Accuracy of Clinical Symptoms, Electrocardiographic and Echocardiographic Parameters for Diagnosis of Significant Proximal Right Coronary Artery Lesion in Acute Inferior Wall Myocardial Infarction

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Abstract

Background: Patients with inferior wall myocardial infarction (IWMI) associated with right ventricular (RV) infarction have much higher rates of adverse events.

Aim: To detect accuracy of clinical and ECG findings, echocardiography and tissue Doppler (TDI) as predictors of proximal right coronary artery (RCA) stenosis as a culprit lesion in inferior wall myocardial infarction.

Methods: In a prospective study patients with first episode of acute IWMI underwent early conventional and tissue Doppler echocardiographic assessment (within 24 h) of symptom onset and RV indices; Tricuspid annular systolic plane excursion (TAPSE), myocardial performance index (MPI) and tissue Doppler velocities from RV free wall were measured. Patients underwent coronary angiogram within one month. Our patients were divided into two groups (A,B) according to angiographic findings based on the presence (A) or absence (B) of a significant proximal RCA stenosis.

Results: There were 35 patients with first episode of IWMI, group A (n =14 patients) and group B (n =21 patients). There were significant differences between groups in TAPSE (1.28 cm vs 1.98 cm p < 0.001), MPI-TDI (0.69±0.12 vs 0.38±0.05 p < 0.001), and in S’velocity from RV free wall (0.09 m/s±0.02 vs 0.12 m/s±0.02 p < 0.001). It was found that S’<10 cm/s is a predictor of proximal RCA lesion with sensitivity of 92.86% and specificity of 85.71%, ppv 81.25, npv 94.74. MPI-TDI>0.55 had a sensitivity of 92.86% and a specificity of 100%, 100% PPV and 95.45% NPV. TAPSE<16 mm had a sensitivity of 93%, and a specificity of 100%.

Conclusion: RV indices (S’ velocity, MPI-TDI and TAPSE) are useful in predicting proximal RCA as infarct related artery in IWMI.

Keywords: Right ventricular function, Right coronary artery stenosis, Right ventricular infarction, Inferior wall myocardial infarction.

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Introduction

Right ventricular (RV) infarction is one of the major causes of RV contractile dysfunction. RV involvement occurs in 20-50% of inferior infarctions [1]. Patients with RV infarction associated with inferior infarction have much higher rates of significant hypotension, bradycardia requiring pacing, and in-hospital mortality compared to isolated inferior infarction [2]. Occlusion of proximal dominant RCA is usually responsible for RV infarction in inferior wall myocardial infarction [3]. The classic clinical triad of right ventricular infarction includes distended neck veins, clear lung fields, and hypotension [4].

The electrocardiogram often proves inadequate to predict proximal RCA stenosis as the infarct related artery [5]. Electrocardiogram changes are transient and disappear in 48% of cases within 10 hours making it a less dependable tool [6].

Echocardiography, being non-invasive, widely available, relatively inexpensive, and having no side effects, is the modality of choice for the assessment of morphology and function of the RV in clinical practice. Recent developments have provided several new methods for analysing the RV [7].
Conventional measurement of area and volume have limited utility in assessing RV function, (6) due to the complex geometry of the right ventricle and difficulty in defining the endocardial borders [9].

By using of Doppler myocardial imaging, several global and regional parameters such as timing, direction, and amplitude of the velocity of the ventricular wall can be determined. The technique is less dependent on chamber geometry. Furthermore, no endocardial border delineation is needed, which makes TDI valuable even if the echocardiographic image quality is suboptimal [7].

In this study we tried to assess whether Echocardiographic assessment of RV function is useful to predict proximal RCA stenosis and hence identify a subset of inferior wall myocardial infarction patients at a higher risk of adverse clinical events.

**Patients and methods:**

Our study was performed between Jan. 2014 and Nov. 2015 at Fayoum University hospital in Egypt. It included 35 consecutive patients with a first episode of acute IWMI within 24 hours of symptoms onset and admission to the coronary care unit.

Inferior wall myocardial infarction was defined as ischemic cardiac pain lasting more than 30 min, characteristic ST-segment elevation of 0.1 mv or more in two or more inferior leads, and CK-MB elevation more than twice the upper reference limit. RV infarction was defined as ST-segment elevation 0.1 mv or more in V4R in ECG taken within 6 hours of symptoms onset. All study patients received streptokinase thrombolytic therapy on admission.

Significant proximal RCA stenosis was defined in coronary angiography by the presence of occlusion, 70% stenosis or more, acute thrombosis or dissected plaque in the RCA before the origin of RV branch.

Exclusion criteria included previously documented abnormal ventricular function, left bundle branch block, atrial fibrillation, valvular heart disease more than mild, pulmonary hypertension with RV systolic pressure more than 40mmHg, pulmonary embolism, and poor echo window.

All patients underwent full history taking, Electrocardiogram (left and right side ECG), Cardiac enzymes, troponin I, Echocardiographic assessment of RV function within 24 hours of onset of symptoms. Echocardiographic measurements were performed according to guidelines of American Society of Echocardiography [10].

For the assessment of RV function TAPSE, MPI and Tissue Doppler velocity of RV free wall were measured as outlined below (see also figure 1).

**TAPSE:** In apical 4-chamber view, M-mode cursor was placed through tricuspid annulus at lateral RV free wall. From M-mode tracing the amount of longitudinal motion of annulus at peak systole was measured.

**MPI** by pulsed-wave Doppler method (MPI-PW): In apical 4-chamber view, pulsed wave Doppler trans-tricuspid flow velocities are recorded by placing the sample volume between the leaflet tips in the center of the flow stream. Doppler beam was aligned parallel to RV inflow and measurements were taken at end expiration. Trans-tricuspid early rapid filling velocity (E), peak atrial filling velocity (A), Tricuspid valve closure opening time (TCO) was measured as the time interval from tricuspid valve closure marked at the end of A wave to tricuspid valve opening marked at the beginning of E wave in the next cardiac cycle in the pulse wave Doppler tracing.

Pulsed Doppler of RV outflow was taken by placing the sample volume in RV outflow tract. Ejection time (ET) was calculated as time from onset to cessation of flow. Beats with less than 5% variation in R-R interval were taken to allow accurate measurement of myocardial performance index (MPI). MPI was calculated as TCO-ET divided by ET.

Pulsed wave tissue Doppler was acquired by placing TDI cursor on the right ventricular free wall at the level of tricuspid annulus. A major positive velocity (S') was recorded with the movement of annulus towards apex during systole. With the movement of annulus towards the base during diastole, two major negative waves were recorded-one during early diastole (E') and one during late diastole (A'), (S') duration was measured as ejection time (ET), the time between the end of (E') and the beginning of (E') as isovolumic relaxation time (IRT), time between end of (A') and beginning of (S') as isovolumic contraction time (ICT). Right ventricular MPI is calculated as (IRT + ICT)/ET. The echocardiography machine used was Siemens, Acuson CV 70.

Coronary angiography was performed within one month of the inferior wall MI. Patients were divided into two groups according to the angiographic findings, group A with significant proximal RCA stenosis, and group B without significant proximal RCA stenosis.

Statistical analysis; Independent-samples t-test of significance was used when comparing between two means, Chi-square (X2) test of significance was used in order to compare proportions between two qualitative parameters. Probability (P-value); P-value <0.05 was considered significant.
Results
This study included 35 consecutive patients with a first episode of acute inferior wall myocardial infarction within 24 hours of symptoms onset and admission to coronary care unit. Group A with proximal RCA stenosis included 14 patients and group B without RCA stenosis included 21 patients.

Our results showed statistically significant difference between proximal RCA lesion group A and group B regarding blood pressure and HR (see table 1). Our results revealed that congested neck veins and ST-segment elevation of 1 mm in lead V4R were statistically significant in the prediction of proximal RCA as the culprit lesion (see table 1). TAPSE and S’ were significantly lower in proximal RCA stenosis group (A). MPI by pulsed Doppler and tissue Doppler were higher in proximal RCA stenosis group (see table 2). The sensitivity, specificity, positive predictive value and negative predictive value of these parameters were calculated to assess proximal RCA lesion (see table 3).

We constructed ROC curves to determine the optimal cut off values for S’ and MPI-TDI. It was found that S’ < 10 cm/s predicted proximal RCA lesion with sensitivity of 92.86 % and specificity of 85.71 %, MPI-TDI > 0.55 with a sensitivity of 92.86 % and specificity of 100% (see figures 2 and 3).

Discussion
The clinical description of right ventricular myocardial infarction was first given by Saunders in 1930 when he reported a case with triad of hypotension, elevated jugular veins, and clear lung fields and extensive RV necrosis in autopsy [11]. The in-hospital mortality rate for IWMI with RV infarction is 31% compared to 6% in IWMI without RVMI [12]. The mortality of cardiogenic shock due to right ventricular infarction (55%) was comparable to that due to left ventricular infarction (59%) in spite of patients being younger and having a higher incidence of single vessel disease [13]. Observational studies have suggested that early reperfusion in inferior wall MI with RV infarction is beneficial. In patients with IWMI with RVMI, in whom PCI was successful, persistent hypotension and mortality were less compared to patients in whom PCI was unsuccessful [14].

Our study has shown no statistically significant difference between groups regarding demographic data and risk factors. In this study the BP recordings in the acute stage were significantly different between the two studied groups (P< 0.001). A study by Witt et al (2010), revealed that RV infarction is usually associated with depressed RV function, although it does not always lead to hemodynamic impairment [15]. This is also consistent with other data showing that RV-MI is often silent, with only 20–30% of patients developing clinically evident hemodynamic manifestation [16].

Table 1. Comparison between the 2 groups regarding blood pressure, HR and JVP.

<table>
<thead>
<tr>
<th></th>
<th>Group (A)</th>
<th>Group (B)</th>
<th>t/x*</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure</td>
<td>101.07 ± 7.12</td>
<td>133.33 ± 7.80</td>
<td>-5.40</td>
<td>0.021</td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td>63.21 ± 6.08</td>
<td>79.52 ± 5.22</td>
<td>-4.48</td>
<td>0.032</td>
</tr>
<tr>
<td>Heart rate(HR)</td>
<td>69.64 ± 6.03</td>
<td>80.00 ± 6.12</td>
<td>-4.93</td>
<td>0.029</td>
</tr>
<tr>
<td>Congested neck veins</td>
<td>9 (64.3%)</td>
<td>1 (4.8%)</td>
<td>14.58</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ST elevation in V4R(ECG)</td>
<td>10 (71.4%)</td>
<td>0 (0%)</td>
<td>21.00</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Figure 2. ROC curve shows that optimal cut off values for MPI-TDI > 0.55 with a sensitivity of 92.86 % and specificity of 100%.

Figure 3. ROC curve shows that optimal cut off values for S’. It was found that S’ < 10 cm/s predicted proximal RCA lesion with sensitivity of 92.86 % and specificity of 85.71 %.
We found that elevated JVP suggest proximal RCA lesion in patients with inferior MI. In our study specificity was 95.24% and sensitivity was 64%, and these results were supported by Mittal et al (1996), who reported that raised jugular venous pressure had high specificity (96.8%) but low sensitivity (39%) in diagnosing RV infarction [14].

According to Dell'Italia et al (1983), the diagnosis of RV infarction by physical examination depends on the triad of hypotension, venous distension and clear lung fields in the setting of inferior wall myocardial infarction but it is only 25% sensitive. JVP elevation greater than 8 cm and Kussmaul’s sign predict RVMI with greater sensitivity but less specificity [17]. In our study the sensitivity of ST segment elevation in V4R was 0.71% and specificity 100%. This was supported by many studies, such as those of Antman et al, (2004) who reported that right sided ST-segment elevation, particularly in lead V4R, correlates closely with occlusion of the proximal RCA and is indicative of acute RV injury [18]. Zehender et al (1993), had reported that ST-segment elevation in lead III more than II is 97% sensitive but only 70% specific for right ventricular infarction [20].

In our study TAPSE was significantly lower in patients with proximal RCA lesion (mean 1.28 cm Vs 1.98 cm p<0.001). Earlier studies had shown a good correlation of TAPSE with ECG evidence of RV infarction, but the number of patients was less and there was no angiographic correlation [21]. TAPSE was also an independent predictor of mortality in inferior wall MI [22]. Kaul et al. (1984), found that TAPSE has a good correlation with radionuclide derived right ventricular ejection fraction [23]. TAPSE has some limitations in that measurement is restricted to longitudinal function of RV free wall and functional status of LV may have an influence on it [24].

Assessment of RV wall motion abnormalities is subjective and often difficult when echocardiographic windows are poor. In this study we didn’t depend on this parameter. In this study, (MPI-PW) was found to correlate with proximal RCA stenosis (mean 0.51 Vs 0.34, p<0.05). Our cut off was 0.4 which shows 85.71% sensitivity and 90.48% specificity. In earlier studies, MPI 0.30 by pulsed wave Doppler was correlated with the presence of RVMI but angiographic correlation was not studied [25]. But MPI calculated in this method is less reliable as it utilizes two

Table 2. Comparison between the 2 groups with regard to echocardiographic assessment.

<table>
<thead>
<tr>
<th>ECHO</th>
<th>Group (A) With proximal RCA stenosis</th>
<th>Group (B) Without proximal RCA stenosis</th>
<th>t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ±SD</td>
<td>Mean ±SD</td>
<td>t</td>
<td>p-value</td>
</tr>
<tr>
<td>TAPSE M-mode (abnormal if &lt; 1.6 cm)</td>
<td>1.28 ±0.24</td>
<td>1.98 ±0.41</td>
<td>-5.703</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ET by PW</td>
<td>244.36 ±18.55</td>
<td>264.14 ±21.78</td>
<td>-2.788</td>
<td>0.009</td>
</tr>
<tr>
<td>TCO</td>
<td>371.0 ±28.88</td>
<td>353.0 ±26.97</td>
<td>2.032</td>
<td>0.041</td>
</tr>
<tr>
<td>MPI by PW (abnormal if &gt; 0.4)</td>
<td>0.51 ±0.23</td>
<td>0.34 ±0.05</td>
<td>3.295</td>
<td>0.003</td>
</tr>
<tr>
<td>IRT by TDI</td>
<td>86.91 ±11.71</td>
<td>52.57 ±9.24</td>
<td>6.980</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ICT by TDI</td>
<td>82.06 ±18.70</td>
<td>47.00 ±6.60</td>
<td>7.930</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ET by TDI</td>
<td>242.50 ±13.25</td>
<td>258.05 ±24.15</td>
<td>-2.192</td>
<td>0.036</td>
</tr>
<tr>
<td>MPI BY TDI (abnormal if &gt; 0.55)</td>
<td>0.69 ±0.12</td>
<td>0.38 ±0.05</td>
<td>10.610</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>S’ m/s (abnormal if S’ &lt; 10 cm/s)</td>
<td>0.09 ±0.02</td>
<td>0.12 ±0.02</td>
<td>-5.010</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>E’ m/s</td>
<td>0.06 ±0.02</td>
<td>0.08 ±0.03</td>
<td>-1.652</td>
<td>0.109</td>
</tr>
<tr>
<td>A’ m/s</td>
<td>0.11 ±0.02</td>
<td>0.13 ±0.03</td>
<td>-2.204</td>
<td>0.035</td>
</tr>
<tr>
<td>LVEF (%)</td>
<td>47.86 ±5.75</td>
<td>49.86 ±5.39</td>
<td>-1.048</td>
<td>0.302</td>
</tr>
</tbody>
</table>

Table 3. Accuracy of clinical signs, electrocardiographic and echocardiographic parameters for diagnosis of significant proximal RCA lesion (S’, TAPSE, MPI-PW, MPI-TDI, JVP and ECG)

<table>
<thead>
<tr>
<th></th>
<th>Sens.</th>
<th>Spec.</th>
<th>PPV</th>
<th>NPV</th>
<th>Accuracy</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>S’ by TDI &lt; 10 cm/s</td>
<td>92.86</td>
<td>85.71</td>
<td>81.25</td>
<td>94.74</td>
<td>88.57</td>
<td>&lt;0.001 HS</td>
</tr>
<tr>
<td>TAPSE M-mode &lt;1.6 cm.</td>
<td>85.71</td>
<td>90.48</td>
<td>85.71</td>
<td>90.48</td>
<td>88.57</td>
<td>&lt;0.001 HS</td>
</tr>
<tr>
<td>MPI by PW &gt; 0.4</td>
<td>85.71</td>
<td>90.48</td>
<td>85.71</td>
<td>90.48</td>
<td>88.57</td>
<td>&lt;0.001 HS</td>
</tr>
<tr>
<td>MPI BY TDI &gt; 0.55</td>
<td>92.86</td>
<td>100.00</td>
<td>100.00</td>
<td>95.45</td>
<td>97.14</td>
<td>&lt;0.001 HS</td>
</tr>
<tr>
<td>Congested neck veins (Elevated JVP)</td>
<td>64.29</td>
<td>95.24</td>
<td>90.00</td>
<td>80.00</td>
<td>82.86</td>
<td>&lt;0.001 HS</td>
</tr>
<tr>
<td>ST elevation in V4R</td>
<td>71.43</td>
<td>100.00</td>
<td>100.00</td>
<td>84.00</td>
<td>88.57</td>
<td>&lt;0.001 HS</td>
</tr>
</tbody>
</table>
different cardiac cycles for measurement of time intervals. In our study tissue Doppler indices (S') and MPI-TDI showed highly significant correlation with proximal RCA lesion (p<0.001). These indices were easy to measure even when the echocardiographic windows were poor. Karkourou et al (2011), concluded that S’ was significantly lower and RV-MPI was significantly higher in patients with RV-MI compared to patients without RV-MI [26].

They also found that patients with proximal RCA lesion had lower S’ and higher RV-MPI than patients with distal RCA or left coronary lesion. Alam et al. (2000), reported that patients with RV-MI had a significantly decreased peak systolic tricuspid annular systolic velocity (S’). Their results suggested that tricuspid annular systolic velocity by TDI can be used to assess RV infarction in association with inferior MI [21]. Moreover Rambaldi et al (1998), reported that significant RCA disease can be identified with the assessment of systolic velocity obtained by TDI from the RV free wall close to the lateral tricuspid annulus in the apical four-chamber view during dobutamine stress echocardiography [27].

Ozdemir et al (2003), reported that the S’ obtained by TDI was observed to be significantly lower in patients with proximal RCA lesion compared to those with distal RCA or LCX as the culprit lesion. they considered a value of 12 cm/s as the cutoff value with a sensitivity, specificity, negative predictive value and positive predictive value of 63%, 88%, 74%, and 81% respectively in the identification of proximal RCA as the culprit lesion and prediction of RV-MI. they considered cut off values for RV-MPI of 0.70 with sensitivity, specificity, npv and ppv of 94%, 80%, 97% and 63% respectively, in identifying RV-MI and in showing the proximal RCA lesion as the culprit lesion [28]. Meluzin et al (2001), reported that an S’ velocity less than 11.5 cm/s was predictive of a RV dysfunction with a sensitivity of 90% and a specificity of 85%. [29] MPI was found to correlate with radionuclide derived RVEF in earlier studies [30].

In a study done by Fan et al. in (2005), S’ was found to be significantly reduced in patients with proximal RCA lesion and RV-MI as compared to those with non-proximal RCA lesion (7.0 ± 2.0 cm/s vs. 8.7 ± 1.9 cm/s, p < 0.01). RV Tei index in patients with proximal RCA lesion and RV-MI also increased as compared to those with non-proximal RCA lesion (0.65 ± 0.19 vs. 0.40 ± 0.15; p< 0.01) [31].

In our study ROC curves were used to determine the optimal cut off values for TAPSE, S’ and MPI-TDI. S’<10cm/s predict proximal lesion RCA lesion with sensitivity of 92.86% and specificity of 85.71 %ppv 81.25, npv 94.74, MPI-TDI>0.55 predict proximal RCA lesion with a sensitivity of 92.86 % and specificity of 100%,100% PPV and 95.45% NPV. TAPSE<16mm showed (sensitivity 93%, specificity 100%, PPV 85.48, NPV 88.57).

Our study results are supported by the study of Rajesh et al (2013) (31) when they studied 67 patients with first episode of acute IIMI. There was significant difference between proximal RCA stenosis group (n=26) and the other group (n=41) in TAPSE (13.5 ± 1.3 vs 21.3 ± 1.7, p < 0.001), MPI by tissue Doppler (0.87± 0.1 vs 0.55 ± 0.2, p < 0.001) and in tissue Doppler systolic velocity from RV free wall (S’ 9.8 ± 1.1 vs 15.0 ±1.5, p < 0.001). TAPSE < 1.6 cm (sensitivity 93%, specificity 100%), MPI-TDI >0.69 (sensitivity 94.7%, specificity 93.5%), S’ < 12.3 cm/s (sensitivity 90.3%, specificity 94.3%) were useful in predicting presence of proximal RCA stenosis. Finally they found that RV function indices like TAPSE, MPI-TDI and S velocity are useful in predicting proximal RCA stenosis in first episode of acute IIMI. The possible reason for the difference between the cut off value in many studies may be attributed to the small number of patients

Conclusions

Echocardiographic assessment of various parameters of RV function (Tissue Doppler systolic annular velocity, myocardial performance index and TAPSE) showed significant difference between groups with or without proximal RCA lesion. Finally, RV indices (S’ velocity, MPI-TDI and TAPSE ) are easy to perform and useful in predicting proximal RCA as infarct related artery in IIMI.

Limitations

Echocardiographic assessment should ideally be performed before any reperfusion strategy as there is a possibility of recovery of RV function. But it was considered unethical to delay reperfusion for echocardiographic assessment.

Declarations of Interest

The authors declare no conflicts of interest.

Acknowledgements

The authors state that they abide by the “Requirements for Ethical Publishing in Biomedical Journals” [32].

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