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Wearable cardiac monitoring: where are we now and where are we going?

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Take Home Messages

- Advances in non-invasive heart rate & rhythm monitoring are progressing faster than we can validate new technologies
- Devices differ in duration of monitoring and type of data provided: from continuous heart rate data to 30-second 'event' six-lead ECG traces
- Leadless alternatives to traditional Holter monitors are preferred by patients but most are not currently available on the NHS due to lack of validity and cost-effectiveness data
- Interpreting data from patients' self-initiated cardiac monitoring is a challenge and is likely to constitute an increasing proportion of our cardiology workload over the coming decades
- Other challenges for the future include: liability and data protection, exacerbation of health anxiety and health inequality

Introduction

Non-invasive ambulant cardiac monitoring is on the rise (1). There is now a dizzying (pardon the metaphor!) array of products that allow patients to monitor their heart rate and electrocardiogram (ECG), often without needing to consult a clinician. Many patients (or should we call them 'consumers'?), opt to do so, even in the absence of symptoms or cardiovascular abnormality. Few of the newer wearable technologies are currently funded on the NHS, but patients bring their self-funded gadgets' data to our clinics. As cardiologists we need to know: what are the different products capable of? How can we use these newer devices and their data in our practice? And what are the future challenges we face in this new world of patient-initiated cardiac monitoring?

About the author

Olivia Clayton studied undergraduate medicine at The University of Birmingham (MBChB) then went on to do Foundation Training in North East Yorkshire. Migrating even further north she worked as a teaching fellow in general internal medicine in Newcastle Upon Tyne before ultimately entering cardiology speciality training in the Severn Deanery. She currently works as a cardiology ST5 in Musgrove Park Hospital Taunton and is interested in pacing, MRI and heart failure.

What are the different products capable of?

Table 1 briefly summarises the extensive array of non-invasive heart rate or ECG monitoring products available at time of writing.

Photoplethysmography (PPG)

Photoplethysmography has been around since the 1930s (2) and is the technology used in hospital pulse oximetry ('sats') probes. It uses a light source and photodetector to detect changes in light absorption that occur with pulse (3). It's relatively cheap and most commonly available in wrist-based devices. Bradyarrhythmias, tachyarrhythmias and heart rate variability can all be determined. In addition, beat-to-beat analysis has the potential to detect possible atrial fibrillation (AF) with over 90% sensitivity when combined with artificial intelligence algorithms (4-6). Of note however, PPG traces are not diagnostic without formal ECG data (+/- clinician input). False positive 'alerts' (commonly due to artefact, poor quality traces in cold peripheries) particularly on non-ECG capable devices run the risk of increasing our workload and patients' health anxiety.

Surface electrocardiogram (ECG)

Electrode-embedded wearable or small portable devices offer leadless ECG traces recorded either 'on demand' or continuously, broadening the diagnostic capabilities compared to PPG alone (7). Newer generation smart watches with ECG

Table 1. Summary of non-invasive heart rate and ECG monitoring devices available

Type	Device examples	Est. cost*	Duration	Type of data	How it works
Heart rate monitoring only	Standard digital BP machine Finger probe pulse oximeter Most smart phone cameras	£ £ £££+	Single	Pulse rate	PPG
	Smart watches (most) Wrist heart rate monitor Other (e.g. ear buds, ring, chest strap)	£££+ ££+ £££+	Continuous	Pulse rate & heart rate variability	PPG
Single or two-lead ECG	Newer generation smart watches e.g. Samsung, Withings, Apple, Huawei, FitBit, Garmin + others	££££	Continuous heart rate monitoring + Event monitor (30 seconds)	Pulse rate, heart rate variability & single-lead ECG (usually lead I)	PPG & ECG One electrode on back of watch and a second electrode on the side or front of watch for contralateral finger
	Some chest straps Textiles	££+	Continuous (part day while worn)	Single or two-lead ECG (chest leads)	ECG Electrodes directly against chest wall
≥ Three-lead ECG	Standard Holter Monitor	££+ (but recyclable)	Continuous (4h - 3 days)	Three-lead ECG (or up to 12-lead for shorter durations)	ECG
	Adhesive patch e.g. Zio XT, ECG On-Demand	££+	Continuous (up to 14 days per patch)	Three-lead ECG (chest leads)	ECG Electrodes directly against chest wall
	Portable hand-held device e.g. AliveCor KardiaMobile	££	Event monitor (30 seconds - 5 minutes)	Three- or six-lead ECG (limb leads)	ECG Placed on knee with two thumbs on front provides 3 electrodes

**£ <50, ££ 50-150, £££ 150-250, ££££ 250+ (estimated costs from November 2022)*

ECG = electrocardiogram; PPG = photoplethysmography.

monitoring capability are fast becoming fashionable amongst health-conscious consumers. Other single-function technologies exist; adhesive patches are unsurprisingly proving better tolerated than traditional Holters (8), providing longer duration monitoring options spanning weeks rather than days, and portable 'event monitor' devices offer on-demand ECG traces; perfect for intermittently symptomatic (but conscious!) patients.

How can we use newer devices in our practice?

"My smart watch told me my heart rate was 150 while I was just sat still!"

PPG in commercially available heart rate monitors has been shown to correlate closely with heart rate on an ECG, even in running athletes (9), so it's best to assume that abnormal PPG readings are valid rather than dismiss them as artefact.

Validity of leadless ECGs and smart device arrhythmia-detection algorithms are not as well-established, but are looking promising, as detailed in a comprehensive summary published earlier this year by Xinarakou *et al.* (7). Consider how many and which leads have been provided when determining how much information can be gleaned from your patients' data.

In an asymptomatic patient with the presentation above and a non-ECG-capable device, a non-invasive, leadless portable cardiac event monitor would appear preferable to an implantable loop recorder or arbitrary-duration standard Holter monitor. However, NHS funding is not yet widely available in the UK for most of these newer technologies as validity and cost-effectiveness data is still lacking.

What is currently NICE-approved?

The Zio XT® Patch is now approved "for people needing longer than 24 hours ECG monitoring", with the caveat that organisations gather data on long-term clinical consequences (10). This follows a randomised controlled trial (RCT) that found a significantly higher paroxysmal AF diagnostic yield post stroke using 14-day patch compared to 'short-duration' Holter monitoring (16.3% vs 2.1%, OR 8.9, n = 90) (11); an effect which may of course be due to duration of monitoring alone, but is still relevant.

Use of the AliveCor KardiaMobile® 6L device is currently being evaluated for QTc monitoring in psychiatry patients (12), but has not been approved for other indications.

Future Challenges

A data tsunami accompanies the uptake in consumer-purchased cardiac monitoring products. Physiologist and physician workload is a concern, particularly with high false positives and 'inconclusive' arrhythmia algorithm reports, where formal medical advice is then encouraged (7). Heart rate 'alerts' from PPG devices may propagate health anxiety, even in those with no cardiac pathology, paradoxically increasing cardiovascular risk.

We can expect an increase in true arrhythmia detection in asymptomatic patients, not all of which will be clinically relevant. The European Society of Cardiology recommends opportunistic screening for AF in all patients ≥65 years of age" (13), however, in the STROKESTOP trial, AF screening in over fourteen thousand 75- and 76-year-olds demonstrated only a marginal reduction in the primary combined endpoint of stroke, systemic embolism, major bleeding and all-cause death over a 5-year follow-up period (HR 0.96, 95% CI 0.92 – 1.00). Similarly, the LOOP trial used implantable loop recorders (ILR) to screen 6205 individuals for AF and found no significant reduction in the risk of stroke or systemic arterial embolism in the ILR group despite increased incidence of AF (14). The true clinical rationale for AF screening and anticoagulation in low-risk patients therefore remains controversial, as does the duration of AF deemed to be significant.

Liability is also an issue. Who ensures the data is analysed and interpreted correctly? How is personal data safely stored and protected? Who is responsible if a diagnosis is missed? The company who made the device and developed the arrhythmia algorithm software? Or the physician being inundated with referrals from the worried well?

Digital health as an entity fuels the growing gap in health inequality, with e-commerce making the more expensive PPG- & ECG- capable products (e.g. new generation smart watches) widely researchable and available, but to the wealthy and educated only.

Conclusions

Non-invasive cardiac monitoring with PPG or ECG is a rapidly developing area with new devices appearing faster than we can validate their accuracy for clinical use. Monitoring options other than the traditional cumbersome Holter monitoring or invasive implantable loop recorder are welcome and some early validity studies on adhesive patches, portable cardiac event monitors and smart watch technology are promising. Smart watch and home heart rate monitoring trends bring a wealth of challenges for the future.

Disclosures

None

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