

Original Article**Electrocardiographic Significance of Lead aVR in Acute Myocardial Infarction**

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Email: [drmilind72gmail.com](mailto:drmilind72gmail.com)**Abstract**

**Introduction:** Role of lead aVR in localizing the level of obstruction in AMI has generated considerable interest in recent times. There is a plethora of articles studying the utility of lead aVR (ST segment elevation) in AMI with conflicting and contradictory results.

**Methodology:** This prospective study comprised of 100 subjects of Acute myocardial infarction (AMI) was aimed to determine utility of ST segment changes in lead aVR in terms of ST elevation in prediction of coronary artery involvement & correlating culprit coronary artery lesion on coronary angiogram (CAG). A12 lead ECG was done at admission and CPKMB level was done in all patients. CAG (coronary angiogram) was performed within 72 hrs. of hospitalisation in most of the cases except few in whom CAG was performed within 7 days. On ECG, lead aVR changes in the form of ST elevation were noted in terms of culprit coronary artery and were correlated and confirmed on CAG.

**Results:** Analysis of admission ECG revealed ST elevation in lead aVR in 28% of the cases. On CAG single & double vessel disease was observed in majority of the cases. LMCA occlusion was seen in 12% cases. (12 out of 100) 10 (35.7%) cases out of 28 who showed ST segment elevation in aVR had significant LMCA occlusion on CAG, Diabetes, cardiogenic shock & Triple vessel disease were found as independent predictors of elevated ST segment in lead aVR. It was statistically highly significant CPKMB levels were significantly high in cases with elevated ST in lead aVR ( $p = <0.0001$ ).

Correlation between elevated ST in lead aVR & significant LMCA occlusion (>50%) on CAG was found statistically significant  $p = <0.0001$ , Odds ratio = 19.44 95% CI (3.55-190.30).with Sensitivity of 83.3%, Specificity 87.5%, positive predictive value 35.71%, negative predictive value as 97.22% & accuracy of 80%.

All 28 cases with elevated ST segment in lead aVR showed significant LAD occlusion on CAG. While 72 cases without ST elevation in lead aVR revealed LAD occlusion in 54 (75%) cases. this difference was statistically significant  $p = 0.003$ . but sensitivity, specificity positive & negative predictive value & diagnostic accuracy (34%, 1%, 1% 28.8% & 28.18% respectively) is less than LMCA prediction with ST segment elevation in lead aVR.

**Conclusion:** ST elevation in lead aVR has more predictability for significant occlusion of LMCA on CAG than LAD

**Keywords:** Acute Myocardial infarction (AMI), ECG, aVR lead, Coronary angiography (CAG) Left anterior descending artery (LAD), Left main coronary artery (LMCA).

## Introduction

The Electrocardiogram (ECG) is one of the simplest and oldest cardiac investigations available. Yet it can provide a wealth of useful information and remains an essential part of assessment of cardiac patients. A detailed analysis of pattern of ST segment elevation may influence decision regarding the use of reperfusion therapy<sup>1</sup> The augmented limb leads were developed to derive more localized information than the bipolar leads I, II and III could offer. For this purpose from the existing limb electrodes, new leads aVR, aVF and aVL were constructed, being unipolar leads looking at the right, left and lower part of the heart with the reference electrode constructed from the other limb electrodes. Thus, the purpose of lead aVR was to obtain specific information from the right upper side of the heart, such as the outflow tract of the right ventricle and the basal part of the septum. In practice, however, most electrocardiographers consider lead aVR as giving reciprocal information from the left lateral side, being already covered by the leads aVL, II, V5 and V6. This has been the reason that lead aVR has become largely ignored.<sup>2</sup>

Many clinicians refer to the 12 lead ECG as 11 lead ECG, noting the commonly held belief that lead aVR rarely offers clinically useful information than bipolar leads I, II, III could offer. Lead aVR remains largely neglected for identifying the culprit lesion.<sup>3</sup>

Over the past several years, observational and epidemiological studies have provided an insight to the importance of lead aVR in the resting ECG recorded during chest pain. Lead aVR may contain important information regarding the prognosis of the patient with ischaemic myocardium and the location of the culprit lesion. Lead aVR can be useful in identifying left main coronary obstruction. Lead aVR can also help in differentiating between LMCA and proximal LAD. ST elevation in lead aVR more than in lead V1 is suggestive of LMCA disease and vice versa is suggestive of proximal LAD disease<sup>4</sup> In presence of acute inferior wall MI, PR segment

elevation in inferior leads and PR segment depression in lead aVR, are suggestive of atrial infarction<sup>4</sup>

The evidence for the utility of ST segment elevation in lead aVR, in identifying the LMCA occlusion came from the study of Kosuge et al, recently, which showed that ST segment elevation in lead aVR identified LMCA occlusion with 80% sensitivity, 93% specificity, 56% positive predictive value and 98% negative predictive value<sup>5</sup>

Role of lead aVR in localizing the level of obstruction in AMI has generated considerable interest in recent times. There is a plethora of articles studying the utility of lead aVR (ST segment elevation) in AMI with conflicting and contradictory results. However data from central India is scarce.

Hence hypothesis electrocardiographic significance of lead aVR in AMI, was tested to determine the utility of ST segment changes in lead aVR in localizing the level of obstruction (LMCA) in acute myocardial infarction.

## Material and Methods

This prospective observational study comprised of 100 subjects of Acute myocardial infarction (AMI) was aimed to determine utility of ST changes in lead aVR in terms of ST elevation in prediction of coronary artery involvement & correlating culprit coronary artery lesion on coronary angiogram in AMI. Also to determine sensitivity, specificity, positive predictive value, negative predictive value and overall accuracy of ST segment elevation in lead aVR to predict LMCA disease.

All acute MI cases were consecutive & fulfilling criteria for acute MI. Study could include those 100 cases of acute MI in 2 yrs who were willing for early Coronary angiography.

This study was carried out in ICCU set up of government institution tertiary care hospital from Jan 2015 to December 2016 (2 yrs period)

**Inclusion Criteria:** 100 Cases of AMI irrespective of gender & risk factors fulfilling

criteria for AMI<sup>6</sup>

Typical rise and/or fall of biochemical markers of myocardial necrosis with atleast one of the following

- a) A Ischemic symptoms.
- b) Development of pathological Q waves in ECG.
- c) ECG changes indicative of ischemia (ST segment elevation or depression)
- d) Imaging evidence of new loss of viable myocardium or new regional wall motion.

#### Exclusion criteria

1. Documented evidence of previous / recent past within 6 wks ) MI
2. Prinzmetal angina
3. Non ST elevation MI
4. Not willing to participate in the study

#### Clinical Data

Data was collected in a preset proforma as per objective of the study. Purpose of the study was Carefully explained to the cases & consent of participation in the study was obtained. Institutional Ethic committee clearance was also taken.

Following admission to the hospital, brief history was elicited in each case with reference to the time of onset and duration of symptoms like chest pain/ and or dyspnoea, and the presence of risk factors like diabetes, hypertension, smoking and alcohol.

A12 lead ECG was done at admission and CPKMB levels was done in all patients within half an hour of admission to the hospital Raised CKMB levels is one of the criteria for diagnosis of Acute MI. we did estimation of CKMB once at admission & values were correlated with ST segment elevation in lead aVR on ECG.

Further patients also underwent 2D echo within 24 hrs of presentation to the hospital for the evaluation of regional wall motion abnormalities and to know the LV function. Then these patients were subjected to CAG (coronary angiogram) within 72 hrs of hospitalization in most of the cases except few (07 cases) in whom CAG was

performed within 7 days.

After taking informed consent these patients were subjected to CAG (coronary angiogram).

After ECG recording, lead aVR changes in the form of ST elevation was noted in terms of culprit coronary artery and were correlated and confirmed on coronary angiogram.

ST segment shift was determined as the mean value of five successive beats measured at 60 ms after the point of the QRS complex. ST segment elevation was defined as present when ST segment elevation was  $\geq 0.05$  mV in the limb leads and ST segment elevation was  $\geq 0.1$  mV in the precordial leads. The data for ST segment shifts were subjected to statistical analysis. while ST segment elevation of  $\geq 0.5$  mm in lead aVR was considered significant in the present study<sup>7</sup>

On coronary angiogram significant occlusion was considered as  $>50\%$  for LMCA &  $>70\%$  for LAD/LCX/RCA & all branches like OM/Diagonals/PDA/PLV<sup>8</sup>

#### Statistical analysis

Continuous variable (age, CPKMB) were presented as mean  $\pm$ SD. Age and CPKMB were compared with presence or absence of elevated ST segment in lead aVR by performing independent t- test. Categorical variables (Gender, symptoms, traditional risk factors and angiogram parameters, ECG parameters) were expressed in actual numbers and percentages. Categorical variables were compared by chi – square statistics. For small number, Fisher exact test was used wherever applicable. Association of ST elevation in aVR and LMCA was assessed by calculating Odd's ratio and 95 % confidence interval. Diagnostic evaluation of ST segment elevation aVR with LMCA was done by estimating sensitivity, specificity and accuracy. p value  $<0.05$  was considered as statistically significant. Statistical software STATA version 13.00 was used for statistical analysis.

#### Results

Total 100 cases of AMI were enrolled in the

study. 80 males & 20 females with M:F 1:0.72. mean age of males was  $52.42 \pm 12.41$  & Female was  $51.05 \pm 9.87$ .

Age did not show significant correlation with elevated ST segment in aVR

100% of the males had >02 risk factors in the form of Diabetes, hypertension, smoking and alcoholism. Not a single female had history of smoking or alcohol.

Alcohol was considered as indirect risk factor for coronary artery disease since chronic Alcoholism causes dyslipidemia leading to atherosclerosis.

Diabetes, cardiogenic shock & Triple vessel disease were found as independent predictors of elevated ST segment in lead aVR. It was statistically highly significant (Table 1)

Association of ST segment elevation in aVR with Killips class, acute heart failure, Ejection fraction & death was not done since it was not the aim of our study.

Cardiogenic shock was seen in 23 out of 28 cases of acute MI who showed ST segment elevation in aVR

Amongst type of Myocardial infarction, Anterior wall myocardial infarction was present in 80% (80/100) of the cases while Inferior AMI & Inferoposterior wall MI comprised 14% & 06% cases respectively. Author could not find any reason for high proportion of Anterior wall MI in the present study

Analysis of admission ECG revealed ST elevation in lead aVR in 28 out of 100 cases (28%) (see Fig1) In addition to ST elevation in lead aVR other leads also showed ST segment elevation in precordial leads & limb leads depending on type of MI. Remaining 72 out of 100 cases of AMI did not show ST segment elevation in aVR. All 28 cases with ST segment elevation in lead aVR had anterior wall MI changes on ECG.

CPKMB levels were significantly high in cases with elevated ST in lead aVR. ( $p = <0.0001$ ) (Table 2)

Mean level CPKMB (IU/L) was  $133.07 \pm 14.45$  in all 28 cases who showed ST segment elevation

in aVR. as compared to  $84.94 \pm 10.27$  in cases who did not have ST segment elevation in lead aVR.

On Coronary angiogram (CAG) single & double vessel disease was observed in majority of the cases.

On coronary angiogram (CAG) single & double vessel disease was observed in majority of the cases. Single vessel disease was detected in 47% cases (47/100) while double & triple vessel disease was observed in 42 & 11 cases respectively.

Significant occlusion (ie >50%) of Left main coronary artery was seen in 12% (12/100) cases of acute MI irrespective of lead aVR changes. (Fig2)

10 (35.7%) cases of MI out of 28 who showed ST segment elevation in lead aVR had significant occlusion of LMCA. Percentage of occlusion could not be analysed separately in all 12 cases due to small sample size.

Correlation between elevated ST in lead aVR & LMCA occlusion on CAG was found statistically significant  $p = <0.0001$ , Odds ratio = 19.44 95% CI (3.55-190.30). (Table3)

This observation of elevated ST segment in lead aVR on ECG localizing the significant LMCA occlusion on CAG has sensitivity of 83.3%, Specificity 87.5%, positive predictive value 35.71%, negative predictive value as 97.22% & accuracy of 80%.

There was a significant correlation between Mean CPK-MB elevation & LMCA occlusion on CAG ( $P = <0.001$ ) (Table4)

All 28 cases with elevated ST segment in lead aVR showed significant occlusion (ie  $\geq 70\%$ ) of LAD on CAG. Out of 72 cases without ST elevation in lead aVR revealed LAD occlusion in 54 (75%) cases. This difference was statistically significant  $p = 0.003$  (Table5) but its sensitivity, Specificity, positive & negative predictive value & diagnostic accuracy was 34%, 1%, 1%, 28.8% & 28.18% respectively which is less than LMCA occlusion prediction with ST segment elevation in lead aVR.

Subanalysis of LAD occlusion in terms of proximal or distal segment of LAD was not done due to less sample size.

Further correlation between elevated ST segment in lead aVR and number of coronary vessel involvement on CAG showed single & double vessel occlusion in most of the cases which was statistically highly significant.  $p = <0.0001$  (Table 6) Due to small sample size elevated ST in lead aVR & other associated ECG changes were not correlated with CAG.

### Discussion

Initially aVR lead was neglected<sup>9,10</sup> The purpose of lead aVR was to obtain specific information from the right upper side of the heart such as outflow tract of the right ventricle and basal part of the septum. However, most electrocardiographers in practice consider lead aVR as giving reciprocal information from left lateral side, being already covered by the leads. aVL, II, V5 and V6. This has been the reason that lead aVR has been largely ignored.

As all the depolarization is going away from this lead, all the waves are negative (P, QRS, and T) in this lead. Ischemia of the basal part of the inter-ventricular septum is the electrocardiographic explanation for the occurrence of ST segment elevation in lead aVR<sup>10</sup>.

ST segment depression in lead aVR, in inferior wall ST elevation MI, predicts left circumflex infarction or larger RCA infarction involving large postero-lateral branch<sup>11</sup>.

Plethora of articles over the past ten years have indicated that aVR changes occur in acute coronary syndrome. ST segment elevation in lead aVR in Acute coronary syndrome could indicate stenosis of LMCA or three vessel coronary artery disease.

In the present study conducted in 100 cases of AMI showed ECG evidence of ST elevation in lead aVR in 28 cases. On coronary angiogram significant occlusion (ie>50%) of Left main coronary artery was seen in 12% (12/100) cases of acute MI irrespective of lead aVR changes.

10 (35.7%) cases of MI out of 28 who showed ST segment elevation in lead aVR had significant occlusion of LMCA. Percentage of occlusion could not be analysed separately in all 12 cases due to small sample size

The sensitivity of ECG in identifying the LMCA occlusion in present study was 83.3% while the specificity, Positive predictive value (PPV), Negative predictive value (NPV) and overall accuracy were 87.5%, 35.71%, 97.22%, and 80% respectively.

Previous evidence of an association between ST segment elevation in lead aVR and LMCA occlusion, came from the Yamaji et al (2001)<sup>12</sup> who retrospectively studied the admission 12-lead ECGs in 16 consecutive patients with acute LMCA obstruction (LMCA group), 46 patients with acute left anterior descending coronary artery (LAD) obstruction (LAD group) and 24 patients with acute right coronary artery (RCA) obstruction (RCA group). STE in aVR ( $\geq 0.5\text{mm}$ ) occurred with a significantly higher incidence in the LMCA group (88%) than in the LAD (43%) or RCA (8%) groups.

Though the results of the present study in predicting LMCA occlusion are comparable to Yamaji et al, we differ from him. ours is prospective study with large sample size while study quoted above was retrospective & included only 16 cases AMI.

Similar kind of results were reported in another study conducted in 2005 where sensitivity was 78% & specificity 86% in prediction of LMCA occlusion in cases with ST elevation in aVR on ECG which is slightly more than the results of above study but comparable.<sup>13</sup>

Rostoff et al (2005)<sup>14</sup> compared the admission ECG's in two groups of patients with acute coronary syndrome, including 46 with and 104 patients without left main coronary artery stenosis. They reported that in patients with left main coronary artery stenosis, ST-segment elevation in lead aVR was two times more frequent (69.6% v/s 34.6%) than in remaining patients.

In one of the retrospective studies conducted in 2005 author concluded that lead aVR ST elevation distinguished the LM group from the non LM group (LAD, RCA and LCX ) with 80% sensitivity, 76% specificity and 77% accuracy<sup>15</sup>, while results of similar kind of study in 2008 revealed ST elevation in aVR predicted LMCA occlusion with 50 % sensitivity, 91 % specificity, 55% PPV, and 89% NPV.<sup>16</sup>

All 28 cases with elevated ST segment in lead aVR showed significant occlusion (ie $\geq$ 70%) of LAD on CAG. While 72 cases without ST elevation in lead aVR had LAD occlusion in 54 (75%) cases. This difference was statistically significant but its sensitivity, Specificity, positive & negative predictive value & diagnostic accuracy was 34%,1%,1% 28.8% & 28.18% respectively which is less than LMCA occlusion prediction with ST segment elevation in lead aVR.

Association of ST elevation & Depression in lead aVR & culprit artery LAD on CAG has been studied since long.

Engelen D et al (1999)<sup>17</sup> reported that ST-elevation in lead aVR (STaVR), ST-depression in lead V5 (STV5) and STV1  $>2.5$  mm strongly predicted LAD occlusion proximal to S1, whereas abnormal Q- waves in V4–6 were associated with occlusion distal to S1 respectively, abnormal Q-wave in lead aVL was associated with occlusion proximal to D1, whereas ST aVL was suggestive of occlusion distal to D1. For both the S1 and D1, ST $\downarrow$  of 1.0 mm strongly predicted proximal LAD occlusion, whereas absence of ST $\downarrow$  predicted distal occlusion. There by the study concluded that in anterior AMI, the ECG is useful to predict the LAD occlusion site in relation to its major side branches.

Aygul N et al (2008)<sup>16</sup>&Kotuko et al (2009)<sup>18</sup> in their study on cases with STEMI reported that ST $\uparrow$  aVR & greater ST segment elevation in lead aVR are the good indicators of proximal LAD occlusion.

Subanalysis of LAD occlusion in terms of proximal or distal segment was not done in the

present study due to less sample size.

In the present study out of total 28 cases showing ST elevation in aVR, 10 had Triple vessel disease (TVD), while double vessel disease (DVD) and single vessel disease (SVD) was present in 02 & 16 cases respectively. There were total 11 TVD cases, out of which 10 were having elevation of ST segment in aVR. Correlation of ST elevation on aVR and TVD on CAG was statistically significant

The present study did not find association between gender and ST segment elevation in lead aVR.

Piotr Kukla et al (2012)<sup>19</sup> in their retrospective study of 320 consecutive patients with inferior wall STEMI (206 males, 114 females) found that female gender was independent predictor of ST segment elevation in lead aVR.

Small sample size and overall less number of females (20%) in present study could be the explanation for absence of association between gender and lead aVR ST elevation.

Our study did not find any association between hypertension, smoking and alcoholism and ST segment elevation in lead aVR .while Rostoff et al (2005)<sup>14</sup> observed that patients with ST segment elevation in lead aVR were more likely to have hypertension.

Diabetes & cardiogenic shock were found as independent predictors of ST elevation in lead aVR in the present study.

Similar results are reported in previous study (2012) also.<sup>20</sup> Recent publications showed that ST segment elevation in lead aVR was associated with triple vessel CAD or with left main disease both of which predispose to cardiogenic shock in MI.

Amongst lab parameters present study showed that the mean CPKMB in cases having ST segment elevation in lead aVR is higher than those cases who were not having ST segment elevation in lead aVR. The difference was statistically significant

These observation were comparable to the results of the studies conducted by Senaratne et al (2003)

<sup>20</sup>& Piotr kukla (2012)<sup>19</sup> et al. In both of these study association of ST depression & raised CPKMB was also observed. The present study did not observe ST depression in lead aVR.

The present study also observed significant correlation between elevated mean CPK-MB & occlusion of LMCA on CAG which has not been studied previously.

The present study revealed ST elevation in lead aVR in 28 cases out of total 100 cases. No case had ST segment depression in lead aVR.

Plethora of articles on Acute coronary syndrome analyzed for correlation of ST segment depression in lead aVR & culprit artery on CAG showed excellent specificity & sensitivity in differentiating LCX from RCA occlusions drawn from these data was the use of the ST segment in lead aVR remains a simple method with good result for predicting culprit artery.<sup>11,17,20</sup>

Possibly due to small sample size, ST depression in lead aVR was not observed and so we could not assess significance of ST depression in lead aVR in the present study.

Few authors have also studied association of high 30 days mortality in AMI patients showing ST elevation >1.5mm in aVR.<sup>19,21,22</sup>

The present study could not analyse the association between the ST segment elevation in lead aVR and in hospital mortality since it was not the aim of our study.

### Conclusions

1) The electrocardiogram (ECG) is one of the simplest and oldest cardiac investigations available, yet it can provide a wealth of useful information and remains an essential part of the assessment of cardiac patients. In view of its association with severe coronary artery disease, ST segment elevation in lead aVR could be used as a readily available tool, for early selection of cases for coronary angiography and revascularization

2) Elevated ST segment in lead aVR on ECG localizes the LMCA occlusion with Sensitivity of 83.3%, Specificity of 87.5%, Positive

Predictive Value of 35.71% and Negative Predictive Value of 97.22% and Accuracy of 80%. 3) DM, Triple vessel disease and cardiogenic shock were found to be the independent predictors of ST elevation in lead aVR in acute myocardial infarction.

### Limitation

1. More number of cases are required to support the findings of our study.
2. All 100 cases were subjected for CAG within 72 hrs. only in 7 cases there was delay of 5-7 days from ECG recording to undergo CAG. All these 7 cases did not show ST segment elevation in lead aVR. This delay was a minor limitation of the study.

### Strength

All cases have undergone CAG which is gold standard so inference of study result full proof and significant.

**Conflicts of interest:** None reported by authors.

### References

1. Dallas Price. How to read an Electrocardiogram (ECG). Part One: Basic principles of the ECG. The normal ECG. SSMJ 2010;3(2):1-4.
2. Anton P. M. Gorgels, D. J. M. Engelen, Hein J. J. Wellens, *Maastricht, The Netherlands* Lead aVR, a Mostly Ignored But Very Valuable Lead in Clinical Electrocardiography JACC 2001 :Vol. 38, No. 5, November 1, :1355-6)
3. Hurst JW. Methods used to interpret the 12-lead electro-cardiogram: Pattern memorization versus The use of vector concepts. ClinCardiol. 2000;23(1):4-13.
4. Chenniappan M, Sankar RU, Saravanan K, Karthikeyan. Lead aVR-the neglected lead. The Journal of the Association of Physicians of India. 2013; 61(9):650-654

5. Kosuge M, Ebina T, Hibi K, Morita S, Endo M, Maejima N, et al. An early and simple predictor of severe left main and/or three-vessel disease in patients with non-ST-segment elevation acute coronary syndrome. *Am J Cardiol.* 2011 Feb 15;107(4):495-500.
6. Braunwald's Heart Disease. A Textbook of Cardiovascular Medicine, 9<sup>th</sup> edition. New Delhi; Elsevier, a division of Reed Elsevier India Pvt limited; 1088.
7. Prediction of Acute Left Main Coronary Artery Obstruction by 12-Lead Electrocardiography ST Segment Elevation in Lead aVR With Less ST Segment Elevation in Lead V1 Yamaji H, Iwasaki K, Kusachi S, Murakami T, Hirami R, Hamamoto H, Hina K, Kita T, Sakakibara N, Tsuji T. *J Am Coll Cardiol.* 2001 Nov 1;38(5):1348-54.
8. Eric Topol, Paul Teirstein, Text book of interventional cardiology, 7<sup>th</sup> edition, Imprint Elsevier Publication 2015
9. Pahlm US, Pahlm O, Wagner GS. The standard 11-lead ECG. Neglect of lead aVR in the classical limb lead display. *J Electrocardiol.* 1996; 29(Suppl):270-4.
10. M Chenniappan, Lead aVR: The Neglected Lead, *MEDICINE UPDATE* 2013;97.
11. Kanei Y, Sharma J, Diwan R, et al. ST-segment depression in aVR as a predictor of culprit artery and infarct size in acute inferior wall ST-segment elevation myocardial infarction. *J Electrocardiol.* 2010;43:132-5.
12. Yamaji H, Iwasaki K, Kusachi S, Murakami T, Hirami R, Hamamoto H, et al. Prediction of acute left main coronary artery obstruction by 12-lead electrocardiography. ST segment elevation in lead aVR with less ST segment elevation in lead V1. *J Am Coll Cardiol.* 2001 Nov 1;38(5):1348-54.
13. Kosuge M, Kimura K, Ishikawa T, et al. Predictors of left main or three-vessel disease in patients who have acute coronary syndromes with non-ST-segment elevation. *Am J Cardiol.* 2005;95:1366-9.
14. Rostoff P, Piwowarska W, Konduracka E, Libionka A, Bobrowska- Juszczuk M, Stopyra K, et al. Value of lead aVR in the detection of significant left main coronary artery stenosis in acute coronary syndrome. *Kardiol Pol* 2005;62:128-37.
15. Kriengkrai Hengrussamee, Wirash Kehasukcharoen, Sudaratana Tansuphaswadikul, Significance of Lead aVR ST Segment Elevation in Acute Coronary Syndrome, *J Med Assoc Thai* 2005; 88 (10): 1382-7.
16. Aygul N, Ozdemir K, Tokac M, Aygul MU, Duzenli MA, Abaci A et al. Value of lead aVR in predicting acute occlusion of proximal left anterior descending coronary artery and in-hospital outcome in ST-elevation myocardial infarction: an electrocardiographic predictor of poor prognosis. *J Electrocardiol.* 2008;41 (4):335-41.
17. Piotr Kukla, Leszek Bryniarski, Dariusz Dudek, Tadeusz Królikowski, Kalina Kawecka-Jaszcz. Prognostic significance of ST segment changes in lead aVR in patients with acute inferior myocardial infarction with ST segment elevation, *Kardiol Pol* 2012; 70(2): 111-118.
18. Manohara P.J. Senaratne, Chandana Weerasinghe, Gisele Smith, Donna Mooney, Clinical utility of ST-segment depression in lead AVR in acute myocardial infarction. *Journal of Electrocardiology Volume*, 2003;36:11-16.
19. Madhu Gupta, Maheswar Prasad Kurmi, Bhoj Raj Sharm, Liping Chen, Ravi Shahi, Sun Jian, Clinical Significance of ST Segment Depression in Lead aVR to Predict Culprit Artery in An Acute Inferior



- Wall Myocardial Infarction. NHJ. 2015;12 (1):5-9 5.
20. Englein DJ, Gorgels PA, Emile CC, Ebo D, Oude Ophuis JA, Dassen WR et al. Value of the electrocardiogram in localizing the occlusion site in the left anterior descending coronary artery in acute anterior myocardial infarction. J Am Coll Cardiol 1999;(34):389-95.
21. Kotoku M, Tamura A, Abe Y, Kadota J. Determinants of ST-segment level in lead aVR in anterior wall acute myocardial infarction with ST-segment elevation. J Electrocardiol. 2009;42:112.
22. Cheuk-Kit Wong, Wanzhen Gao, Ralph A.H. Stewart, Jocelyne Benatar, John K. French, Philip E.G. et al aVR ST elevation: an important but neglected sign in ST elevation acute myocardial infarction, Eur Heart J. 2010; 31(15): 1845–1853.
23. Ala Hussain Abbase, Ameer Ahmad AL jubawii. The Significance of ST Segment Elevation in Lead aVR in Acute Anterior Myocardial Infarction, Medical Journal of Babylon, 2011; 8(4): 490-96.