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# Smart-watching the heart: Ready now or a way to go?

Improved management strategies have resulted in substantial reduction of early mortality in patients with congenital heart diseases. However, adult-onset arrhythmias remain a significant problem and account for significant morbidity and mortality [1]. Increased arrhythmia vulnerability is multifactorial and includes structural malformation inherent to disease conditions, structural and electrophysiological remodeling from surgical procedures, and hemodynamic stress. Incidence of arrhythmia is particularly high in patients with moderate and severely complex diseases [1]. Arrhythmias in adult congenital heart disease (ACHD) are associated with sudden death, progression of heart failure, and thromboembolic complications [1,2]. Early diagnosis and appropriate management of arrhythmias may reduce morbidity and mortality in the ACHD population [3].

Although arrhythmias are easily diagnosed on electrocardiograms (ECG), documentation of arrhythmias on routine ECGs is frequently difficult due to the paroxysmal nature of arrhythmias. Long-term ECG monitoring is required to capture arrhythmias. Despite the availability of various long-term ECG monitoring systems, a significant number of paroxysmal arrhythmias remain undetected. The advent of Smartwatches with photoplethysmography (PPG) technology allow recording of ECG for long-term assessment of heart rate and rhythm as “wearable monitors”. The current Apple-watch-based automated algorithms are limited to diagnosing only atrial fibrillation [4]. However, the captured ECG (iECG) also provides an opportunity for analysis by a physician [4]. Typically, a Smartwatch from the conventional wrist position can capture a single-lead ECG (Einthoven's lead I) and be able to diagnose only atrial fibrillation (AF) and bundle branch block [4,5]. However, recording from unconventional positions is reported to provide the opportunity for superior analysis of cardiac depolarization and repolarization and, allows identification of ECG changes beyond AF [6]. In the healthy populations with structurally normal hearts, three-lead ECG recording (Einthoven I, II, and III) using an Apple Watch Series 4 was comparable to the standard corresponding leads from 12-lead ECG [6]. However, the ACHD population represents a different subset due to the abnormal activation pattern of the heart from abnormal anatomy.

In this issue of the *Indian Pacing and Electrophysiology Journal*, Striepe et al. evaluated the accuracy of three lead iECG recordings with the Apple Watch 4.1 (WatchOS 5.2.1) in adult patients with congenital heart disease [7]. Conventional three-lead ECG recordings were compared with AppleWatch derived iECG recordings collected by alternative positioning of the Smartwatch. These recordings were analyzed by two experienced cardiologists, blinded to the patient clinical data, before comparison of the results. The automatic rhythm analysis reported was also compared to physician findings. More than half of the cohort in this prospective analysis consisted of moderate to complex congenital heart disease. The authors demonstrated a moderate to strong correlation between iECGs and conventional ECGs for heart rate, PR interval, QRS duration, QRS amplitude, and QT interval. However, both P wave duration and amplitude demonstrated a weak correlation. The weakest correlation of both P wave duration and amplitude was noted in lead I. Due to the longitudinal relationship between the P wave axis and the axis of lead I, this lead is not ideal for detecting P waves. Among three leads, Einthoven like lead III showed the strongest relationship for the P wave. However, iECG could not be evaluated in this lead in a significant number of patients (11%, $n = 12$). Although the iECG parameters were not influenced by situs, heart anatomy or body habitus, obesity and abdominal circumference were the major reason of inability to perform the iECG, especially for lead III.

The study indicates that capturing a multichannel ECG by Smartwatch during symptoms is practically feasible in the majority of the ACHD population studied with appropriate patient training beforehand. This may be helpful in immediately recording the cardiac rhythm in multiple leads. Unfortunately, the ability for the automatic rhythm analysis to detect atrial fibrillation and paced rhythms was inadequate in this study (though underpowered for this). Only one of three patients with AF were correctly identified by the Smartwatch, the other two were classified as *sinus rhythm* and *not classifiable* respectively. This suggests that Smartwatch algorithms have a way to go to be useful for screening arrhythmia in an asymptomatic population, perhaps with better training and development in this patient group, these artificial intelligence algorithms could be improved. Additionally, the mean heart rate during the recordings were 72 bpm (conventional ECG) and 78 bpm (iECG). It is, therefore, challenging to extrapolate the accuracy of findings to higher heart rates where the efficacy of PPG recordings are known to be inferior [8]. More concerning for the ACHD population is the poor P wave correlation between iECG and conventional 12 lead ECG. Unlike the general population where AF is the most common abnormal arrhythmia, reentrant or focal atrial tachycardias are most common in patients with moderate to severe complex ACHD population [1,2]. Due to extensive structural remodeling of reentrant arrhythmia circuit, the tachycardia rate is often slower compared to the general population and identification of abnormal P wave morphology plays a crucial role in diagnosing atrial arrhythmias. The inability to differentiate an abnormal P wave from sinus P wave may hinder the appropriate diagnosis being made, regardless of how well trained the algorithms are. Atrial tachyarrhythmias with variable AV block may also be incorrectly diagnosed as AF due to the same issue.

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Importantly, this study demonstrates the feasibility of a novel method of documenting arrhythmia in the ACHD population. The introduction of additional precordial lead positions has been reported to increase the diagnostic yield of P wave abnormalities, and it may be that this is important in the patients with ACHD too [9]. Further studies will be needed, with extended lead position and improved recording techniques, which may further improve the accuracy of Smartwatch-based ECG monitoring in diagnosing arrhythmias in the ACHD population. Nevertheless, to establish the role of these technologies in routine clinical practice, a number of other considerations cannot be overlooked. The cost of devices remains prohibitive for most patients, alongside the ability to send data in an expedient and secure fashion. At the same time, clinicians will need support in introducing these technologies into the routine care of their patients and understanding what pitfalls may exist with Smartwatch PPG recordings [10]. While we are not there yet, Smartwatch-detected ECG monitoring could provide an opportunity for earlier treatment of arrhythmia in adult patients with congenital heart disease in the near future.

Finally, as noted earlier, the current study was essentially a study of SmartWatch capabilities in sinus rhythm. The commonest arrhythmia requiring intervention in patients with adult congenital heart disease is atrial flutter. It is challenging to diagnose atrial flutter even on 12 lead ECGs if alternate flutter waves overlap with QRS complexes. The diagnosis of arrhythmias on Smartwatch based systems currently seems to depend on fast or irregular ventricular rates and diagnosis of atrial flutter with slow/controlled ventricular rates will remain challenging with current algorithms unless additional sensors, leads or device positions are utilized.

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