Research Article

Wireless, Pocket-Sized ECG Monitor: A Potential Tool used in the Detection of Cardiovascular Disease

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Abstract

Recent technological advancements in medical/ healthcare and mobile computing have caught attention of researchers for remote health-monitoring systems. The application of mobile technology in health monitoring enables remote monitoring of people, which would help in (a) improving communication between healthcare professionals and patients and (b) providing timely action in case of emergency.

Smartphones have now become the integral part of people's lives and therefore these devices can integrate healthcare more seamlessly into everyday lives. The primary objective behind this innovation was to develop a reliable and efficient remote heart-monitoring system that would help healthcare professionals monitor their patients remotely. Also the users can make use of this technology in their routine lifestyle for cardiac care and get timely support anytime, anywhere in case of emergencies.

This paper presents information about accuracy of a smartphone ECG monitor, which is pocket-able, leadless, supporting up to 6 leads and has function remote-sharing functionality. The accuracy of measurement in terms of sensitivity and specificity is done in comparison with a typical traditional ECG machine. The possible need, usage and potential benefits of such a device from the point of view of the patients are analyzed via interviewing the people.

The proposed device is mechanized by a *Sanket* app running on compatible iOS and Android phones that connects wirelessly via Bluetooth technology to the device. Six-lead ECG can be measured anytime, anywhere and the reports can be easily downloaded and instantly shared with the healthcare professional for immediate clinical advice. The ECG reports are also saved in cloud for future reference. The device mainly consists of electronics such as sensors, comparators, filters and Bluetooth chip. In this study, the ECG variables, namely, heart rate, PR, QRSD, QT and QTc were monitored, displayed and saved in our system. The proposed device was field-tested to establish its accuracy and reliability. The test results showed that our device was able to measure the ECG variables with a high accuracy.

Keywords: Remote health monitoring, Smartphone, Leadless ECG monitor, Sanket app, iOS, Android devices, Heart Rate, PR, QRSD, QT and QTc, GE2000, Cardiovascular disease, STEMI, LBBB, RBBB, True positive, True negative, False positive, False negative, Specificity, Sensitivity.

Introduction

Globally, patient-monitoring devices are estimated to reach $22.174 billion by 2018 at a CAGR of 5.5% during the forecast period (2013-2018). Remote health monitoring is one of the fastest growing areas within the medical device industry. Statistics have shown that consumers are more inclined toward using smarter and friendlier medical devices for monitoring health parameters remotely. In case of chronic diseases, continuous remote monitoring can reduce untimely hospitalization frequency and duration and, therefore, help improve the quality of life of the patients. Statistics have revealed that India has the 3rd largest smartphone market in the world and advent of low-cost smartphones coupled with low mobile tariffs

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has empowered consumers to use mobile internet. Technology has enabled transmission of biomedical data to remote centers or to experts/ specialists for immediate analysis and interpretation. For example, physicians can make use of this data for immediate diagnosis and related treatment even before the onset of symptoms, thus ensuring advanced medical care. Also, patients can embrace this technological advancement to incorporate healthcare monitoring in their day-to-day activities. The minimum specification required for a device to fall under the category of remote monitoring is wireless, light-weight, specific sensors, body compatibility, battery consumption, and capability of real-time processing.

This paper describes the accuracy and efficiency of a low-cost, portable, wireless device namely *Sanket* 1.0 in assessing the baseline ECG intervals and detecting the onset of cardiovascular diseases as against the standard 12-lead ECG machine. The device is mechanized by a *Sanket* App that runs on all compatible Android and iOS devices.

Objective

In this study, we compared the 6-lead ECG captured by *Sanket* to the 12-lead ECG captured by GE2000 in clinic patients with cardiovascular diseases, and patients who showed symptoms of cardiovascular disease. The baseline ECG intervals were assessed for accuracy and efficiency. The accuracy of *Sanket* in detection of cardiovascular diseases as against the standard 12-lead ECG machine was hence established.

Methodology

This study was conducted for 1 week in Medanta Medicity Hospital at Gurgaon with 28 participants in total. Consent was obtained from all participants by signature on the consent form. They were educated about the objectives of the study and guidelines for using the data for publication purpose. The sample size consisted of patients who had some previous history of cardiovascular disease and patients with related symptoms of cardiovascular disease. 12-lead ECG was captured for all the 28 participants using a standard 12-lead ECG machine, namely, GE2000 by the standard procedure of using gel and placing electrodes at appropriate position on the body while the patient is lying horizontally (i.e. resting ECG).

Immediately, 6-lead ECG was captured using *Sanket* for all the participants. The *Sanket* device captured the signals just by touch and transmitted them over Bluetooth to the connected phone which had the app running. All the baseline ECG parameters, namely, HR, PR, QT, QTc, and QRSD were captured using both the standard 12-lead and 6-lead ECG. The accuracy and efficiency of the ECG variables from *Sanket* were measured by comparison of the respective data from the GE machine. The ECGs captured by *Sanket* were also analyzed and interpreted by automated algorithms built in the application.

ECG reports were analyzed for the presence of abnormal rhythm or beats. The cardiovascular diseases interpreted by 12-lead ECG machine were observed for visibility in the 6-lead ECG by *Sanket*.

Statistical Analysis

It was observed that in comparison with the standard 12-lead ECG machine GE 2000, *Sanket* was able to correlate the following cardiovascular diseases - left axis deviation, ectopic PVC beats, hyperkalemia, WPW, RBBB, right axis deviation, ischemia, left atrial hypertrophy, LBBB, first degree heart block, myocardial ischemia and STEMI. The ECG reports captured by *Sanket* correlated with cardiovascular diseases in 18 participants similar to standard 12-lead. Statistical analysis showed that 15 participants were true-positive (i.e., cardiovascular disease was detected on both the ECGs captured by 12-lead machine and *Sanket*).

Table 1.Sensitivity and Specificity of the ECGs obtained by Sanket

	Disease Present	Disease Absent	
A (True-positive)	15	3	B (False-positive)
C (False-negative)	3	7	D (True-negative)
Sensitivity	83.3		
Specificity	70		
Positive likelihood ratio (PLR)	277.8		
Negative likelihood ratio (NLR)	23.8		
Disease prevalence	64.3		
Positive predict value	83.3		
Negative predict value	70.0		

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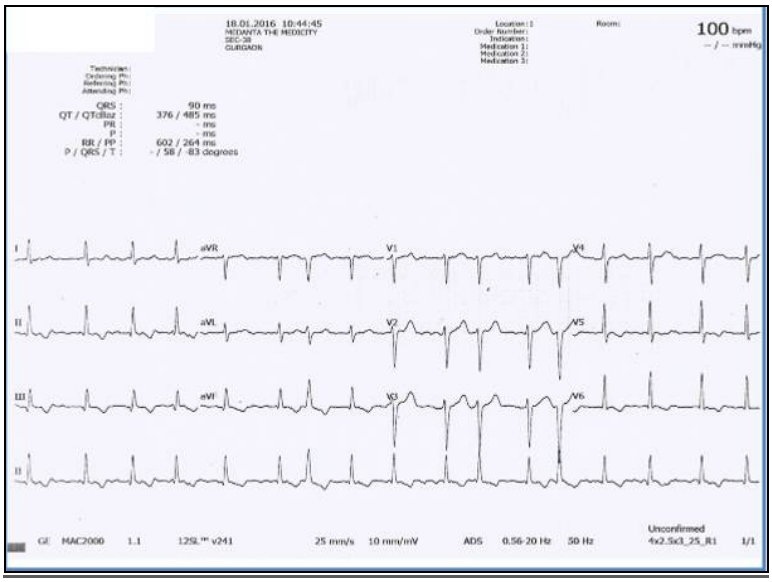
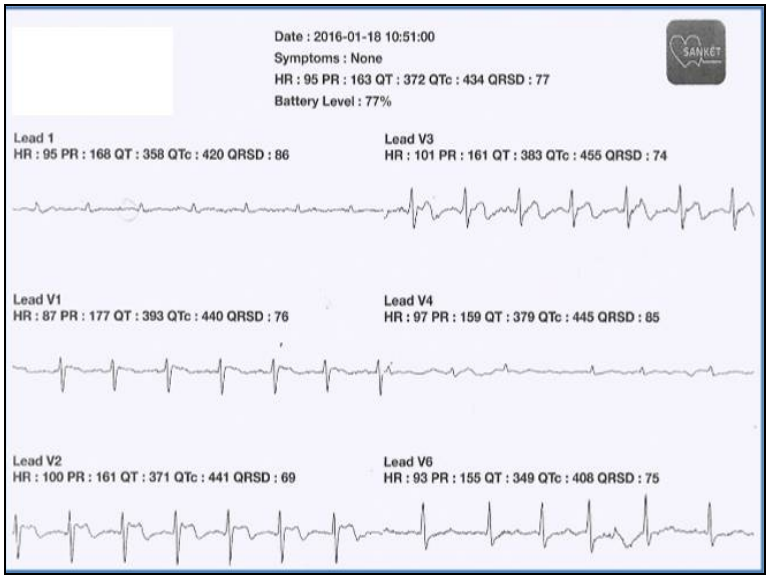
Three participants were false-positive (i.e., cardiovascular disease was detected on the ECG captured by *Sanket* and not by 12-lead machine). Three participants were false-negative (i.e., cardiovascular disease was detected on the ECG captured by 12-lead machine and not by *Sanket*. Seven participants were true-negative (i.e., cardiovascular disease was not detected in either of the ECG reports captured by 12-lead machine and *Sanket*.

Analysis of ECG Rhythms with Sanket and Standard 12-lead ECG Machine GE 2000 for Correlation of various Cardiovascular Diseases

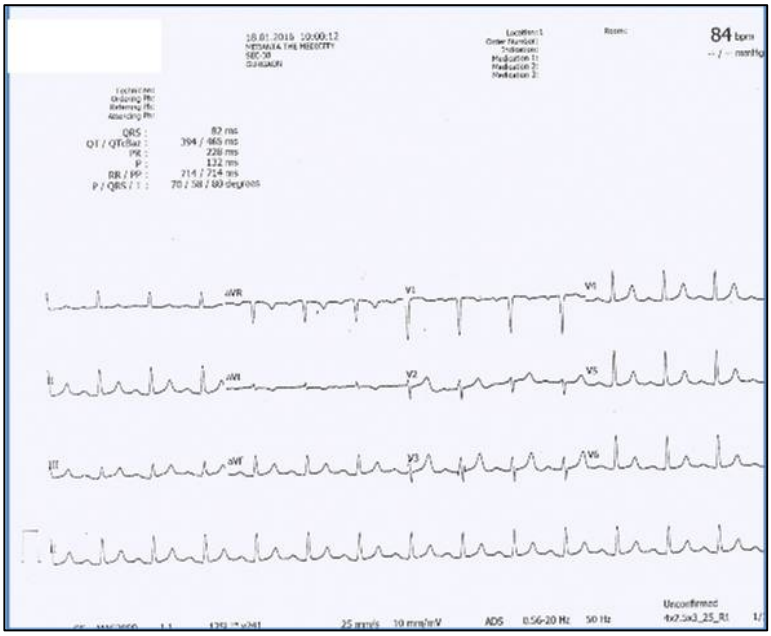


(a)



(b)

Figure 1(a) and (b).Disease Present: Myocardial Ischemia-Inverted T wave in V4-V6 (a=1, b=0, c=0, d=0)



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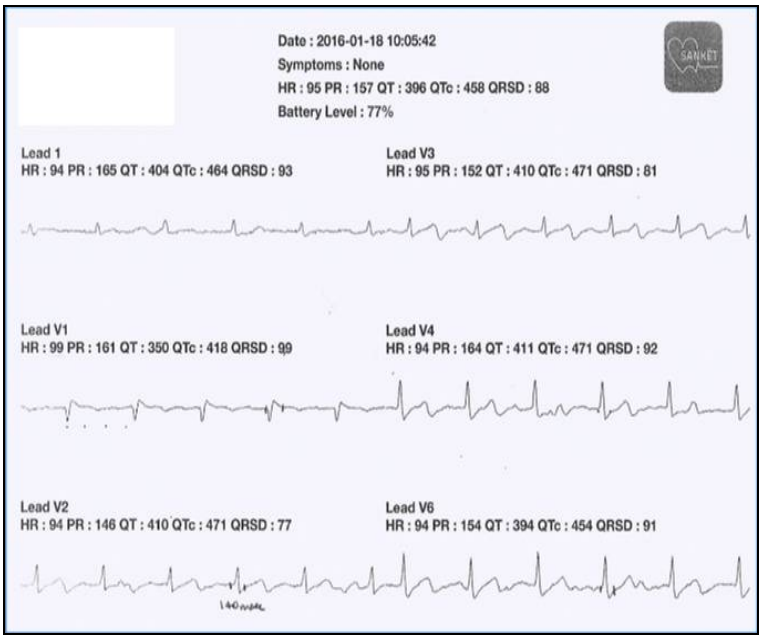
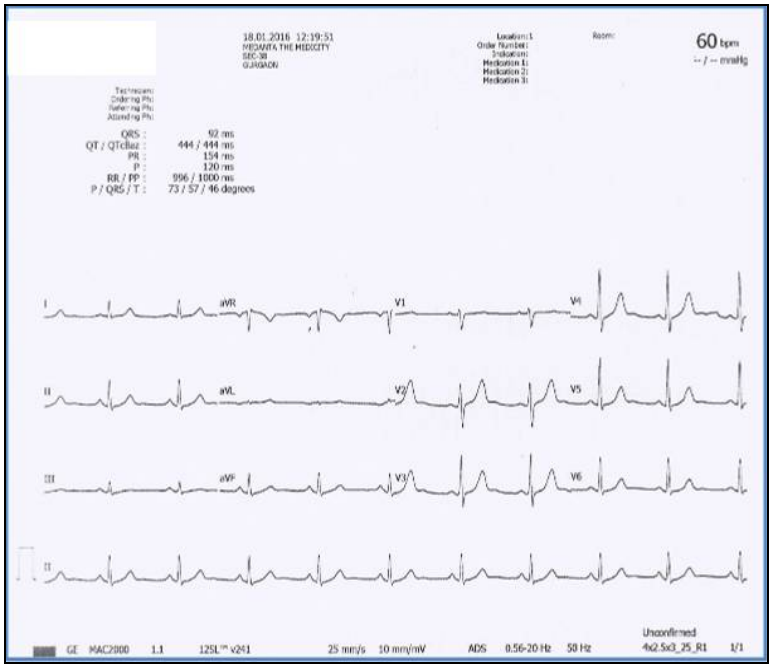


(b)

Figure 2(a) and (b).Disease Present: First degree heart block, High PR (a=0, b=1, c=0, d=0)



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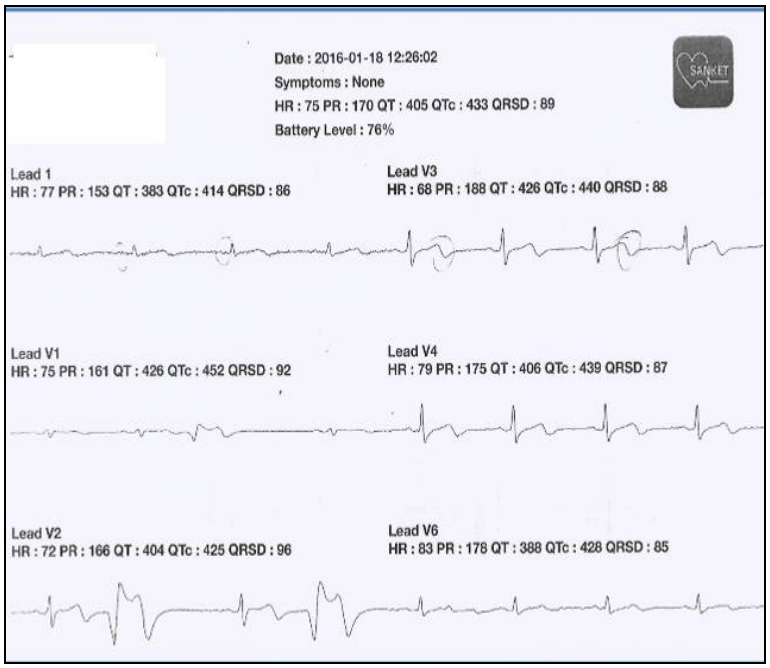
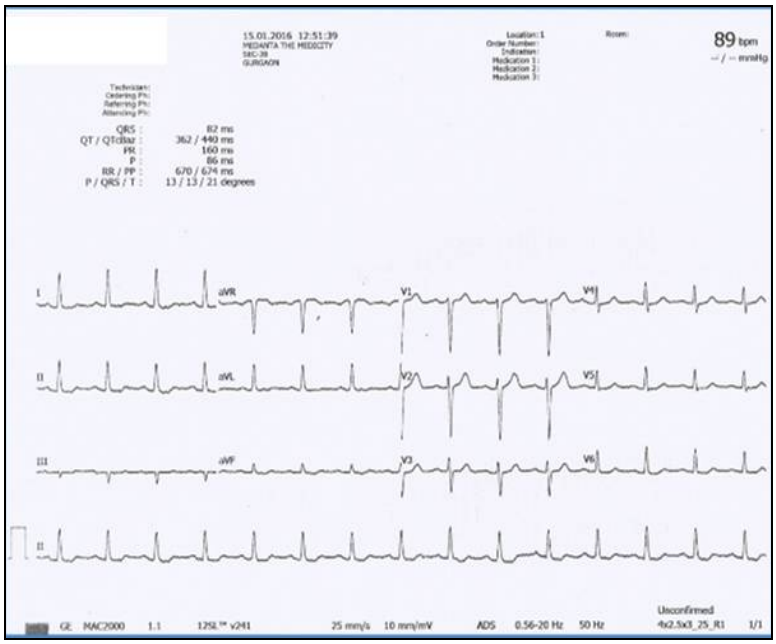
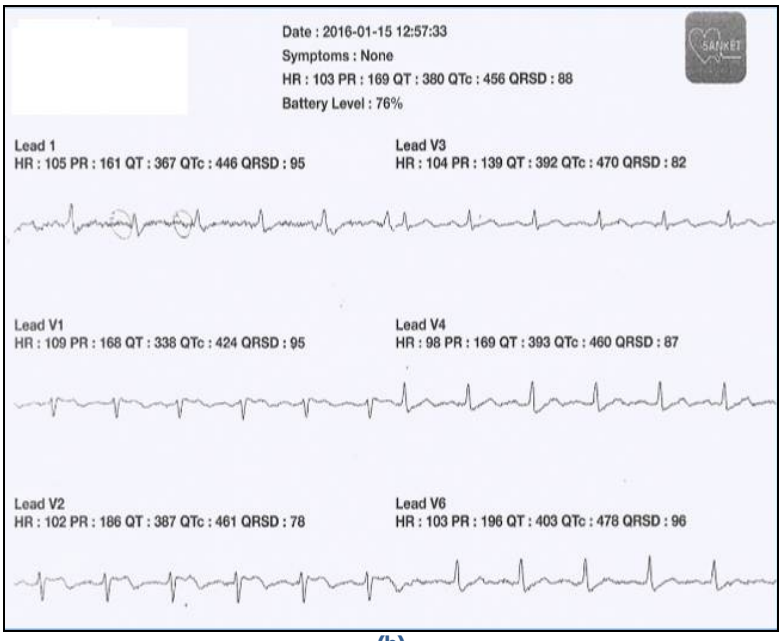


(b)

Figure 3(a) and (b).Disease Present: FALSE T wave inversion in V3, V4 (a=0, b=0, c=1, d=0)



(a)



(b)

Figure 4(a) and (b).Disease Present: NORMAL (a=0, b=0, c=0, d=1)

Results

From statistical analysis, sensitivity and specificity was summarized for detection of the specific major cardiovascular diseases. The overall sensitivity was found to be 83.3% and specificity was found to be 70%. The percentage of disease prevalence in the sample size of the above-mentioned study was found to be 64.3%.

Conclusion

The study was conducted in a random group of patients with previous history of cardiovascular disease and those who showed some related symptoms of cardiovascular disease. The ECGs obtained on *Sanket* were found to be almost similar in accuracy and efficiency as compared to the ECGs obtained from standard 12-lead machine. The device

could detect the abnormalities with a high degree of sensitivity and specificity.

Also, informal verbal discussion with patients involved in the study provided further insights about the user experience of the overall device and technology. When this device was used by the patients for measuring ECG, they found this method of capturing ECG to be more user-friendly and less cumbersome. The patients were amazed by the technology used in the device for measuring and monitoring ECG. They expressed their willingness to incorporate this device in their day-to-day remote health monitoring. All agreed on a common viewpoint that this device would prove to be a turning point in the remote heart monitoring for both healthy people and patients with some cardiovascular disease. The patients appreciated the ease of portability associated with the device. Specifically, subjects indicated that this device could serve as a very potential tool in monitoring and detecting abnormalities remotely. Simultaneously, they appreciated the fact that the associated technology would help them to communicate and share biomedical data instantly with their physicians for immediate interpretation and analysis. This would help to counter the emergency situations remotely minimizing health risks.

We hope that this report would add further dimension to the growing use of remote healthcare monitoring devices and help in improving general wellbeing of humanity.

Conflict of Interest: None

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