Original Article

DOI: 10.7860/JCDR/2021/50365.15207

Internal Medicine Section

Can the 12-Lead Electrocardiogram Predict Myocardial Viability?

ARPUDH MICHAEL ANANDARAJ[1], LIJO VARGHESE[2], JESU KRUPA[3], BINITA RIYA CHACKO[4], APARNA IRODI[5], LEENA ROBINSON VIMALA[6], OOMMEN KATTUNILAM GEORGE[7]

ABSTRACT

Introduction: In patients with coronary artery disease and left ventricular dysfunction, the assessment of myocardial viability, prior to revascularisation has been shown to be of significant benefit. Most methods to assess myocardial viability such as Positron Emission Tomography (PET) and Cardiac MRI (CMR) are not readily available in resource constrained settings. The present study sought to determine if an easily available and inexpensive tool, such as the 12-lead surface Electrocardiogram (ECG) can be used as a screening tool to assess for myocardial viability. It is hypothesised that the R wave height as a marker of electrical activity would correlate with viability.

Aim: To determine if the surface ECG can be used to predict myocardial viability.

Materials and Methods: This retrospective study was conducted at the Christian Medical College and Hospital, Vellore, Tamil Nadu, India. Among all patients who had undergone CMR viability assessment as part of their routine care between February 2008 and October 2017, and analysis and preliminary write up was done between November 2017 and Decemeber 2018, 119 patients with previous anterior wall myocardial infarctions were identified. The 12-Lead ECGs of these patients were assessed for the height of R wave in lead V3 and sum of R wave heights in all precordial leads. Myocardial viability was assessed based on the extent of Late Gadolinium Enhancement (LGE) on CMR. Measures of diagnostic accuracy including sensitivity, specificity, predictive values and likelihood ratios were calculated.

Results: It was found that a R wave height of less than 3 mm in lead V3 was 90.3% sensitive for the detection of non viable myocardium. Similarly, when the sum of the R wave heights in all precordial leads was less than 28.5 mm, it was 93.2% sensitive for the detection of non viable myocardium.

Conclusion: In patients with previous anterior wall myocardial infarctions when the R wave height was less than 3 mm in lead V3, it was 90.3 % sensitive to identify those with non viable Left Anterior Descending artery (LAD) territory. The 12-Lead ECG is therefore a sensitive, inexpensive and easily available screening test to assess for LAD territory non viability.

Keywords: Cardiac magnetic resonance, Cardiac viability, Electrocardiography, Ischaemic heart disease, Magnetic resonance imaging, R wave height

INTRODUCTION

Ischaemic heart disease is the number one cause of death in adults, in low and middle-income countries [1]. Ventricular dysfunction is an important consequence of coronary artery disease. This dysfunctional myocardium does not necessarily represent tissue that is irreversibly damaged [2-4]. Observational data demonstrates that revascularisation improves left ventricular function and has a benefit in those patients with demonstrable viable myocardium [5-9]. Hence, determining who is likely to benefit from revascularisation is of important clinical significance.

Methods of assessment of myocardial viability include stress echocardiography, radionuclide myocardial perfusion imaging, Positron Emission Tomography (PET), Myocardial Contrast Echocardiography (MCE) and Cardiac Magnetic Resonance Imaging (CMR) [1,10-12]. These investigations may not be readily available in resource constrained settings. Screening of patients for further investigation, by a relatively inexpensive and easily available test, may be resource effective in these settings. One such test may be the 12-lead surface Electrocardiogram (ECG).

Previous studies have shown that certain ECG parameters such as the height of R wave in lead V3 and sum of R wave in V1-V6 correlate with infarct size, in patients with previous anterior wall myocardial infarctions [13,14]. Author hypothesised that the R wave, as a marker of electrical activity, would correlate with myocardial viability. The objective of this study was to determine if either, R wave height in lead V3 or the sum of R wave heights in lead V1-V6 (in those with previous anterior wall myocardial infarctions) could be used to predict cardiac viability as assessed by CMR (in the territory of the LAD artery), thus serving as a simple bedside marker to screen for cardiac viability. To the best of the authors knowledge, this was the first study that has sought to predict myocardial viability with specific ECG parameters, using CMR as the gold standard of viability.

MATERIALS AND METHODS

In this retrospective study, all patients from the Christian Medical College and Hospital, Vellore, Tamil Nadu, India, who had undergone a CMR viability assessment between February 2008 and October 2017, were screened for a previous anterior wall myocardial infarction. The data analysis and preliminary write up was done between November 2017 and Decemeber 2018.

Inclusion and Exclusion criteria: In these 119 patients, clinical data was collected that included demographic details, coronary artery disease risk factor profiles, details of the Acute Coronary Syndrome (ACS) (anterior wall myocardial infarction), primary therapy for ACS, angiographic details, ECG, CMR and echocardiographic data. Those patients with incomplete data or other possible causes of low R wave height in precordial leads (such as left bundle branch block, dextrocardia, chronic obstructive pulmonary disease and Wolf-Parkinson-White syndrome) were excluded.

Study Procedure

CMR was performed using multiplanar cine Steady State Free Precision (SSFP) sequences and LGE, using phase sensitive inversion recovery method. Myocardial viability was assessed

based on the extent of LGE on CMR using a 17-segment model [15]. A myocardial segment with greater than 50% LGE (scar segments), for the purpose of this study, was considered non viable [15,16]. For prediction of global functional recovery-individual patients with less than four scar segments were considered to have global viable myocardium [17]. The primary ECG parameter of interest was the height of the R wave in lead V3. Summation of R wave heights in all precordial leads was also studied. The outcome assessors of the ECG and CMR data groups were independent and blinded to the results of the respective other group. Measures of diagnostic accuracy including sensitivity, specificity, predictive values and likelihood ratios were calculated.

STATISTICAL ANALYSIS

Summary statistical methods were used to describe all study variables. Comparison between two study groups (viable and non viable myocardium) was done using either independent two-sample t-test or Fisher's-exact test, as appropriate. A detailed analysis at various cut points of R wave height was used to arrive at threshold (for both height of the R wave in lead V3 and sum of R wave height in all precordial leads) in distinguishing between viable and non viable myocardium. All statistical analysis was performed using STATA V11 (Statacorp, College station, Texas, USA).

RESULTS

A total of 125 patients with prior anterior wall myocardial infarction were identified. Six patients were excluded due to incomplete data. The demographic characteristics of the remaining patients (n=119) are included in [Table/Fig-1]. The average age of these patients was 54 years. Fifteen of 119 (12.6%) patients were women. The mean duration between the index acute anterior wall myocardial infarction and the ECG was 3.01 years. Sixteen patents had viable and 103 patients had non viable myocardium as judged by CMR. The mean duration between ECG and CMR was 16.7 days. Of 119 patients, 32 underwent reperfusion therapy (26.9%). Three patients underwent primary PCI while 29 patients underwent thrombolysis. Coronary angiogram was done in 77 patients (this included both elective and primary) in which 43 patients had single, 22 had double and 12 had triple vessel coronary artery disease respectively. The mean ejection fraction in these patients was 39.9%. The baseline characteristics compared fairly evenly between the groups with viable and non viable myocardium {as assessed by Late Gadolinium Enhancement (LGE) on CMR}.

Variable	All patients	Patients with viable myocardium	Patients with non viable myocardium	p-value
Number of patients	119	16	103	
Age, (years)*	54.2 (10.1)	49.2 (13.8)	54.9 (9.5)	0.066
Gender				
Female**	15 (12.6)	2 (12.5)	13 (12.6)	0.989
Male**	104 (87.4)	14 (87.5)	90 (87.4)	
Diabetes**	51 (42.9)	4 (25)	47 (45.6)	0.139
Hypertension**	42 (35.3)	5 (31.3)	37 (36)	0.577
History of smoking**	51 (42.9)	6 (37.5)	45 (43.7)	0.651
Effort angina**	26 (21.8)	2 (12.5)	24 (23.3)	0.381
Exertional dyspnea**	51 (42.9)	2 (12.5)	49 (47.6)	0.008‡
Congestive heart failure**	10 (8.4)	0	10 (9.7)	0.213
NYHA class III/IV**	7 (5.8)	0	7 (6.8)	0.056
Aspirin**	92 (77.3)	14 (87.5)	78 (75.7)	0.275
B-blocker**	85 (71.4)	11 (68.8)	74 (71.8)	0.695
ACE-Inhibitor**	46 (38.7)	7 (43.8)	39 (37.9)	0.731
Statin**	94 (78.9)	11 (68.8)	83 (80.6)	0.118
Thrombolysis**	29 (24.3)	3 (18.8)	26 (25.2)	0.252
Primary PCI**	3 (2.5)	1 (6.3)	2 (1.9)	
Single vessel disease**	43 (36.1)	5 (31.3)	37 (36)	0.521
Double vessel disease**	22 (18.5)	5 (31.3)	17 (16.5)	
Triple vessel disease**	12 (10.1)	2 (12.5)	9 (8.7)	
LVEF‖	39.9 (6.69)	43.4 (4.43)	39.4 (6.82)	0.035‡
Wall motion score index†, ††	1.29 (1.17,1.41)	1.17 (1.05, 1.23)	1.35 (1.18, 1.47)	0.002‡
Number of scar segments†, ††	5 (4,6)	3 (2,3)	5 (5,6)	<0.001§

[Table/Fig-1]: Baseline Characteristics.
Values are reported as n (%),*Mean (Standard Deviation) for normally distributed variables and †Median (Interquartile range) for skewed variables.
The p-value is reported with; ‡for significant values; §for highly significant values. Significant p-value is <0.05
Either independent two-sample t-test (‖), Fisher's-exact test (**) or Mann-Whitney U test (††) were used as appropriate

R Wave Height Analysis

a) R wave height in lead V3

The R wave height of less than 3 mm in lead V3 was 90.3% sensitive for the detection of non viable myocardium. The specificity at the same cut-off point was 25%. The positive predictive value was 88.57%. The negative likelihood ratio was 0.39. The accuracy (probability that the patient is correctly classified) was 81.51%. When the cut-off point was increased to <6 mm the negative likelihood ratio decreased to 0.1 [Table/Fig-2] illustrates the graded change in likelihood ratio and sensitivity with the increase in the cut point).

b) Sum of R Wave Height in all Precordial Leads

When the sum of R wave height in all precordial leads was <28.5 mm, it was 93.2% sensitive for the detection of non viable myocardium with a specificity of 25%. The positive predictive value was 88.89% and the negative likelihood ratio was 0.27. The accuracy was 84.03%.

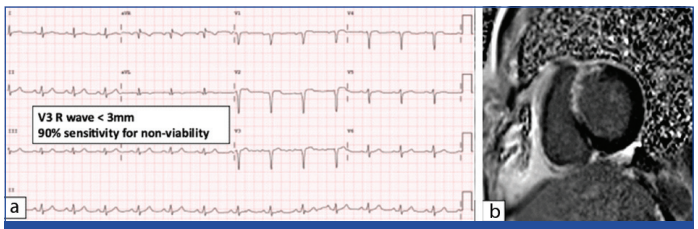
R wave height	<3 mm	<4 mm	<5 mm	<6 mm
Sensitivity	90.3	93.2	95.15	98.06
Negative likelihood ratio	0.39	0.27	0.26	0.1
Positive predictive value	88.57	88.89	88.29	88.60
Accuracy	81.51	84.03	84.87	87.39

[Table/Fig-2]: Detailed analysis at various cut points of R wave height in lead V3.

DISCUSSION

In this study, authors sought to determine if the height of the precordial R wave on the 12-lead surface ECG can be used to predict myocardial viability. In patients who had previously sustained an anterior wall myocardial infarction, the two parameters studied were: R wave height in lead V3 and the sum of R wave height in all precordial leads (i.e., lead V1-V6). Using an R wave height cut-off of less than 3 mm in lead V3 yielded 90.3% sensitivity for the detection of non viable myocardium with a negative likelihood ratio of 0.39 and an accuracy of 81.51%. Although there is a low specificity at this cut point, the high sensitivity makes this a valuable screening tool. In resource constrained settings- an inexpensive and easily interpretable tool is helpful. In view of the sensitivity of the 12-Lead ECG in detecting non viable myocardium, we could be reasonably certain (90%) that those patients judged non viable by ECG would indeed have non viable myocardium. Such patients thus

need not be subject to further expensive investigations [Table/Fig-3]. In view of the low specificity, the value of an R wave height greater than 3 mm in lead V3 is limited.



[Table/Fig-3]: a) ECG showing an anteroseptal MI with R wave height <3 mm; b) Cardiac MRI showing a scarred, non viable mid anteroseptum segment.

Similarly, the sum of precordial R wave heights, when less than 28.5 mm were 93.2% sensitive for the detection of non viable myocardium. With a likelihood ratio of 0.27 and an accuracy of 84%. In a resource constrained setting this information could be used to screen patients prior to subjecting them to expensive tests that are also not easily available- like the CMR.

Cost analysis: The present cost of a 12-Lead ECG is INR 295/- in this institution and the cost of a CMR is 44 times greater at INR 13,000/-. In the study population of 119 patients, the net cost incurred by subjecting all patients to a CMR would be INR 15, 47,000/- (USD - 21,674/-). In this same population, if screening is done by using the 12-lead ECG first, authors would have subjected only 14 patients to the CMR. This works out to just 14% of the cost incurred by subjecting all patients to a CMR upfront. The net saving (Including ECG for all patient) would have been INR 13,29,895 (USD - 18,632/-).

A previous study by Al-Mohammad A et al., found that q waves on ECG are specific but not sensitive to detect scarred myocardium assessed by PET scanning, the same study also found that Q waves that were followed by R waves were not more likely to be associated with hibernating myocardium than QS complexes [18]. However, there were only 16 patients who had R waves after Q waves in that study. Other studies that have sought to correlate resting ECG parameters with myocardial viability, have studied QT dispersion, and late potentials on signal averaged ECG. These studies found that patient with preserved myocardial viability had lower baseline QT dispersion and lesser frequency of late potentials [19,20].

Limitation(s)

The intrinsic limitations of a single centre retrospective observational study design apply to this study. The present study with a sample size of 119 patients is the largest study, to our knowledge, that has looked to relate ECG parameter with cardiac viability. Having said that, the total number of patients who had viable cardiac tissue, was small (16 out of the total of 119). Another limitation, which could have contributed to a selection bias, was that cases were chosen based on screening of CMR images, of those with LAD territory infarcts, hence patients with previous LAD territory infarcts without residual scar in LAD territory may have been missed. There may also be a potential for referral bias as the centre where the study was conducted is a tertiary referral centre.

The definition of global viability was based on previous CMR studies that reported better clinical outcomes in patients who had <4 scarred segments as opposed to those who had 4 or more [17]. It would be more accurate however to consider myocardial viability as a continuum and hence a volumetric analysis of scarred myocardium may have been more appropriate [21].

CONCLUSION(S)

In this study, that sought to associate R wave height on the 12-lead ECG to myocardial viability, as assessed by the CMR, in patients with previous anterior wall myocardial infarctions, it was found that, when the R wave height was less than 3 mm in lead V3, it was 90.3% sensitive to identify those with non viable LAD territory. The 12-lead ECG is therefore a sensitive, inexpensive and easily available screening test to assess for LAD territory non viability.

Acknowledgement

The authors would like to sincerely thanks to Dr. Prasanna Samuel, Dr. J Richard and Dr. Jayaprakash Muliyil for their statistical advice.

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PARTICULARS OF CONTRIBUTORS:
1. Associate Physician, Department of Cardiology, Christian Medical College and Hospital, Vellore, Tamil Nadu, India.
2. Professor and Senior Interventional Cardiologist, Department of Cardiology, KMCH Institute of Medical Sciences, Coimbatore, Tamil Nadu, India.
3. Assistant Professor, Department of Cardiology, Christian Medical College and Hospital, Vellore, Tamil Nadu, India.
4. Assistant Professor, Department of Cardiothoracic, Division of Medical Imaging, Sunnybrook Health Sciences Center, Toronto, Canada; Ex-Professor, Department of Radiology, CMC, Vellore, Tamil Nadu, India.
5. Professor, Department of Radiodiagnosis, Christian Medical College and Hospital, Vellore, Tamil Nadu, India.
6. Professor, Department of Radiodiagnosis, Christian Medical College and Hospital, Vellore, Tamil Nadu, India.
7. Professor, Department of Cardiology, Christian Medical College and Hospital, Vellore, Tamil Nadu, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Arpudh Michael Anandaraj,
Associate Physician, Department of Cardiology Christian Medical College and Hospital, Vellore-632004, Tamil Nadu, India.
E-mail: arpudh@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: May 17, 2021
- Manual Googling: Jun 06, 2021
- iThenticate Software: Jun 24, 2021 (7%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **May 16, 2021**
Date of Peer Review: **Jun 13, 2021**
Date of Acceptance: **Jul 07, 2021**
Date of Publishing: **Aug 01, 2021**