1. **Introduction**

Diagnosing atrial fibrillation (AF) involves detection of the typical AF rhythm pattern using an electrocardiogram (ECG). Opportunistic screening for untreated AF is recommended in people aged >65 years by pulse taking or ECG rhythm strip [1]. Recurrent or extended ECG monitoring can improve detection of AF, but this is not always practical given the time inconvenience and associated costs. Photoplethysmography (PPG)-based smart devices may provide an opportunity for large-scale screening of AF by maximising convenience and minimising costs and time. An overview of the current available evidence regarding the accuracy and feasibility of using PPG-based smart devices for AF detection will be described in this editorial; although it is not a comprehensive review.

AF is the most common sustained arrhythmia and is a major cause of stroke and cardiovascular morbidity and mortality globally, but people with AF are often asymptomatic and remain undiagnosed. Oral anticoagulants (OACs) can prevent strokes related to AF [2]. Furthermore, an integrated approach to AF management using the AF Better Care (ABC) pathway can be applied to improve outcomes for people with AF by: A) Avoiding stroke with Anticoagulants; B) Better symptom management with a patient-centred approach to rhythm- or rate-control; and C) Cardiovascular or co-morbidity management [3]. Data to support the use of OACs in preventing stroke in patients with asymptomatic AF are lacking but use of OACs is recommended in all AF patients unless they are at low-risk for stroke based on the CHA2DS2VASc score [1]. AF burden ≥5.5 hours on any day in the most recent 30 days is associated with an approximate doubling of the risk of a thromboembolic event compared with no AF burden [4]. Early detection of AF is critical to monitor patients with AF and implement patient-centred interventions to reduce risk of stroke and improve outcomes; therefore, innovative approaches to improve screening and detection of AF are of high interest.

1. **Expert commentary**

Photoplethysmography (PPG) involves optically measuring changes in tissue blood volume through the skin. PPG-based technologies detect the typical AF rhythm by monitoring heart rhythm intervals. This is different to ECG which measures electrophysiological events during cardiovascular contractions. Usually, to detect AF with ECG, significant clinical time and expertise is required to interpret and analyse the results. Initial screening with PPG-based smart devices linked with automated complex algorithms, which detect suspected AF have the potential to reduce clinical input and time. However, it is still unclear which features of the signal produced using PPG-based technologies should be utilised to develop algorithms for detection of AF. A recent study developed an algorithm for detection of AF with up to 97.2% sensitivity and 99.6% specificity but noted increased demands for signal quality were required to achieve this [5].

The majority of smart watches and activity trackers measure heart rate with PPG technology, and as such, there are potential benefits of widespread adoption, with easily accessible and user-friendly technology to screen for AF. However, there must first be a clear understanding of the diagnostic sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of PPG-based smart devices compared to ECG. The negative predictive value is important as a false negative result may falsely assure people they do not have AF, while a false positive result (positive predictive value) could cause unnecessary concern for the individual. Timely confirmation of the AF diagnosis with an ECG is required following screening for AF, therefore ECG should be considered complementary to PPG-monitoring [6].

The predictive ability of PPG-based smart devices is associated with the PPG algorithm, smart devices (the quality of PPG signals in ‘real-world’ setting, the battery life of smart devices, measurement method: active or periodic measurement), and AF burden (monitoring time). Validated studies on PPG-based smart devices are important to clarify an optimal approach to detect AF before using smart devices in clinical practice.

Recent studies examining PPG-based smart devices to detect AF have involved the use of smart wristbands/watches linked to a smartphone application [7], or the use of smartphone cameras [8]. The time people are monitored using smart devices to detect AF has varied in studies from a few minutes [7-9] to 14 days [10]. Studies have included patients from different settings including hospitals [7,9,11,12], primary care [8] or all adults who own a particular device [10]. The comparators used in studies have included single-lead ECG devices [7], 3-lead ECG [12], and 12-lead ECG screening [8,9]. Single-lead hand-held ECG devices are recommended for mass AF screening by the European Heart Rhythm Association so this is a relevant comparator, but ideally studies should compare results to extended ECG-based diagnosis, which is needed for confirmation of AF. Furthermore, the detection rate of single-lead hand-held ECG devices is affected by the length of the recording period, whether repeated recordings are performed and co-morbidities of the patients [6].

The Huawei Heart Study [10] and Apple Heart Study [13] have monitored over 187,000 people aged 18 years and older and 419,000 people aged 22 years and older, respectively, for suspected AF using PPG signals via smart watches. The mean age of participants was relatively low in both the Huawei (35 years) and Apple (41 years) studies, therefore the detection rates of suspected AF in both studies were also low (<1% in both studies). The Huawei study used 14-day monitoring and 0.23% of participants had suspected AF. Of participants with suspected AF, 62% were followed-up and compared to clinical evaluation, ECG or 24-hour Holter and the PPG signals had a positive predictive value of 0.92 [10]. The Apple Heart Study monitored participants for a median of 117 days and 0.52% of participants received notification of an irregular pulse; 21% returned an ECG patch and the positive predictive value for the PPG signals was 0.84. In both studies, due to the cohort size and feasibility of following-up such large populations, people without suspected AF were not followed-up; therefore, the negative predictive value could not be calculated. Targeting people with risk factors for AF or stroke is likely to be a better approach, as a higher prevalence of AF will be detected. Limiting screening to older adults and/or those with co-morbidities is likely to be a more cost-effective approach, but the minimum age to begin screening is currently unclear. Furthermore, a higher risk of developing AF has been shown for male endurance athletes, but the applicability of AF screening for this population is unknown [14].

1. **Key Issues**

The results of studies examining PPG-based smart devices to detect AF are promising. However, results are difficult to compare due to heterogeneity between studies. Few studies have compared PPG-based devices against the gold standard comparator of 12-lead ECG or Holter ECG. Studies have noted issues with the use of PPG-based smart devices including recordings being uninterpretable due to inadequate signal [7]. Other issues include potential influences of extrasystoles and premature ectopic beats, ventricular arrhythmia, interference caused by blood pressure changes and fluctuations in vascular elasticity, reduced PPG penetration in subjects with higher skin pigmentation, or poorer signal in patients with tremor [7,8,12]. Furthermore, adherence may be an issue in home-based monitoring, and the characteristics of the population, such as co-morbidities, should be considered when determining the appropriateness of PPG-based smart devices as a screening tool for AF (Figure 1). Further research is needed to determine the feasibility and acceptability of older people using wearable technology for AF detection and determine if conditions such as frailty or cognitive impairment may be barriers to the use of wearable technology. Finally, it is important to explore how to combine a PPG-screening approach with integrated AF care to reduce adverse events following detection of AF. Several screening studies have not demonstrated that AF screening would reduce adverse events even though the diagnosis and detection of AF improved with smart devices [15].

1. **Conclusions**

The accuracy of PPG-based devices shown in available studies for detection of AF and the availability of smart-based devices should encourage further research. There is a need to focus on addressing the challenge of improving signal quality and algorithms to detect AF, so PPG-based smart devices could be a viable option for population level screening. Further research is needed to determine the applicability of PPG-based devices to detect AF in different populations considering factors such as age and co-morbidities. As AF is more likely in older adults and those with certain comorbidities, future studies targeting approaches for screening AF in older and/or comorbid populations are likely to generate a more cost-effective approach. The majority of studies to date have included hospital-based populations and therefore future studies using PPG-based smart devices should focus on ambulatory community-dwelling older people and those with comorbidities which increase the risk of AF and/or stroke. Screening using PPG technology has the potential to increase detection of people with asymptomatic AF. Further research is needed to determine the accuracy of PPG-technology for AF detection, the efficacy of OACs to prevent strokes for asymptomatic AF patients detected by PPG-screening and the feasibility and acceptability of using wearable technologies to screen for AF in the older population.

DECLARATIONS OF INTEREST

GYHL: Consultant for Bayer/Janssen, BMS/Pfizer, Medtronic, Boehringer Ingelheim, Novartis, Verseon and Daiichi-Sankyo. Speaker for Bayer, BMS/Pfizer, Medtronic, Boehringer Ingelheim, and Daiichi-Sankyo. No fees are directly received personally. DAL has received investigator-initiated educational grants from Bristol-Myers Squibb (BMS) and Boehringer Ingelheim; has been a speaker for Boehringer Ingelheim, Bayer, and BMS/Pfizer; and has consulted for BMS, Bayer, Boehringer Ingelheim, and Daiichi-Sankyo. GYHL, DAL and YG are co-authors for the Huawei Heart Study. SLH: None declared.

Figure 1. Considerations for developing population-based screening for atrial fibrillation using photoplethysmographic (PPG)-based smart devices.

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