

# ST abnormality detection via. Smartphone-based ECG and its Validation with 12 Lead Gold Standards

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## Abstract

ST-segment related cardiac abnormalities are the leading cause of death in the world. With prominent involvement of ST-segment elevations in the chest and limb leads, the ST segment related abnormalities like ST depression and ST elevation can be calculated in the 12 lead Gold Standard ECG. Of these most widely occurring Myocardial Infarctions like Anterior Wall, Myocardial infarction can be detected in the chest Leads ECG test. From the perspective of being a point of care, the smartphone-based portable ECG machines are capable of detecting these Myocardial infarctions. Hence, in this study, the effort is imparted on evaluating the accuracy of these portable ECG technologies in compliance with the 12 lead gold standard. The evaluation for the 24 subjects taken in the cardiac care unit of the Fortis Hospitals in Dehradun. The study showed the negligible False Positives and near to 100% accuracy in diagnosing the Anterior Wall Myocardial Infarction using these 7 lead Single channel smartphone ECG.

**Keywords:-** Portable ECG, ST Abnormality, Anterior wall Myocardial Infarction, Spandan ECG Device

**Acronyms:** Cardiac Care Unit (CCU), Electrocardiography (ECG), Negative Predictive Value (NPV), Positive Predictive Value (PPV)

## Introduction

Studies have shown that ischaemic heart diseases are a prominent cause of death worldwide [1]. Among various cardiac abnormalities, Myocardial Infarction is the most prominent characteristic which interrupts the blood supply to the other parts of the body from the heart. The crucial part of prevention from this defect in the heart is early detection so that the effective treatment of myocardial infarction can be brought up without any severity and high mortality.

ECG plays an effective role in providing clinical findings at the primary care level. The ST-segment elevations are computed by the logical algorithms and manual diagnosis to classify the kind of Myocardial infarction present in the subject. Hence, ECGs have high diagnostic value in the Cardiac care units and Intensive care units. The smartphone-based portable ECGs are the new emerging technology which is penetrating in the healthcare markets for monitoring and diagnosing cardiac health. The algorithms are developed to analyze the ECG traces for Arrhythmia and other abnormalities and provide an overview of the cardiac health conditions. Hence, these devices are vastly accepted in the ambulances, home, and clinical physicians. The portability of these smartphone-based ECG devices is the most important feature that makes them acceptable for wide applications in the healthcare industry. The accuracy of these portable devices and their false-positive interpretations are the concerns that keep these smartphone-based devices still in suspicion to use in diagnosis. Hence, this study is focused on verifying the capabilities of a smartphone-based ECG in detecting the ST Elevation, Depression, and other associated abnormalities in respect to the 12 lead Gold Standard provided the intervention of cardiologist in the Cardiac Care Unit. Firstly, an investigation was done to diagnose the ECG of the subject suffering from severe chest pain. The tall T waves and High ST elevation were taken as the markers of the presence of the Anterior wall myocardial infarction. The Q waves were also analyzed for changes in 6 hours of onset denoting the significant myocardial necrosis.

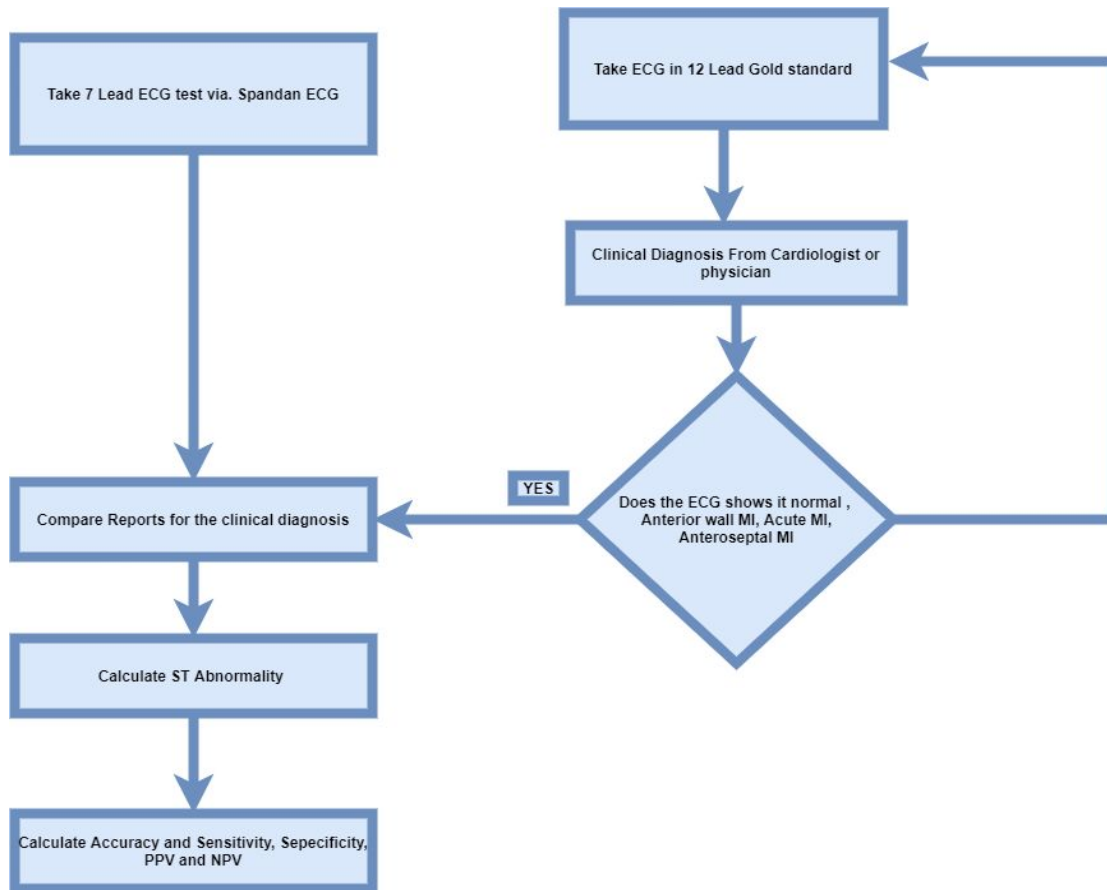
The localization of the ischemia in the chest and limb leads reveals the diagnosis of the patient according to the visualization of the ECG. Here are some of the MI related to the chest and limb leads detected according to its localization.

In acute anterior wall infarction, the ST elevation is usually present in V2 to V4. The presence of ST elevation in V2 to V6 may represent LAD occlusion proximal to the first diagonal branch. Whereas, the presence of ST elevation

in V4 to V6 without ST elevation in V1 to V3 usually is caused by LCX or distal diagonal occlusion. If the ST elevation is present in lead I and aVL, it signifies occlusion of the first diagonal branch (if associated with ST elevation in V2).

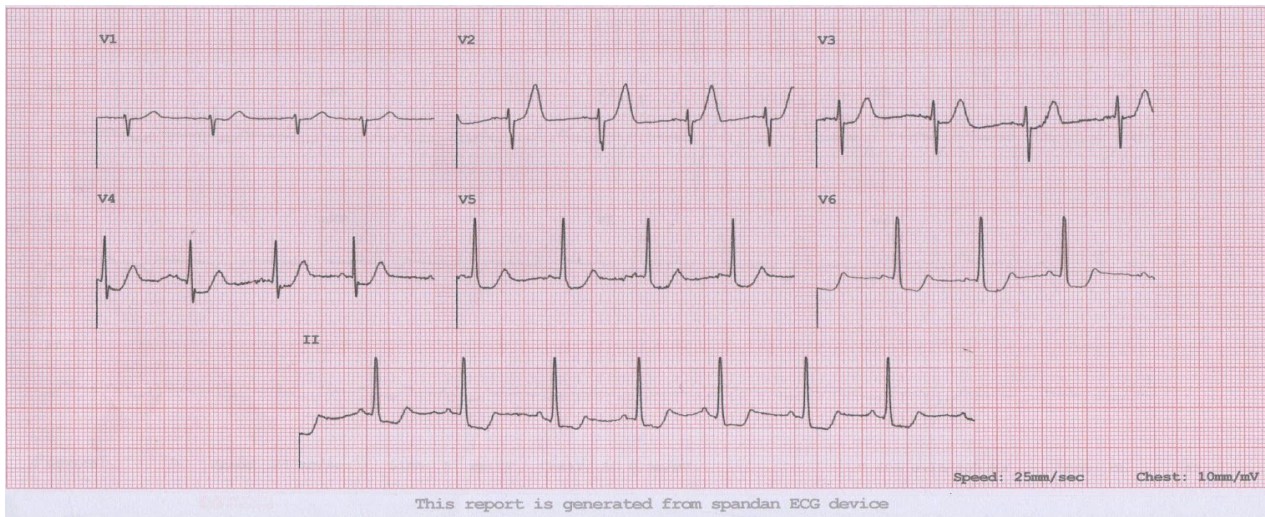
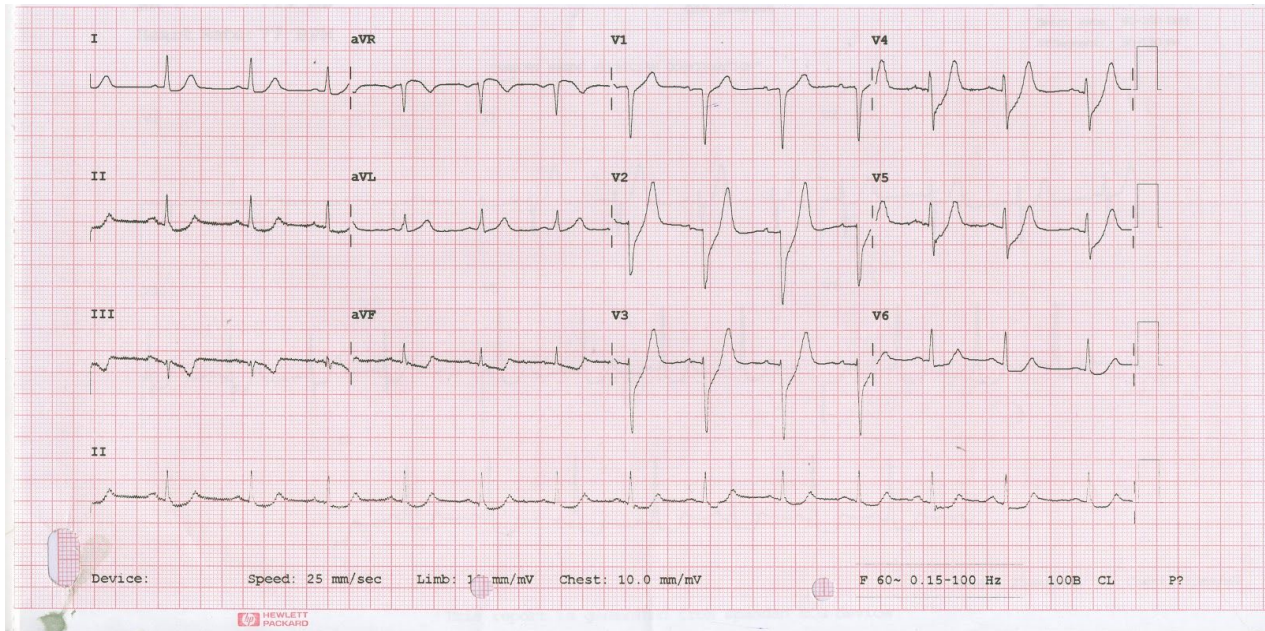
## Methodology

The clinical trials were taken under the supervision in the CCU of Fortis Hospitals Dehradun. These Supervised tests were controlled tests under the observance of a Cardiologist, to which the diagnosis was made in comparison to the 12 lead gold standard GEMAC2000 machine. A total of 24 test cases were taken with specific ST abnormalities of Anterior wall Myocardial Infarction. Figure 1. shows the methodology by which the clinical trials were analyzed, and conclusions have been drawn from the study. The finalization of the subjects to be diagnosed is done under the supervision of a cardiologist under the consideration of severity in the abnormality in the Cardiac Care Unit.



The cardiologists and investigators reviewed the final ECG reports of all patients who had undergone CCU at the institution between October 2019 and February 2020, we selected 24 patients with a listed diagnosis of an Anterior wall Myocardial infarction. ECG (or the first ECG during the admission available for review) was then obtained. These 24 ECG tracings were recorded and then reviewed by two investigators who were blinded to clinical data of the respective patients. The investigators evaluated the presence of ST-elevation of more or less than 0.1 mV in each of the chest leads (V1 to V6) and Lead II. All measurements of ST-segment deviation were measured 60 ms after the J point. For the purpose of this study, ST-segment elevation was defined as being in reference to the preceding TP segment. Using our hypotheses, we developed an algorithm for the prediction of the culprit lesion site. Figure 2 and Figure 3 show the example of one of the ECG traces taken by GEMAC 2000 12 lead Gold Standard machine and Spandan portable ECG respectively. The investigators were asked to identify the location of the culprit lesion causing the Anterior Wall MI. Investigators provided a review of the classification and localization of the cases

considered for the study. Later at the end of the Trials and calibration procedures, the data is evaluated on the basis of the confusion matrix. Specificity and Sensitivity of the smartphone ECG of the cases were considered to diagnose Anterior Wall MI with smartphone-based portable ECG devices.



## Results and Discussion

The trials for the ST elevation abnormality is conducted under the supervision of the cardiologist and investigators. The tests under the supervision of a cardiologist were taken in cardiac care units which consists of highly severe cases. The overall test for 24 subjects for abnormal and normal st elevations was taken care of. The chest lead of V1 to V6 and lead II are taken in the GEMAC 2000 12 lead gold standard and Spandan Portable ECG device.

The tests were conducted under the clinical consideration of taking consent from the patient to access personal data like Name, Age, and Height. The data were then compared on the basis of the classification done by cardiologist personally for both GEMAC 2000 and Spandan ECG device reports respectively.

The results were estimated in the perspective of the confusion matrix, the main objectives of the study were as follows

1. To Have the lowest minimum false negatives
2. To attain the lowest false positive in ST abnormality detection
3. To make sure that the Portable ECG devices are reliable in detecting the ST-Elevation related abnormalities.

<b>Subject name</b>	<b>12 Lead Gold Standard Detection</b>	<b>Spandan ST abnormality Detection</b>	<b>Interpretation</b>
<b>1</b>	Acute Ischemia St Depression V1, V5, V6 and Lead 2 (all 3 mm)	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>2</b>	The case where lead 3 is necessary	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>3</b>	The case where lead 3 is necessary	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>4</b>	Acute Anterior wall mi v2.v3, v4, & v5	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>5</b>	ST elevated V2, V3, V4	ST-elevation and Depression Abnormality	Severe ST Abnormality, Risk of heart failure. Consult your Cardiologist
<b>6</b>	Cannot Diagnose	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>7</b>	RBBB & Anteroseptal Ischemia/Infarction ECG	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>8</b>	Lead I, II and AVF Inferior wall MI- Acute Myocardial Infarction	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist

<b>9</b>	Anteroseptal mi (q wave is present but Spandan wave doesn't show q wave)	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>10</b>	Cannot Diagnose	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>11</b>	Cannot Diagnose	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>13</b>	CBV	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>14</b>	Cannot Diagnose	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>15</b>	Anterior Infarct St elevation V2, V3, V4, V5, V6 " ST" elevation	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>16</b>	V2, V3, V4 - "Anterior MI"	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>17</b>	V1,V2, V3, "ST" elevation	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>18</b>	ST elevated V2, V3, v4 Anterior wall MI	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>19</b>	Old Anterior wall MI	ST-elevation and Depression Abnormality	ST Abnormality. Consult your Physician, Cardiologist
<b>20</b>	ST-Elevation Abnormal V2-V5	ST-elevation Abnormality V2- V3	ST Abnormality. Consult your Physician, Cardiologist
<b>21</b>	ST-Elevation Abnormal V2-V3	ST elevation in v2-v3	ST Abnormality. Consult your Physician, Cardiologist
<b>22</b>	ST Abnormal in V1- V3	ST abnormal in v1 -v3	Abnormality in V1 to V3

23	ST abnormal in V1 to V3	Abnormal ST in V1 to V3	ST Abnormality. Consult your Physician, Cardiologist
24	ST Elevated in V2-V3	ST abnormal in V5, V6	Abnormality in V5, V6 and Lead 2

On the basis of the investigator's review, the detection of the true cases and false cases were classified in comparison to the 12 lead Gold Standard traces. The traces by Spandan portable ECG detected the ST-Elevation related abnormalities with 100% accuracy as shown in table 2. The sampling rate of 500Hz ECG satisfies the criteria for detecting fast electrical events within milliseconds.

Total cases	True Detection	False Detection
24	24	0

The positive and negative cases detected are classified as the cases with ST abnormality and cases with normal ECG as investigated by the cardiologist and review investigators. As seen in Table 3. There were 18 positive detection cases and 6 negative detections with Spandan ECG as compared to the 12 lead Gold Standard.

Total cases	Positive Detection	Negative Detection
24	18	6

Hence, as per the data evaluation by the Cardiologist and the investigators, the grouping of the cases was done for the confusion matrix as shown in table 4. The data shows there were 18 cases of True Positives (TP), 4 cases of True Negative (TN), and 2 cases of False Positives. As there were no False Negatives the Spandan portable ECG's possibility of detecting the Possible ST-Elevation related abnormalities are calculated in terms of the sensitivity, specificity, Positive Predictive Values (PPV) and Negative Predictive Values (NPV) respectively.

St abnormality detection in Spandan ECG/ 12 lead gold standard	True Results	False Results
Positive Detection	True Positive (18)	False Positives (2)
Negative Detection	True Negatives (4)	False Negatives (0)

The specificity of ST abnormality detection is given mathematically as:-

$$sensitivity = \frac{True\ Positive}{True\ Positive + false\ negative}$$

Hence ST abnormality detection via. Spandan is 100% sensitive in V1 toV6 and leads 2 or it can be observed that the Probability of detecting the abnormality in 7 leads from lead 2 in limb and v1 to v6 chest lead is 100%.

$$Specificity = \frac{True\ Negative}{True\ Negative +False\ Positive}$$



The specificity of Spandan’s ST detection algorithm stands 66%, it means that the probability of detecting a negative test when the defect is absent is 66%.

$$PPV = \frac{\text{True Positive}}{\text{True Positive} + \text{false Positive}}$$

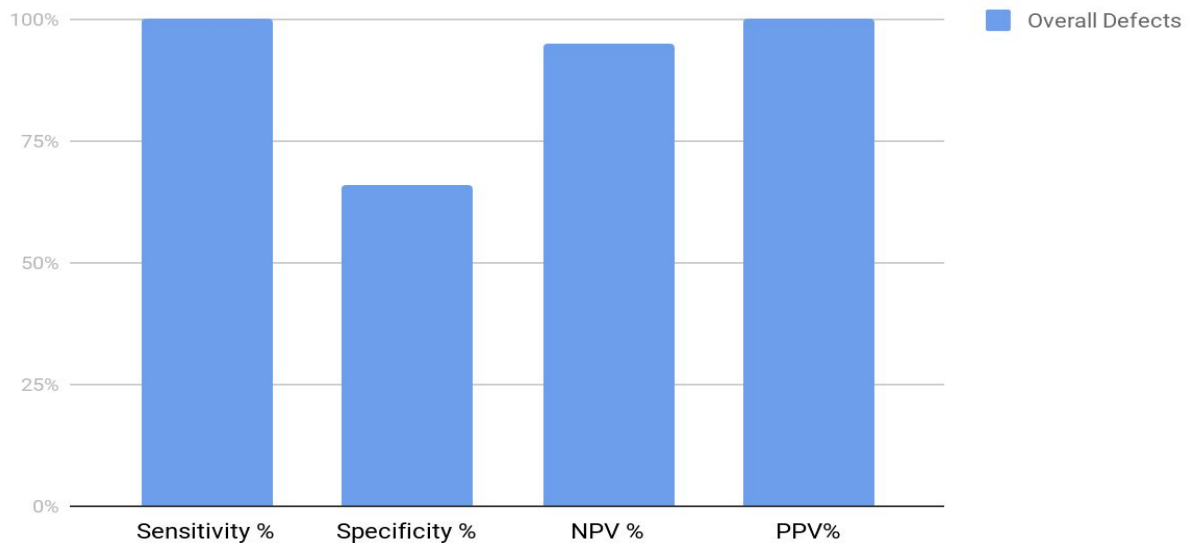
The obtained PPV for the cases of ST abnormality and related ischemia is 95%. Hence, the probability of the patients having the ST abnormality while the patient’s test is positive is 95%.

$$NPV = \frac{\text{True Negative}}{\text{True Negative} + \text{false Negative}}$$

The obtained NPV is 100%, which can be interpreted as the probability of not having any ST related abnormality in V1-V6 and Lead II when the patient tests negative.

Parameters	Overall Defects
Specificity %	66%
Sensitivity %	100%
NPV %	95%
PPV%	100%

### Accuracy of Spandan ECG V/s 12 lead Gold standard



### Conclusion

As per the study, the smartphone-based ECG showed promising results in CCU based tests. As the 12 lead gold standards are concordant to the 7 lead single-channel tests in detecting Acute MI, Anteroseptal MI, and Anterior

wall MI, there is a higher possibility if the Acute MI can be Detected in Lead III and augmented leads too using the smartphones. The Specificity and Sensitivity for large samples showed the variation of 5 % in trace accuracy but investigators were capable of detecting the abnormalities by eradicating the error due to loosened skin and Baseline Wandering. As per the data analyzed the future scope stands with analyzing the same parameters with large data samples of 1000 subjects. But the classification and availability of the cases in single clinical trials is where the complexity of the study stands. Cardiovascular disease is the leading cause of death and what matters in preventing it is regular and periodic monitoring of cardiac health and pre-determination of the changes in the ECG parameters. Hence, Spandan portable ECG stands a viable source of information in confirming the parametric changes in patients suffering from cardiac problems using the smartphone.

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