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Original Contributions

THE NEGLECTED LEAD ON ELECTROCARDIOGRAM: T WAVE INVERSION IN LEAD AVL, NONSPECIFIC FINDING OR A SIGN FOR LEFT ANTERIOR DESCENDING ARTERY LESION?

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☐ Abstract—Background: The electrocardiogram (ECG) is the most important diagnostic tool for acute myocardial infarction (AMI). T wave inversion (TWI) in lead aVL has not been emphasized or well recognized. Objective: This study examined the relationship between the presence of TWI before the event and mid-segment left anterior descending (MLAD) artery lesion in patients with AMI. Methods: Retrospective charts of patients with acute coronary syndrome between the months of January 2009 and December 2011 were reviewed. All patients with MLAD lesion were identified and their ECG reviewed for TWI in lead aVL. Results: Coronary angiography was done on 431 patients. Of these, 125 (29%) had an MLAD lesion. One hundred and six patients (84.8%) had a lesion > 50% and 19 patients (15.2%) had a lesion < 50%. Of the 106 patients who had a MLAD lesion > 50%, 90 patients (84.9%) had TWI in lead aVL and one additional lead. Of the 19 patients who had an MLAD lesion < 50%, 8 patients (42.1%) had TWI in lead aVL and one additional lead. Isolated TWI in lead aVL had an overall sensitivity of 76.7% (95% confidence interval [CI] 0.65–0.86), a specificity of 71.4% (95% CI 0.45–0.88), a positive predictive value of 92%, a negative predictive value of 41.7%, a positive likelihood ratio of 2.7 (95% CI 1.16–6.22), and negative likelihood ratio of 0.32 (95% CI 0.19–0.58) for predicting a MLAD lesion of > 50% (*p* = 0.0011). Conclusions: TWI in lead aVL might signify a mid-segment LAD lesion. Recognition of this finding and early appropriate referral to a cardiologist might be beneficial. Additional studies are needed to validate this finding. Published by Elsevier Inc.

☐ Keywords—ECG; mid-segment LAD lesion; T wave inversion in lead aVL

INTRODUCTION

Electrocardiogram (ECG) is a valuable tool for identifying conditions that are potentially life threatening or

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that require definitive management, such as acute myocardial infarction (AMI), high-grade atrioventricular (AV) blocks, Brugada syndrome, and Wellens' syndrome (1–9). ST elevation in leads that correspond to specific coronary vessels is a commonly recognized hallmark of AMI (10–12). These specific lead changes are well recognized across specialties and are easily identified by most physicians, in some cases with the help of a computer-assisted ECG reading (10,13–15). On the contrary, changes seen in Brugada and Wellens' syndrome are not well recognized across specialties and computer-assisted readings are not helpful as they generally read these findings as normal or nonspecific.

Other significant ECG changes, such as reciprocal ST depressions and T wave inversions (TWI), are well recognized and accompany ST elevations. Their significance in patients with coronary artery disease has been the subject of many studies (4,5). These changes localize the site of a coronary lesion as well as are early and sensitive markers of MI (16–18). For example, reciprocal changes presenting as ST depression or TWI in lead aVL indicate a significant coronary artery lesion in the left anterior descending (LAD) artery, and may sometimes be the only manifestation of AMI. (4,5,18). Farhana et al. conducted a prospective study on the correlation of isolated TWI in lead aVL and mid-segment left anterior descending (MLAD) artery lesion in patients with chronic stable angina and found that an association exists. TWI in lead aVL was found to significantly predict MLAD lesion (odds ratio = 2.93; p = 0.001) (18). The importance of these changes have not been emphasized or well recognized across all specialties. The automated ECG reads these conditions as nonspecific or normal in the majority of cases.

The objective of our study was to restrospectively examine the correlation between TWI in lead aVL and MLAD in patients with symptoms of acute coronary syndrome (ACS).

METHODS

All patients that underwent percutaneous coronary intervention (PCI) between January 2009 and December 2011 were included in the study. A waiver was obtained from the Institutional Review Board. Logbooks from the cardiac catheterization laboratory were reviewed for all LAD lesion types and corresponding demographics with special attention given to patients with MLAD lesions. ECGs recorded in the 12-lead format were reviewed for changes in aVL by two independent physicians (one cardiologist and one emergency department [ED] physician). Special attention was given to the T wave in lead aVL as well as changes in leads I, V5, and V6. All ECGs in the month of the angiography and up to 1 year before coronary angiography were evaluated in individual patients. In addition, presence of the ECG findings associated with T wave changes, such as left ventricular hypertrophy (LVH) and bundle branch blocks (BBB) were also analyzed.

Subgroups

Two subgroups were identified: 1) all patients who were evaluated in the ED for emergent PCI (EMPCI group) due to possible ST elevation or new/presumed new left BBB and 2) all patients who underwent elective PCI (ELPCI group) for various reasons, such as ACS with elevated cardiac troponin level, positive stress test, or worsening symptoms of ACS with known stent placement or coronary artery bypass graft (CABG) in the past. Demographics such as age, sex, and cardiovascular risk factors were recorded and analyzed. Descriptive statistics and the two-tailed Fisher's test were used to analyze the data.

RESULTS

A total of 431 patients underwent PCI (EMPCI, 152 patients [35.3%], ELPCI, 279 patients [64.7%]) between January 2009 and December 2011. Very few patients had no previous ECG available for review in the electronic medical record. Tables 1 and 2 summarize patient demographics and clinical data, respectively.

A total of 125 patients (29%) from both groups were found to have an MLAD lesion. One hundred and six

Table 1. Demographics and Clinical Data

	EM-PCI Group		EL-PCI Group	
	Male	Female	Male	Female
Demographics				
Sex, n	34	27	63	23
Mean age (y)	66	69	60	64
Type of risk factors, n				
DM	17	16	19	10
Family history of CAD	15	15	17	5
HLP	23	17	35	13
HTN	31	23	47	17
Obesity			3	6
Smoking	20	9	31	13
Total number of risk factors, n				
1	2	2	9	3
2	7	6	22	3
3	9	6	19	5
4	12	7	8	4
5	3	4	1	3
6			1	1

CAD, coronary artery disease; DM, diabetes mellitus; EL-PCI, elective percutaneous coronary intervention; EM-PCI, emergent percutaneous coronary intervention; HLP, hyperlipidemia; HTN, hypertension.

Table 2. Angiographic Data

	EM-PCI Group		EL-PCI Group	
	Male	Female	Male	Female
Coronary Lesions, n				
SVD	9	9	20	5
DVD	12	12	25	13
TVD	13	6	18	5
No. of lesions in LAD, n				
1	26 (M)		51 (20 P, 30 M, 1 D)	
2	26 (22 P&M, 1 P&D, 3 M&D)		28 (21 P&M, 2 P&D, 5 M&D)	
3	7		10	
No. of lesions in LAD, n				
1	16	10	33	21
2	13	13	20	8
3	4	3	10	
Lesions and TWI in lead aVL, n	>50%	<50%	>50%	<50%
Total MLAD lesions	53	11	53	8
Isolated PLAD	16 (15 TWI)	3 (3 TWI)		
Isolated MLAD	23 (20 TWI)	5 (2 TWI)	25 (10 TWI)	
Isolated DLAD	1 (1 TWI)			
T wave inversions, n	>50%	<50%	>50%	<50%
TWI in lead aVL and I	46	6	44	2
Isolated in aVL	26	3	20	1
aVL and other leads	44	2	46	6
TWI in lead aVL and I excluding LVH and BBBs	40	5	33	1
Isolated TWI in lead aVL excluding LVH and BBBs	20	5	17	1

BBB, bundle branch block; DLAD, distal left anterior descending artery; DVD, double-vessel disease; EL-PCI, elective percutaneous coronary intervention; EM-PCI, emergent percutaneous coronary intervention; LAD, left anterior descending artery; LVH, left ventricular hypertrophy; MLAD, mid-segment left anterior descending artery; PLAD, proximal left anterior descending artery; SVD, single-vessel disease; TVD, triple-vessel disease; TWI, T wave inversion; P, proximal; M, mid; D, distal.

patients (84.8%) had > 50% lesions and 19 patients (15.2%) had < 50% lesions. Of the 106 patients who had MLAD lesions of > 50%, 90 (84.9%) had TWI in lead aVL and one additional lead, mostly lead I. Of the 19 patients who had MLAD lesions of < 50%, 8 (42.1%) had TWI in lead aVL and one additional lead, mostly lead I. TWI in lead aVL along with lead I has a sensitivity of 86.5% (95% confidence interval [CI] 0.79–0.92), a specificity of 55.6% (95% CI 0.34–0.75), a positive predictive value (PPV) of 91.8%, a negative predictive value (NPV) of 41.7%, a positive likelihood ratio of 1.95 (95% CI 1.16–3.28), and a negative likelihood ratio of 0.24 (95% CI 0.13–0.46) for predicting the presence of MLAD lesion in this cohort ($p = 0.0002$). Evaluating isolated TWI in lead aVL, it had an overall sensitivity of 76.7% (95% CI 0.65–0.86), a specificity of 71.4% (95% CI 0.45–0.88), a PPV of 92%, an NPV of 41.7%, a positive likelihood ratio of 2.7 (95% CI 1.16–6.22), and a negative likelihood ratio of 0.32 (95% CI 0.19–0.58) for predicting an MLAD lesion of > 50% ($p = 0.0011$).

Excluding those patients with LVH or BBB from the 106 patients who had MLAD lesions of > 50%, 73 patients (68.9%) had TWI in lead aVL and one additional lead, mostly lead I. Of the 19 patients who had MLAD lesion of > 50%, 6 (31.6%) had TWI in lead aVL and one additional lead, mostly lead I. TWI in lead aVL and one additional lead, mostly lead I, for predicting the presence of MLAD lesion, when excluding conditions such as LVH or BBBs, had a sensitivity of 90.1% (95% CI 0.82–0.95), a specificity of 62.5% (95% CI 0.39–0.82), a PPV of 92.4%, an NPV of 55.6%, a positive likelihood ratio of 2.4 (95% CI 1.27–4.54), and a negative likelihood ratio of 0.16 (95% CI 0.07–0.34) for predicting an MLAD lesion of > 50% ($p = 0.0001$).

Excluding those patients with LVH or BBBs from the 106 patients who had MLAD lesions of > 50%, 37 patients (34.9%) had isolated TWI in lead aVL, and of the 19 patients who had MLAD lesions of < 50%, 6 (31.6%) had isolated TWI in lead aVL. Isolated TWI in lead aVL had a sensitivity of 82.2% (95% CI 0.69–0.91), a specificity of 62.5% (95% CI 0.39–0.82), a PPV of 86%, an NPV of 55.6%, a positive likelihood ratio of 2.19 (95% CI 1.15–4.19), and a negative likelihood ratio of 0.28 (95% CI 0.14–0.59) for predicting MLAD lesions of > 50%, when excluding conditions such as LVH and BBBs ($p = 0.0028$).

DISCUSSION

Electrocardiographs (ECGs) have been helpful in the recognition of AMI and initiation of early PCI or thrombolytic therapy. Other important diagnostic findings on ECG that alter management include the recognition of

Brugada syndrome, high-grade AV blocks, and Wellens' sign. These findings mandate urgent therapy and definitive management, such as implantation of automated implantable cardiac defibrillator for Brugada syndrome, implantation of permanent pacemaker for high-grade AV blocks, and PCI or CABG for Wellens' sign/syndrome. These interventions are only possible if health care providers recognize these specific findings and understand their significance. Unfortunately, many computer-assisted reading devices have not been programmed to detected these recently discovered abnormal ECG signs. This emphasizes the importance of physicians continuing to review and interpret of ECGs despite normal readings by the computer. Wellens and his group discovered that 75% of patients who had Wellens' sign (biphasic T waves in leads V2 and V3) on their initial ECG and who were treated medically, developed extensive anterior wall infarction within a few days (3). This observation led to a subsequent study by the same group which revealed critical proximal LAD lesions on coronary angiography (2). Their observations of patients with Wellens' sign concluded that patient's with these ECG findings should not undergo an ergometric stress test as it could precipitate extensive MI and possibly lead to death (2,3,19). The best management for patients with Wellens' sign is coronary angiography followed by PCI or CABG, based on their angiographic findings (20,21).

T waves are categorized as flattening, inversion, or upright and can signify benign or pathologic conditions (21). T wave changes in lead aVL might be considered nonsignificant by most physicians. There is accumulating evidence, however, that changes in lead aVL have significance for patients (16,21–23). A limited number of studies have indicated that ST segment or T wave abnormality in specific leads can be an early sign of a significant lesion in a specific coronary artery. ST segment depression in lead aVL is considered a sensitive marker for early inferior wall MI (early reciprocal change) and was recently shown to differentiate ST elevation due to AMI from ST elevation due to pericarditis, with a sensitivity of 100% (16,24). Other studies have shown the importance of T wave changes in recognition of right ventricular involvement in inferior wall MI and as a sign of MLAD lesion (22–24). Farhan et al. found 89 ECGs with TWIs in lead aVL associated with definite ischemic changes in different leads. Isolated TWIs, however, were identified in 27 ECGs, and further review showed that this isolated TWI in lead aVL was the only ECG variable predicting a MLAD lesion (18). All ECGs with the isolated TWI in lead aVL were read as normal by the referring physicians (18). As shown by Wellens' group, there is a higher morbidity from a proximal LAD lesion due to the involvement of larger areas of the myocardium. The accumulating evidence with regard to TWI in aVL indicates that this specific ECG finding should not be considered as nonspecific and the diagnosis should not be missed, as it potentially leads to significant morbidity and mortality. Unfortunately, T wave changes in lead aVL have not been emphasized and are not well recognized across all specialties.

The findings of our study appear to indicate that the presence of TWI in lead aVL in isolation or along with lead I are potential predictors for the presence of MLAD lesion. In addition, the results demonstrate that multiple lesions are present within the LAD in most cases. Table 2 summarizes the locations of different lesions within the LAD segments (proximal, mid, and distal). Forty-eight patients (45.3%) had isolated MLAD lesion of > 50%, 30 (62.5%) of which had TWI in leads aVL and I. Five patients (26.3%) had isolated MLAD lesion < 50%, 2 (40%) of which had TWI in leads aVL and I. Some patients had two lesions and some had three lesions within the LAD, and although it is not obvious from this study that TWI in lead aVL signifies only MLAD lesion, there is a strong correlation between this specific ECG finding and MLAD lesion of > 50% when isolated MLAD lesions were selected and their corresponding ECGs reviewed. We did not see a correlation when we studied the changes in lead I only.

The results of our study (odds ratio = 8.04; $p = 0.0002$) and that of Farhan et al. (odds ratio = 2.93, $p = 0.001$) suggest that TWI in lead aVL might be associated with lesions within the LAD segment (18). The extent of myocardium at risk is potentially large and such changes should not be missed. TWI in lead aVL should be regarded as important and should be emphasized in teaching residents and physicians to avoid ignoring such changes as nonspecific. These findings may help initiate earlier intervention. As shown by Wellen's group, this approach might prevent a potential MI with early diagnosis and appropriate initiation of therapy (2,3).

Study Limitations

The study is limited by its small sample size and by the study population, which only included patients with ACS who underwent PCI. In addition, its retrospective nature may mean that some information might be incomplete due to inadequate documentation.

CONCLUSIONS

TWI in lead aVL suggests the presence of LAD lesions, especially in MLAD. Multicenter prospective studies or large multicenter retrospective studies may confirm our results and provide more insight into the correlation of the

ECG changes with the angiographic findings. Recognition of this finding and early appropriate referral to a cardiologist may be beneficial.

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ARTICLE SUMMARY

1. Why is this topic important?

This topic is important because it addresses the need for careful review of electrocardiogram signs that are usually not emphasized during training and are not looked at with special attention.

2. What does this study attempt to show?

This study attempts to show if T wave inversion (TWI) in lead aVL can predict the presence of particular coronary artery lesion (mid-segment left anterior descending artery).

3. What are the findings?

We found that the TWI in lead aVL can predict the presence of significant mid-segment left anterior descending artery lesion.

4. How is patient care impacted?

Patients with chest pain and significant risk factor for coronary artery disease should be aggressively managed with early coronary angiography if they present with TWI in lead aVL, if additional studies validate our findings.