Detecting Right Ventricular Mi From A 12 Lead Ecg When Rv Leads Are Unavailable- A New Algorithm

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ABSTRACT

Coronary heart disease is the most common cardiovascular disease and the major cause of death in middle aged and older people. The presentation of acute myocardial infarction is different depending upon the coronary artery involved. In inferior wall MI the culprit vessel is either right coronary artery or left circumflex coronary artery which is usually confirmed with the help of percutaneous coronary angiogram. However, a 12 lead ECG is a rapid non-invasive tool that can predict the site of occlusion in the involved artery. Moreover, significant mortality has been observed in patients with inferior wall MI complicated with right ventricular and posterior wall MI. Early identification of the culprit artery in patients with symptoms of MI could reduce the time to reperfusion and permit a better risk stratification. Previously reported electrocardiographic (ECG) criteria to distinguish left circumflex (LCCA) and right coronary artery (RCA) occlusion in patients with acute inferior ST segment elevation myocardial infarction (STEMI) afford a modest diagnostic accuracy. This study aimed to develop a new algorithm overcoming limitations of previous studies. Clinical, ECG, and coronary angiographic data were analysed in 209 patients with acute inferior STEMI who underwent primary percutaneous coronary intervention.

KEYWORDS: Inferior wall myocardial infarction; Right ventricular myocardial infarction; Electrocardiography; Right coronary artery; Left circumflex coronary artery; Coronary angiography; ST-segment elevation myocardial infarction.

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INTRODUCTION

Acute myocardial infarction is one of the leading causes of death in the developed world. The prevalence of the disease approaches three million people worldwide. An MI results in irreversible damage to the heart muscle due to a lack of oxygen. An MI may lead to impairment in diastolic and systolic function and make the patient prone to arrhythmias. In addition, an MI can lead to a number of serious complications. The key is to re-perfuse the heart and restore blood flow. The earlier the treatments better the prognosis.

The location of acute myocardial infarction (MI) is an important prognostic factor for risk stratification of patients with ST-segment elevation MI (STEMI). Over the past two decades, several studies have investigated the involvement of myocardial infarction with right ventricle (RV) and its accompaniment with more complications and increased mortality in these patients. According to studies, 18 to 84% of the cases of MI are associated with right ventricular myocardial infarction (RVMI). The incidence of RVMI complicates the prognosis. The mortality rate of RVMI and MI is 25%-30%, while MI accounts for 6%. Patients with inferior MI who also have RV myocardial involvement are at increased risk of death, shock and arrhythmias. This increased risk is related to the presence of RV myocardial involvement itself rather than the extent of left ventricular (LV) myocardial damage. Ischemia and RVMI-related right ventricular dysfunction can be treated upon timely diagnosis. This illustrates the importance of quick and timely diagnosis of RVMI. Accurate and timely diagnosis of these patients is essential in order to improve their outcome.

Acute right ventricular myocardial infarction (RVMI) was first described in the literature in 1974 in a series of six patients. RVMI occurs in one-third to one-half of patients presenting with inferior myocardial infarction (MI), and it significantly contributes to the clinical and hemodynamic instability that these patients are presented with. Occasionally, RVMI can accompany anterior wall MI, and very rarely it can occur in isolation. Right ventricle (RV) involvement in the setting of inferior MI increases the in-hospital morbidity and mortality.

A 12-lead electrocardiogram (ECG) is a rapid, widely available, and non-invasive diagnostic tool that plays a central role in the early evaluation of patients presenting with acute myocardial infarction. In patients with inferior wall ST-segment elevation myocardial infarction, the ECG not only confirms the diagnosis but also provides valuable information regarding infarct location and possible right ventricular involvement. Early identification of the infarct-related artery using ECG findings is particularly important in emergency settings, where timely reperfusion therapy can significantly influence clinical outcomes and reduce morbidity and mortality.

Several electrocardiographic criteria have been proposed to differentiate right coronary artery (RCA) occlusion from left circumflex coronary artery (LCx) occlusion in patients with acute inferior ST-segment elevation myocardial infarction. However, previously reported criteria have shown variable and modest diagnostic accuracy, with inconsistent results across different studies and patient populations. Accurate ECG-based identification of the culprit artery remains challenging, particularly in the presence of right ventricular or posterior wall involvement. Therefore, there is a need for a more reliable and clinically applicable ECG-based algorithm to improve early localization of the infarct-related artery. The present study was undertaken to develop and evaluate a new electrocardiographic algorithm for predicting the culprit coronary artery in patients with acute inferior STEMI, using coronary angiography as the reference standard.

ELECTROCARDIOGRAPHIC EVALUATION IN INFERIOR STEMI

Electrocardiographic signs of right ventricular myocardial infarction (RVMI) provide valuable information for identifying right ventricular involvement and predicting the infarct-related artery in patients with inferior wall ST-segment elevation myocardial infarction. Disproportionate ST-segment elevation in lead III compared with lead II (lead III > lead II) is a useful marker of concomitant RVMI and can also predict proximal right coronary artery (RCA) occlusion. The relationship between ST elevation in lead III and lead II, defined as a ratio of elevation in lead III to lead II greater than one, is strongly suggestive of RVMI.

Precordial lead V1, which is located to the right of the sternum, routinely reflects right ventricular activity. In the setting of inferior wall STEMI, the presence of an r wave greater than the S wave (r > S) in lead V1 is highly suggestive of RVMI and is often associated with acute right ventricular dilatation. Patients with inferior wall STEMI and ST-segment elevation in lead V1 almost always have proximal RCA occlusion, and reciprocal ST-segment depression may be observed in leads V5 and V6. Similarly, an r > S pattern in lead aVR in inferior wall STEMI predicts a larger RCA infarction involving a posterolateral branch. Electrocardiographic relationships between inferior and precordial leads can further help localize the culprit coronary artery. Significant ST-segment elevation in lead III is indicative of RCA occlusion, whereas significant ST-segment depression in lead V3 suggests left circumflex coronary artery (LCx) involvement. In addition, left precordial ST-segment depression, defined as maximal ST-segment depression of ≥0.1 mV in at least one precordial lead, is associated with acute inferior wall myocardial infarction and advanced coronary artery disease.

CORONARY ANGIOGRAPHY

The gold standard diagnostic modality for RVMI is coronary angiography. In the majority of RVMI cases, the right coronary artery (RCA) is the culprit vessel in right-dominant systems when there is an occlusion proximal to the major right ventricular branches in the setting of inferior myocardial infarction. Occasionally, the left circumflex or left anterior descending artery can be the culprit for RVMI. The conus artery, which has a separate ostium from the RCA in approximately 30% of cases, supplies the infundibulum and partially explains the sparing of this region even in proximal RCA occlusions. Despite the initial functional abnormalities associated with RVMI, the ischemic right ventricle usually recovers its function in the long term, even in many patients who do not undergo revascularization.

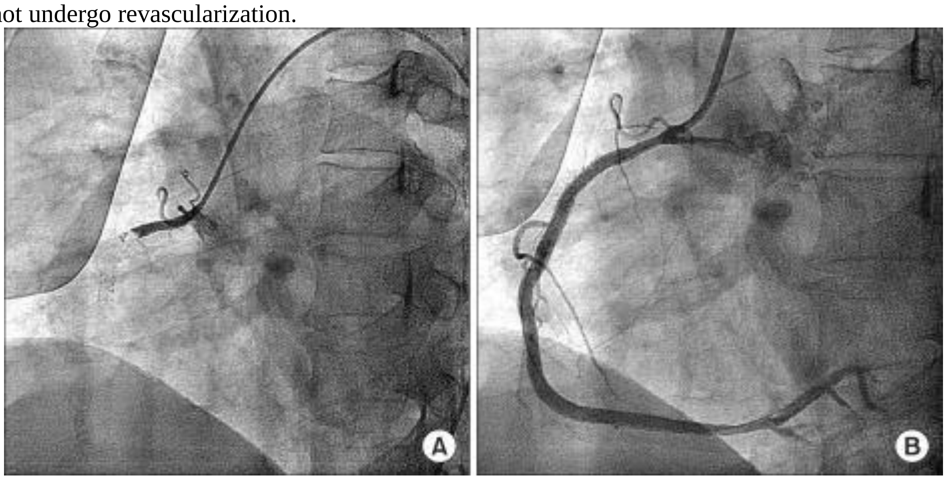

Figure 1: **Coronary angiography demonstrating right coronary artery involvement in inferior wall myocardial infarction. (A) Angiogram showing proximal right coronary artery occlusion in a right-dominant coronary system. (B) Angiogram after revascularization demonstrating restoration of coronary blood flow.**

REVIEW OF LITERATURE:

Right-sided precordial leads are critical to the evaluation of suspected RVMI. Using right sided precordial leads, ST-segment elevation in lead V4R ≥ 1.0 mm is diagnostic of RVMI, but in most cases extended lead ECG's are not available due to time consuming and lack of expertise in recording right precordial lead ECG. Hence this study was to develop a new algorithm from a 12 lead ECG to diagnose RVMI and to predict the site of occlusion.

Jan Kanowsky and Thomas Novotny [1] conducted a study to assess the RVMI electrocardiographic (ECG-RVMI) signs in relationship to ECG-based STEMI localization and to the infarct-related artery in patients treated with primary percutaneous coronary intervention. In all patients, both the standard 12-lead ECGs were recorded. ECG-RVMI was diagnosed by ST-segment elevation above 100 µV in lead III. No statistically significant differences were found in ECG-RVMI patients when comparing clinical variables between those with anterior and inferior wall STEMI. Martial Hamilton et al [2] conducted a study to examine the relationship between right ventricular involvement (RVI) in acute myocardial infarction (AMI) and the increase in mortality and morbidity. The study supports the view that early recognition of RVI, namely by means of electrocardiographic leads in acute myocardial infarction, may have prognostic value. J. W. Eikelboom et al [3] evaluated the prognostic impact of right ventricular (RV) myocardial involvement in patients with inferior myocardial infarction (MI). Six-month mortality was 7.8% in inferior MI compared with 13.2% in anterior MI. Among patients with inferior MI, serious arrhythmias were significantly more common in patients with RV myocardial involvement, who also showed a trend toward higher mortality, pump failure, and mechanical complications.

Xing Huang et al. [4] assessed the utilities of 11 traditional and 2 new criteria to devise a new ECG algorithm to localize the culprit artery in acute inferior STEMI. They analyzed electrocardiographic and angiographic findings of 54 consecutive patients with acute inferior STEMI to devise a new ECG algorithm. In the derivation cohort, the two new criteria, including (1) ST-segment depression in lead I equal to half of that in lead aVL and (2) equal ST-segment elevation in leads II, III, and aVF, did not prove useful. The most powerful electrocardiographic criteria were (1) the ratio of ST elevation in lead III to that in lead II, (2) the ratio of ST depression in lead I to that in lead aVL, and (3) ST changes in lead I; these formed a three-step algorithm. **Hao Liang et al.** [5] conducted an evidence-based evaluation and test accuracy comparison of several electrocardiographic (ECG) criteria in limb leads for identifying the culprit coronary artery (CCA) in patients with acute inferior wall myocardial infarction (IWMI). The study concluded that **ST-segment elevation in lead III greater than lead II (STE III > II)** performed better than other criteria for predicting the right coronary artery (RCA) as the CCA in IWMI, and that **STE III > II combined with ST-segment depression in aVL greater than lead I (STD aVL > I)** constituted potential and simple ECG-based algorithms. **Qun Li, De- Zhao Wang and Bu-Xing Chen [6]** investigated the diagnostic value of electrocardiographic ST-segment changes in acute inferior myocardial infarction (AIMI) caused by left circumflex artery (LCX) occlusion. A total of 240 AIMI patients who underwent percutaneous coronary intervention within 12 hours were retrospectively analysed. The right coronary artery was identified as the infarct-related artery in 177 patients, while LCX occlusion was present in 63 patients. ST-segment elevation in leads II, III, and aVF was observed in all cases. Significant differences between RCA and LCX groups were noted in ST-segment depression in lead I, ST-segment elevation in lead III, STE III–STE II, STD aVL, STD aVL–STD I, and ST-segment deviation in lead V6 ($P < 0.05$). These ECG changes effectively discriminated between LCX and RCA involvement with high sensitivity and specificity.

wona Cygankiewicz et al. [7] developed a sequential electrocardiographic algorithm based on ST-segment changes to identify the culprit artery (RCA vs. LCx) in infero-posterior myocardial infarction. ECG and angiographic data from 63 patients with inferior ST-elevation and single-vessel occlusion were analysed. The three-step algorithm included ST changes in lead I, the ratio of ST elevation in lead III to lead II, and the ratio of precordial ST depression to inferior ST elevation. This algorithm correctly predicted the infarct-related artery in over 95% of patients, with reduced accuracy only in cases of a highly dominant LCx.

Zhong-qun Zhan et al. [8] done a study to prove the prognosis of dominant left circumflex artery (LCx) occlusion–related inferior acute myocardial infarction (AMI) with early diagnosis from ECG. **One hundred thirty-five patients** with first dominant right coronary artery (RCA) or dominant LCx-related inferior AMI were included. The study concluded that **greater ST elevation in lead III than lead II, greater ST depression in aVL than lead I**, and an **S/R ratio greater than 1:3 in aVL** were **not useful** to discriminate between dominant RCA and dominant LCx occlusion–related inferior AMI. **Ikuo Misumi et al. [9] evaluated admission electrocardiography to differentiate left circumflex artery (LCx) and right coronary artery (RCA) occlusion in acute myocardial infarction. ECG findings were compared between patients with RCA occlusion (n = 60) and LCx occlusion (n = 60). ST-segment elevation in inferior or right precordial leads was more frequent in the RCA group, whereas ST elevation in leads V5 and V6 was more common in the LCx group. The mean ST elevation in lead III was higher than in lead II in the RCA group but not in the LCx group. ST elevation in lead III greater than lead II was observed in 78% of RCA cases compared to 44% of LCx cases ($p < 0.01$).**

H. Kataoka et al [10] conducted a study that acute right ventricular (RV) infarction is sometimes accompanied by precordial ST elevation which is also suggestive of left ventricular (LV) anterior wall infarction. Patients with RV infarction (n = 11) and LV anterior wall infarction (n = 42) presenting with precordial ST elevation were compared. The best electrocardiographic variable for identifying RV infarction was inferior lead ST elevation, followed by maximal precordial ST elevation in lead V1, ST elevation limited to only one precordial lead, and a cove-shaped pattern of RV conduction delay. The best electrocardiographic predictors for diagnosing LV anterior wall infarction were isoelectric or depressed ST segments in the inferior leads, precordial ST elevation equal to or greater than 5 mm, maximal ST elevation in lead V3 or V4, and ST elevation in the lateral leads. G Kabakci et al conducted [11] a study to investigate the predictive value of admission and 24-hour electrocardiograms in defining the infarct-related artery (IRA) and right ventricular involvement in acute inferior myocardial infarction. One hundred forty-nine patients with acute inferior MI were included. ST-segment elevation in lead III greater than lead II and ST-segment depression in lead I greater than lead aVL identified the right coronary artery as the IRA with a sensitivity of 64% and a specificity of 100%. Despite high specificity, the moderate sensitivity limited the diagnostic value of these criteria for right ventricular myocardial infarction.

Sérgio Bravo Baptista et al [12] conducted a study to evaluate electrocardiographic criteria for identifying the infarct-related artery in patients with inferior myocardial infarction treated by primary angioplasty. Fifty-three patients were included. Classical ECG criteria including ST depression in lead I, ST depression in leads V1 and V2, ST elevation in lead III greater than lead II, and ST depression in V3/ST elevation in III ratio greater than 1.2 were useful in identifying the infarct-related artery. ST depression in lead aVR demonstrated limited diagnostic utility, with a sensitivity of 33% and specificity of 71%, in differentiating between right coronary artery and left circumflex artery occlusion. Ioannis Styliadis et al [13] evaluated electrocardiographic criteria for identifying proximal right coronary artery obstruction in acute inferior ST-segment elevation myocardial infarction. Admission ECGs of 80 patients were analyzed using eleven established and three new criteria. The absence of ST-segment depression in lead V1 combined with ST-segment depression in lead V2 and an arithmetic sum of ST segments in leads III and V3 greater than 1 were useful in identifying proximal right coronary artery occlusion. ST depression in leads V1–V3 showed the highest specificity (77.2%) and positive predictive value (56.5%), while the ratio of ST elevation in lead V3 to lead III less than 0.5 demonstrated the highest sensitivity (80.9%) and negative predictive value (86.7%).

J. M. San José Garagarza et al. [14] evaluated the diagnostic value of the standard electrocardiogram in identifying the infarct-related coronary artery in inferior acute myocardial infarction. In a cohort of 100 consecutive patients, 67 had right coronary artery lesions and 33 had circumflex artery lesions. ST-segment changes in inferior, lateral, and precordial leads, along with ST-segment relationships between leads II and III and arithmetic sums incorporating lead V2, were analysed to differentiate the culprit artery. **Prieto-Solís [15]** conducted a prospective study evaluating inferior and V2 ST-segment deviations using arithmetic sums (II + V2, III + V2, and aVF + V2) in 66 patients with inferior acute myocardial infarction. Right coronary artery lesions were present in 46 patients and left circumflex artery lesions in 20 patients. The study concluded that the isolated magnitude of inferior ST-segment elevation was not an effective parameter for identifying the infarct-related artery.

R. Martín-Durán [16] analysed the value of the electrocardiogram in identifying the culprit coronary artery in acute inferior myocardial infarction. In 100 patients studied, 67 had right coronary artery lesions and 33 had circumflex artery lesions. A stepwise diagnostic approach using ST elevation in lead I, an arithmetic sum of ST magnitude in leads III + V2 < 0, and ST depression in lead V4R was proposed; however, the requirement for extended leads limited its routine applicability. **Gianaugusto Slavich et al. [17]** evaluated the accuracy of electrocardiographic criteria against coronary angiography in acute ST-elevation myocardial infarction. An ECG-based algorithm using ST-segment elevation and reciprocal depression correctly identified the culprit vessel in 87.5% of 343 patients. Sensitivity was highest for the left anterior descending artery (98.8%) and right coronary artery (93.7%), but lower for the left circumflex artery (31.7%), with specificities exceeding 87%. Proximal or distal lesion location was correctly identified in 62.4% of cases. **Hiroto Shiraki et al. [18]** examined the association between hypotensive shock and in-hospital outcomes in inferior acute myocardial infarction. Hypotensive shock occurred in 48.4% of patients, and right ventricular myocardial infarction was independently associated with post-admission hypotensive shock, regardless of left ventricular involvement, underscoring the importance of early identification of RVMI.

MATERIALS AND METHODOLOGY

This study is a prospective analytical study done in the emergency department (ED) at PRS HOSPITAL, Killipalam, Trivandrum, Kerala, from August 2018- November 2020. PRS hospital is a teaching institute which is a 300 bedded tertiary care hospital with a fully developed emergency room with 2 resuscitation bays, 24 bedded emergency department, decontamination area, with stat lab inside emergency area and radiological facilities, round the clock blood bank and intensive care unit having 35 beds in total. The emergency room and intensive care unit are being managed round the clock by residents and consultants qualified in Emergency and Critical care. After institutional Ethics Committee approval and informed written consent, 209 patients were selected for the study based on the inclusion and exclusion criteria. Patients coming to the ED with presentation of acute inferior wall ST elevation MI are diagnosed with the help of 12 lead electrocardiography, clinical evaluation and PCA; the findings are then tabulated in a preformulated proforma.

Selection of cases: The study included patients aged more than 18 years presenting with acute inferior wall myocardial infarction who had undergone percutaneous coronary angiography. Patients with previous myocardial infarction, pericardial disease, pacemaker implantation, left bundle branch block, and those who refused to participate were excluded from the study.

RESULT

***Baseline Demographic Characteristics*:** The study included 209 patients, with a predominance of males (74.2%). Most patients were aged between 61 and 70 years (36.8%), followed by those aged 51–60 years (29.2%).

Table 1: Baseline demographic characteristics of the study population (n = 209)

Variable	Category	Frequency	Percent
Age (years)	≤ 50	27	12.9
	51–60	61	29.2

Variable	Category	Frequency	Percent
	61–70	77	36.8
	≥ 71	44	21.1
Sex	Male	155	74.2
	Female	54	25.8

***In-hospital clinical features and complications*:** Most patients remained clinically stable during the hospital stay, with heart failure observed in a small proportion of cases (8.6%). Arrhythmias were uncommon overall, with complete heart block occurring more frequently than atrial fibrillation. The majority of patients did not experience additional complications; however, cardiogenic shock was the most frequently encountered adverse event among those who developed complications. Other events such as cerebrovascular accident, acute kidney injury, hypotension, tachyarrhythmia, and right ventricular thrombus were observed infrequently.

Table 2: In-hospital clinical features and complications (n = 209)

Clinical feature	Category	Frequency	Percent
Heart failure	No	191	91.4
	Yes	18	8.6
Arrhythmia	No	196	93.8
	Atrial fibrillation (AF)	5	2.4
	Complete heart block (CHB)	8	3.8
Other complications	None	187	89.5
	Atrial fibrillation	2	1.0
	Acute kidney injury (AKI)	2	1.0
	Cardiogenic shock	6	3.0
	Cerebrovascular accident (CVA)	4	1.9
	Hypotension	1	0.5
	Popliteal artery occlusion	1	0.5
	Right ventricular thrombus	1	0.5
	Tachyarrhythmia	2	1.0
	Urinary tract infection (UTI)	2	1.0
	Ventricular septal rupture	1	0.5

***Electrocardiographic findings*:** Analysis of ECG parameters demonstrated that ST-segment elevation in lead III greater than lead II was the most frequently observed finding, present in a large proportion of patients. Precordial ST-segment depression was also commonly noted, indicating widespread reciprocal changes. Among primary ECG features, r > S patterns were frequently observed in lead aVR and, to a lesser extent, in lead V1. The V3/III ratio further differentiated vessel involvement, with values below 1.2 being more commonly associated with right coronary artery patterns, while higher ratios suggested left circumflex artery involvement. Evaluation of inter-lead relationships revealed strong associations between lead V1 and other ECG parameters, particularly with lead III > II and precordial ST-segment depression. Similarly, lead III > II showed consistent associations with V1, aVR, V3/III ratio, and precordial ST-segment depression, highlighting the clustering of ECG changes in patients with inferior wall myocardial infarction.

Table 3: Electrocardiographic findings and inter-lead relationships (n = 209)

ECG parameter	Category / Relationship	Frequency	Percent
Primary ECG findings	V1 (r > S)	57	27.3
	aVR (r > S)	87	41.6
	III : II (> 1)	163	78.0
	V3/III ratio < 1.2 (RCA)	135	64.6
	V3/III ratio > 1.2 (LCx)	74	35.4
	ST depression in precordial leads (≥ 0.1 mV in ≥ 1 lead)	153	73.2
ECG lead relationship with V1	V1 – aVR	94	45.0

ECG parameter	Category / Relationship	Frequency	Percent
ECG lead relationship with III > II	V1 – III > II	176	84.2
	V1 – V3 / III	108	51.7
	V1 – ST precordial lead depression	162	77.5
	III > II – V1	176	84.2
	III > II – aVR	186	89.0
	III > II – V3 / III	196	93.8
	III > II – ST precordial lead depression	206	98.6

***Angiographic findings*:** Coronary angiography demonstrated predominant involvement of the right coronary artery, which was affected in nearly three-fourths of the study population (Table 4). Left circumflex artery involvement was also frequently observed, reflecting the contribution of multiple vessels in inferior wall myocardial infarction. In addition, involvement of other coronary vessels was noted in a subset of patients.

Table 4: Distribution of vessel involvement after angiography (n = 209)

Vessel involved	Frequency	Percent
Right coronary artery (RCA)	156	74.6
Left circumflex artery (LCx)	104	49.8
Other vessels	55	26.3

Correlation of electrocardiographic variables with angiographic findings: The association between electrocardiographic variables and angiographic findings was analyzed separately for right coronary artery (RCA) and left circumflex artery (LCx) involvement (Tables 5 and 6). Several ECG parameters demonstrated statistically significant associations with vessel-specific angiographic involvement.

The following table represents the association between specific electrocardiographic leads showing ST-segment changes and angiographic right coronary artery (RCA) involvement. Patients with angiographically confirmed RCA occlusion showed significant ECG changes predominantly in leads III > II, V1–III > II, aVR–III > II, and V3/III ratio with associated precordial ST-segment **depression**. In contrast, patients without RCA occlusion demonstrated significant ECG changes mainly involving **precordial ST-segment depression, III > II–V3/III, V1–V3/III, V1–ST precordial lead depression, aVR–V3/III,** and **V3–ST precordial lead depression.** The distribution of these ECG variables in relation to angiographic RCA status was found to be **statistically significant**, as shown in Table 5.

Table 5: Correlation of electrocardiographic variables with angiographic right coronary artery (RCA) involvement

ECG variable	RCA present n (%)	RCA absent n (%)	Total n (%)	χ^2	df	p value
V1	45 (28.8)	12 (22.6)	57 (27.3)	0.768	1	0.381
aVR	69 (44.2)	18 (34.0)	87 (41.6)	1.717	1	0.190
III > II	146 (93.6)	17 (32.1)	163 (78.0)	87.207	1	<0.001
V3 / III	118 (72.1)	53 (94.2)	171 (81.8)	58.100	1	0.003
ST precordial lead depression	103 (66.0)	50 (94.3)	153 (73.2)	16.168	1	<0.001
V1 – aVR	75 (48.1)	19 (35.8)	94 (45.0)	2.390	1	0.122
V1 – III > II	149 (95.5)	27 (50.9)	176 (84.2)	59.101	1	<0.001
V1 – V3 / III	63 (40.4)	45 (84.9)	108 (51.7)	31.400	1	<0.001
V1 – ST precordial lead depression	112 (71.8)	50 (94.3)	162 (77.5)	11.535	1	0.001
aVR – III > II	154 (98.7)	32 (60.4)	186 (89.0)	59.378	1	<0.001
aVR – V3 / III	76 (48.7)	45 (84.9)	121 (57.9)	21.252	1	<0.001
aVR – ST precordial lead depression	120 (76.9)	51 (96.2)	171 (81.8)	9.909	1	0.002
III > II – V3 / III	152 (97.4)	44 (83.0)	196 (93.8)	14.096	1	<0.001
III > II – ST precordial lead depression	154 (98.7)	52 (98.1)	206 (98.6)	0.102	1	0.749

ECG variable	RCA present n (%)	RCA absent n (%)	Total n (%)	χ²	df	p value
V3 – ST precordial lead depression	103 (66.0)	53 (100.0)	156 (74.6)	24.124	1	<0.001
All ECG variables	155 (99.4)	53 (100.0)	208 (99.5)	0.341	1	0.559

The following table represents the association between specific electrocardiographic leads showing ST-segment changes and angiographic left circumflex artery (LCx) involvement. Patients with angiographically confirmed LCx occlusion demonstrated significant ECG changes predominantly involving the V3/III ratio, V3/III with associated precordial ST-segment depression, aVR–ST precordial lead depression, V1–ST precordial lead depression, precordial ST-segment depression, V1–V3/III, and aVR–V3/III. In contrast, patients without LCx occlusion showed significant ECG changes mainly in lead III > II, aVR–III > II, aVR, V1–aVR, and V1–III > II. The distribution of these ECG variables with respect to angiographic LCx status was found to be statistically significant, as shown in Table 6.

Table 6: Correlation of electrocardiographic variables with angiographic left circumflex artery (LCx) involvement

ECG variable	LCx present n (%)	LCx absent n (%)	Total n (%)	χ²	df	p value
V1	38 (36.5)	19 (18.1)	57 (27.3)	8.960	1	0.003
aVR	58 (55.8)	29 (27.6)	87 (41.6)	17.039	1	<0.001
III > II	63 (60.6)	100 (95.2)	163 (78.0)	36.569	1	<0.001
V3 / III	101 (96.4)	60 (58.0)	161 (78.1)	42.100	1	<0.001
ST precordial lead depression	99 (95.2)	54 (51.4)	153 (73.2)	51.017	1	<0.001
V1 – aVR	62 (59.6)	32 (30.5)	94 (45.0)	17.927	1	<0.001
V1 – III > II	74 (71.2)	102 (97.1)	176 (84.2)	26.541	1	<0.001
V1 – V3 / III	86 (82.7)	22 (21.0)	108 (51.7)	79.755	1	<0.001
V1 – ST precordial lead depression	100 (96.2)	62 (59.0)	162 (77.5)	41.271	1	<0.001
aVR – III > II	83 (79.8)	103 (98.1)	186 (89.0)	17.842	1	<0.001
aVR – V3 / III	89 (85.6)	32 (30.5)	121 (57.9)	65.075	1	<0.001
aVR – ST precordial lead depression	102 (98.1)	69 (65.7)	171 (81.8)	36.786	1	<0.001
III > II – V3 / III	95 (91.3)	101 (96.2)	196 (93.8)	2.102	1	0.147
III > II – ST precordial lead depression	103 (99.0)	103 (98.1)	206 (98.6)	0.329	1	0.567
V3 – ST precordial lead depression	102 (98.1)	54 (51.4)	156 (74.6)	60.068	1	<0.001
All ECG variables	104 (100.0)	104 (99.0)	208 (99.5)	0.995	1	0.318

E ***In-hospital outcomes***: The majority of patients had a hospital stay of less than three days, while a smaller proportion required prolonged hospitalization (Table 7). Overall in-hospital mortality was low, with most patients surviving until discharge.

Table 7: In-hospital outcomes among study participants (n = 209)

Outcome variable	Category	Frequency	Percent
Duration of hospital stay (days)	< 3 days	143	68.4
	≥ 3 days	66	31.6
Mortality	No	199	95.2
	Yes	10	4.8

DISCUSSION

Myocardial infarction often occurs as a result of sudden coronary artery failure, causing myocardial necrosis and impaired cardiac muscle function. Treatment is often percutaneous coronary intervention; however, early and precise electrocardiographic diagnosis remains mandatory. Right ventricular myocardial infarction (RVMI) indicates damage to the right ventricular myocardium, although right ventricular involvement is relatively uncommon. The standard 12-lead electrocardiogram is one of the most commonly used investigations in the assessment of cardiovascular disease and remains the most important test for interpretation of cardiac rhythm, detection of myocardial ischemia and infarction, conduction abnormalities, ventricular hypertrophy, pericarditis, and other conditions. Therefore, ECG was used in this study to diagnose acute right ventricular myocardial infarction.

Previous studies have emphasized the use of extended ECG leads for analyzing right ventricular involvement. However, when using lead V4R in inferior wall myocardial infarction, it should be noted that ST-segment deviation in this lead does not persist as long as in standard extremity leads and must be recorded early after the onset of chest pain. Despite being known for more than three decades, lead V4R is rarely recorded in real-world practice. As pointed out by Harju et al., additional ECG leads are often not recorded by emergency service personnel or in emergency departments. This limitation provided the rationale for developing an algorithm based solely on the standard 12-lead ECG.

In this study, 209 patients were included to diagnose RVMI using a 12-lead ECG, predict the site of occlusion, and assess associated mortality. Analysis of the demographic profile showed a male predominance (155 patients), with the highest number of participants belonging to the 61–70-year age group (36.8%).

Although many attempts have been made to diagnose RVMI based on ST-segment changes, relatively few studies have focused exclusively on the standard 12-lead ECG. The relationship between right coronary artery (RCA) and left circumflex artery (LCx) involvement in RVMI was investigated. The most common cause of right ventricular involvement was occlusion of the RCA (75%). Right ventricular myocardial infarction is most commonly caused by obstruction of the right coronary artery, and only 5–10% of patients develop significant hemodynamic symptoms. However, in the present study, RVMI occurred in 25% of cases due to LCx occlusion, a finding that was in agreement with the observations of William et al.

Four ECG-based criteria were evaluated from the baseline ECG: ST-segment elevation in lead III greater than lead II (Criterion 1), r>S in leads V1 and aVR with III/II ratio (Criterion 2), ST-segment depression in lead V3 relative to ST-segment elevation in lead III (Criterion 3), and r>S in leads V1 and aVR with V3/III ratio (Criterion 4). Based on these criteria, four hypotheses were tested to identify the infarct-related artery and diagnose RVMI.

The presence of Criterion 1 and Criterion 2 from the admission ECG defined the RCA as the infarct-related artery with a statistically significant p-value (<0.001). The presence of either Criterion 1 or Criterion 2 was significantly higher in the RCA group compared to the LCx group ($p < 0.001$). Notably, the combined presence of both criteria was observed exclusively in the RCA group and not in any patient in the LCx group, which was also statistically significant ($p < 0.001$). These findings are consistent with previous studies by Herz et al. and Zimetbaum et al.

The anatomical explanation for Criteria 1 and 2 lies in the orientation of ECG leads and coronary perfusion. Lead III reflects the right inferior region, whereas lead II reflects the left inferior and inferolateral regions of the left ventricle. The circumflex artery perfuses the posterolateral and inferoapical regions of the left ventricle, while the RCA supplies the remaining inferior wall, right ventricle, and inferior interventricular septum. Therefore, primary ST-segment elevation is more pronounced in lead III during RCA occlusion, with reciprocal changes observed in other leads.

In the present study, Criterion 1 demonstrated high sensitivity (96%) but low specificity (28%), whereas Criterion 2 showed lower sensitivity (67%) but high specificity (95%). When both criteria were present together, sensitivity remained comparable (63%) while specificity increased to 99%, with high positive and negative predictive values. Similar findings were reported by Zimetbaum et al., although their study used echocardiography rather than angiography for RVMI diagnosis. These results highlight the pivotal role of leads V1, aVR, and the III/II ratio in identifying inferior wall myocardial infarction associated with RVMI.

Criteria 3 and 4, involving the V3/III ratio and r>S in leads V1 and aVR, were strongly suggestive of LCx occlusion and were statistically significant. However, ST-segment depression in precordial leads occurred in both RCA and LCx occlusions and therefore lacked discriminative value. Overall, the present study demonstrates that analysis of a standard 12-lead ECG can reliably predict the site of occlusion in inferior wall myocardial infarction associated with RVMI.

CONCLUSION

In summary, one-third to one-half of inferior MIs is complicated by RVMI and this varies from mild asymptomatic RV dysfunction to severe hypotension, cardiogenic shock, and death. The diagnosis of RVMI can be challenging; the 12 lead ECGs with supplemental right precordial recordings remain the principal diagnostic tool in the acute setting, but the findings may be transient. High clinical suspicion is required for accurate diagnosis and assessment of RVMI by integrating clinical, imaging, hemodynamic study, and angiographic data to avoid any detrimental complications associated with RVMI.

The pathophysiology of the RV makes it resistant to infarction, but acute ischemia can lead to severe hemodynamic consequences. Fluid resuscitation to maintain an adequate RV preload is the first-line therapy. Emergent revascularization, with preference to primary PCIs, is the cornerstone of RVMI management. When refractory hypotension or cardiogenic shock emerges, mechanical circulatory support confers survival benefit. Patients who survive from the acute phase exhibit an overall favourable long-term prognosis. RVMI is seen in up to half of inferior wall MIs, and occasionally, it can accompany anterior wall MI, and very rarely it can occur in isolation. Diagnosis of acute RVMI is based on history, physical examination, cardiac enzymes, electrocardiography, and coronary angiography, whereas non-invasive imaging such as echocardiography or MRI can play a complimentary role in the diagnosis.

The clinical consequences vary from no hemodynamic compromise to severe hypotension and cardiogenic shock depending on the location of the culprit lesion, in that the more proximal the RCA occlusion, the larger the RV infarction and subsequently on the extent of the ischemic injury. Early and complete reperfusion with thrombolysis or percutaneous coronary revascularization, with the latter being the preferred choice, improves outcomes in RVMI patients; however, incomplete or partial revascularization is associated with ventricular tachyarrhythmias, persistent hypotension, and higher mortality. Maintenance of reasonable heart rate and atrioventricular synchrony is essential to sustain adequate cardiac output in these patients.

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