one method proposed to **accelerate diagnosis of STEMI.** It is hoped that in the process, improved access may also help to remove barriers to early identification of MI, such as the **fear of false alarm**, or misattribution of symptoms (particularly in areas where health literacy is low). Table 2 summarises the results of the studies identified in my literature search that evaluate the effectiveness and/or validity of iECG in STEMI: without exception thus far, the results demonstrate significant benefit, and warrant further investigation with higher-powered trials.

Study	Study Type	Intervention	Sample Size	Results
Chauhan et al. (Kangra, HP, India)[6]	Pilot study	Primary health physicians with tele-ECG support in rural community health centres, vs standard care	157 (intervention) ; 177 (control)	Median **time-to-aspirin time decreased significantly**: 0.7±1.45h (intervention) vs 3.5±10h (control), p<0.0001.
Studencan et al. (Prešov, Slovakia)[7]	Retrospective	'STEMI' app enabling remote EMS-cardiologist ECG consultation, vs no consultation	178 (intervention) ; 67 (reference)	Significant **reduction in total ischaemic interval** (241 min vs 181 min, p=0.03)
Chao et al. (Taipei, Taiwan)[8]	Retrospective	'Line' app for smartphone transmission of ECG images to interventional cardiologist vs. traditional phone communication alone.	44 (intervention) ; 40 (reference)	**Time from initial ECG interpretation to cardiac catheterisation reduced** from **28.3±4.1mins** (control) **to 17.6±2.3mins** (intervention)
Muhlestein et al.—ST LEUIS Pilot (Utah, USA)[9]	Pilot study	Simultaneous 12-lead smartphone (AliveCor™ Kardia) vs standard ECGs	6	iECG had **excellent correlation with 12-lead** in all patients.
Barbagelata et al.—ST LEUIS Study[5]	Cross-sectional study	As above	300	Expected mid 2019.

Table 2: Studies evaluating the effects of iECG in Acute Coronary Syndrome/STEMI.



AF Detection

A recent UK study[2] utilising the Kardia app as a portable event recorder in 240 patients visiting A&E with palpitations showed that it increased the number of patients with a diagnosis over five-fold**, reducing** the **mean time-to-diagnosis** by over **70%**, and reducing the **cost-per-diagnosis** from **£1395 to £474**. Early detection of AF, the most common cardiac arrhythmia, followed by treatment with oral anticoagulants, has been shown to significantly reduce the risk of stroke, which is known to pose a disproportionately high burden to LMICs.

Whereas the benefits of population screening for AF remain under considerable debate, with several large-scale trials are currently underway, leveraging the use of iECG technology to overcome resource limitations has made **screening, epidemiological studies, and clinical care in LMICs more feasible** than ever before. Soni et al[3], in the SMART-INDIA trial, illustrated this by issuing village health workers with the Kardia device, enabling over 2000 villagers to be screened in the community, which revealed a higher prevalence of AF in India than previously thought. Similar screens in Hong Kong[4], with over 11,000 participants, have, however, highlighted the need for technical improvements to enhance cost-efficiency, and a more structured downstream treatment pathway.

Summary

- **Smartphone-based ECGs have the potential to be of significant benefit when appropriately incorporated into healthcare settings, reducing expense, time, and need for travel.**
- Already in LMICs such as Vietnam and Senegal, **new, low-cost iECG devices** (e.g. MD-Link, D-Heart) are being developed and trialled with specific challenges in mind, such as low-bandwidth image transfer in areas where mobile signal is poor.
- A crucial step before our adoption of these novel technologies will be their **validation relative to the gold standard 12-lead ECG** in different clinical scenarios.
- To this end, **further, higher powered studies with consistent outcome measures are needed**.

References

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