Pathologic Study of Myocardial Infarction of the Right Ventricle

Takanobu Tomaru, M.D. and Wataru Mori, M.D.

SUMMARY

To evaluate pathologic features of myocardial infarction of the right ventricle (MI-RV), we analyzed 106 autopsy cases with transmural myocardial infarction (MI) (fresh in 46 cases and healed in 60). Anterior MI was observed in 47, posterior MI in 54 and lateral in 5. There were 13 cases (12%) with MI-RV (anterior in 1 case and posterior in 12), which included 10 cases with fresh MI and 3 with healed MI. All cases with MI-RV had associated transmural interventricular septal infarction.

Of the 13 cases with MI-RV, 9 (69%) had right ventricular dilatation (RVD) and 2 had right ventricular hypertrophy. Extensive MI-RV (more than 1/3 of the right ventricle) was observed in 8 (69%) of those with RVD. Of 93 cases of MI without MI-RV, 14 (16%) had RVD. The incidence of RVD was greater in cases with MI-RV than in those without (p<0.005). All 12 cases with posterior MI-RV had significant (>75%) narrowing of the right coronary artery (RCA), and 19 cases (87%) of those with posterior MI without MI-RV, had similar lesions.

In conclusion, the incidence of RVD and significant narrowing of RCA was greater in cases with posterior MI-RV than in those with posterior MI.

Additional Indexing Words:

Myocardial infarction Myocardial infarction of right ventricle (MI-RV) Right ventricular dilatation

Myocardial infarction of the right ventricle (MI-RV) has, until recently, rarely been diagnosed clinically because it was difficult to diagnose by conventional ECG examination. However, hemodynamic,1)-7) echocardiographic8)-13) and radioisotopic examinations9),14),15) have facilitated the clinical diagnosis of MI-RV. There have also been several reports on MI-RV at necropsy,16)-19) but most of them did not describe detailed morphologic findings in relation to clinical features.

As hemodynamic studies have stressed the predominant right ventricular dysfunction in MI-RV,1)-7) we examined the detailed pathologic features of...
MI-RV, including right ventricular morphology, in relation to the clinical features.

**Methods**

The 2,569 cases autopsied at the Department of Pathology from 1975 to 1983 were reviewed. Patients whose MI was limited in most areas to the inner 1/2 of the left ventricular wall (subendocardial MI) were excluded, for there were no patients with MI-RV associated with left ventricular subendocardial MI. There were 106 cases (70 males, 36 females) of transmural MI of the left ventricle. Thirteen (12%) of them had MI-RV. Ten were men and 3 were women, between 42 and 82 (mean 63.2) years old. The other 93 cases of MI without MI-RV were also examined as a control group.

Autopsy cases were classified into 2 major groups, those with myocardial necrosis (fresh MI) and those with myocardial fibrosis (healed MI), as determined by dominant gross and histologic examinations of the heart specimens.

Left ventricular infarction was subdivided according to the location of MI; (1) anterior wall, (2) posterior wall and (3) lateral wall MI. According to the size of MI-RV, the hearts of MI-RV were subdivided into 3 subgroups; grade I, less than 1/3 of the free wall of the right ventricle (RV) involved; grade II, 1/3 to 2/3 involved; and grade III, more than 2/3 of the RV involved. Right ventricular hypertrophy (RVH) was diagnosed when the maximal thickness of the free wall of the right ventricle exceeded more than 5 mm at the level of inflow and outflow tracts of the RV. The presence of right ventricular dilatation (RVD) was determined by visual inspection. In all cases with MI-RV and a considerable number of cases with MI, the coronary arteries were cut at 5 mm intervals at right angles to the longitudinal axis of the vessels and the stenotic degree of each cut surface was judged on gross inspection and microscopic examination. Coronary arterial narrowing of more than 75% in the cross sectional area was considered a significant luminal narrowing.

Statistical analysis was performed using Chi-square test to compare the morphologic and coronary arterial findings between the groups.

**Results**

*Incidence and relation of MI-RV to left ventricular MI:*

The incidence of MI-RV is shown in Table I. Forty-six of the 106 cases with MI had fresh and 60 had healed MI. There were 10 (22%) with fresh MI-RV of the 46 cases with fresh MI and 3 (5%) with healed MI-RV.
Table I. Incidence of Myocardial Infarction of Right Ventricle (MI-RV)

<table>
<thead>
<tr>
<th></th>
<th>Fresh MI</th>
<th>Healed MI</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior MI</td>
<td>1/23 (4%)</td>
<td>0/24 (0%)</td>
<td>1/47 (2%)</td>
</tr>
<tr>
<td>Posterior MI</td>
<td>9/21 (43%)</td>
<td>3/33 (9%)</td>
<td>12/54 (22%)</td>
</tr>
<tr>
<td>Lateral MI</td>
<td>0/2 (0%)</td>
<td>0/3 (0%)</td>
<td>0/5 (0%)</td>
</tr>
<tr>
<td>Total</td>
<td>10/46 (22%)</td>
<td>3/60 (5%)</td>
<td>13/106 (12%)</td>
</tr>
</tbody>
</table>

Statistical comparisons, * p<0.01, ** p<0.005.

Table II. Extent of Myocardial Infarction of Right Ventricle (MI-RV) and Its Relation to Right Ventricular Dilatation (number of patients)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Grade I</th>
<th>Grade II</th>
<th>Grade III</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVD (+)</td>
<td>9</td>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>RVD (-)</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>4</td>
<td>8</td>
<td>1</td>
</tr>
</tbody>
</table>

RVD = right ventricular dilatation; N = number of cases.

of the 60 cases with healed MI. Therefore, the incidence of MI-RV in cases with fresh MI was greater than that in those with healed MI (p<0.005).

There were 47 cases with anterior, 54 with posterior and 5 with lateral MIs. Of the 47 cases with anterior MI, 1 case (2%) had a fresh MI-RV; of the 54 cases with posterior MI, there were 12 cases with posterior MI-RV. The incidence of MI-RV in the cases with posterior MI was greater than that in those with anterior MI (p<0.005). Thus a high incidence of MI-RV was observed in fresh posterior MI. Transmural septal infarction was seen in 58 cases (55%), 28 posterior and 30 anterior septum. All of the 13 cases with MI-RV were included in the 58 cases with septal infarction. Twelve (43%) of the 28 cases with posterior septal MI had posterior MI-RV, and 1 of the 30 cases with anterior septal MI had an anterior MI-RV.

*Gross morphologic features of MI-RV:*

All cases of MI-RV were associated with large left ventricular MI (maximal diameter of MI more than 5 cm). Table II shows the extent of MI-RV and its relation to right ventricular dilatation (RVD). Four cases were grade I (Fig. 1), 8 were grade II (Fig. 2) and 1 was grade III (Fig. 3). As Fig. 1 shows, the grade I MI-RV hearts showed slight RVD, however, the grade III MI-RV hearts showed prominent RVD (Fig. 3). Nine (69%) of the 13 cases with MI-RV had RVD. All 9 cases with RVD were found in the posterior MI group. The MI-RV with RVD were frequently grade II.
Fig. 1. Healed posteroseptal MI associated with grade I MI-RV in a patient with congestive heart failure. Transverse slice of the heart showing marked left ventricular dilatation and mild right ventricular dilatation. MI is limited to less than 1/3 of the right ventricular free wall (arrows). A=anterior; P=posterior; L=left lateral.

Fig. 2. Fresh posteroseptal MI associated with grade II MI-RV. Transverse slice of the heart showing mild right ventricular dilatation and hypertrophy. MI is limited to 1/2–2/3 of the right ventricular free wall (arrows).

Table III shows the right ventricular morphology of examined cases with MI. Only 15 (16%) of the 93 cases without MI-RV had RVD. Fourteen (32%) of the 45 cases with MI associated with septal infarction had RVD. Therefore, the incidence of RVD was highest in those cases with MI-RV (p<0.005).

Two cases (15%) with MI-RV showed RVH. On the other hand, 7 (8%) of the 93 cases with left ventricular MI showed RVH. RVH was not significantly more frequent among the cases with MI-RV than those without MI-RV.

Three cases with fresh MI-RV had ruptures of the posterior wall of the left ventricle. There was no massive pericardial effusion or fibrous peri-
Fig. 3A. Fresh posteroseptal MI associated with MI-RV. Marked right ventricular dilatation is observed in transverse slice of the heart. MI extending to more than 2/3 of the right ventricular free wall.

3B. Photomicrograph of fresh MI-RV. Myofiber necrosis and myocytolysis are observed. Arrow indicates myocardial-cell necrosis and arrow head indicates myocytolysis with infiltration of round cells and appearance of collagen fibers. Hematoxylin and eosin stain ×40.

Table III. Right Ventricular Morphology of Myocardial Infarction
Hearts with or without MI-RV

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Right ventricular dilatation</th>
<th>Right ventricular hypertrophy</th>
</tr>
</thead>
<tbody>
<tr>
<td>With MI-RV</td>
<td>13</td>
<td>9 (69%)</td>
<td>2 (15%)</td>
</tr>
<tr>
<td>Without MI-RV</td>
<td>93</td>
<td>15 (16%)</td>
<td>7 (8%)</td>
</tr>
</tbody>
</table>

MI-RV= myocardial infarction of right ventricle; N=number of cases.
Statistical comparisons, * p<0.05.

carditis in the hearts with MI-RV without cardiac rupture.

Lesions of the coronary arteries:

Table IV shows the coronary artery findings. Of the 13 cases with
Table IV. Coronary Arterial Findings in Patients with Posterior MI with and without Associated MI-RV

<table>
<thead>
<tr>
<th></th>
<th>Number of cases</th>
<th>Number of patients with &gt;75% narrowing of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RCA</td>
</tr>
<tr>
<td>With MI-RV</td>
<td>12</td>
<td>12 (100%)</td>
</tr>
<tr>
<td>Without MI-RV</td>
<td>22</td>
<td>19 (86%)</td>
</tr>
</tbody>
</table>

RCA = right coronary artery; LAD = left coronary artery; LCx = left circumflex artery; MI = myocardial infarction. Statistical comparisons, * p < 0.05.

Table V. Clinical Signs and Pathological Findings on CHF

<table>
<thead>
<tr>
<th>Case</th>
<th>Moist rales</th>
<th>Congestion on chest radiography</th>
<th>Hypotension</th>
<th>Grade of MI-RV</th>
<th>Pulmonary congestion (autopsy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>I</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>–</td>
<td>–</td>
<td>+</td>
<td>II</td>
<td>–</td>
</tr>
<tr>
<td>3</td>
<td>–</td>
<td>–</td>
<td>+</td>
<td>II</td>
<td>–</td>
</tr>
<tr>
<td>4</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>II</td>
<td>–</td>
</tr>
<tr>
<td>5</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>II</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>I</td>
<td>+</td>
</tr>
<tr>
<td>7</td>
<td>++</td>
<td>++</td>
<td>–</td>
<td>II</td>
<td>++</td>
</tr>
</tbody>
</table>

CHF = congestive heart failure. –: none; +: slight to moderate; ++: severe.

MI-RV, all 12 cases with posterior MI-RV had significant narrowing of the right coronary artery (RCA) and the 1 case with anterior MI-RV had significant narrowing of the left anterior descending artery (LAD). In 22 cases with transmural posterior MI without MI-RV, the coronary arteries were also examined in detail. Nineteen cases (86%) had similar narrowing lesions in the RCA. The incidence of significant narrowing of the RCA in cases with MI-RV was greater than that in those without MI-RV, but the difference was not significant. Eight cases (67%) with MI-RV had significant narrowing of the LAD and the incidence was similar to that (64%) in those cases with left ventricular MI. The percentage of cases with significant narrowing of the RCA was greater than that of the LAD (p < 0.05).

Clinical manifestations, chest radiography and pathologic findings:

The clinical course of 7 cases with fresh posterior MI-RV were examined (Table V). There were 5 cases showing moist rales in the clinical course suggesting the presence of pulmonary congestion, which was confirmed by chest radiography. The 2 cases whose lungs showed no congestion at autopsy had hypotension without congestion on chest radiography and/or physical examination. Of the 5 cases with grade II MI-RV, 2 showed
hypotension and 2 showed pulmonary congestion only. Both cases with grade I MI-RV showed pulmonary congestion without hypotension. No case showed isolated right heart failure without pulmonary congestion.

**Discussion**

Myocardial infarction of the right ventricle (MI-RV) has been associated with left ventricular MI in the literature. Almost all of the MI-RV were associated with left ventricular MI. However, there have been a few reports of isolated MI-RV without left ventricular MI. Wade noted that MI associated with MI-RV had major infarction of the left ventricular posterior wall. Isner et al reported MI-RV in 14% of 236 patients with transmural MI and 24% of 139 patients with posterior MI at necropsy. They also found that the incidence of MI-RV was 50% in patients with transmural posteroseptal infarction. However, Hiraoka et al reported the incidence of MI-RV to be 20% of 87 aged patients with MI, 4 (5%) of whom had anterior MI-RV. Wartman et al also described 12 cases (5%) with anterior MI-RV out of 235 cases with MI. We found 1 case of anterior MI-RV associated with anterior MI.

MI-RV occurred as a complication of large transmural left ventricular MI and most (92%) of them were of the posterior wall. The overall incidence of posterior MI-RV was 22% of all MI, and it was 43% in fresh MI. The highest incidence of MI-RV was observed in fresh posterior MI, and this suggests the poor prognosis of MI-RV because of the lower incidence of MI-RV in healed MI.

The diagnosis of MI-RV has been difficult by conventional 12 lead ECG without right precordial leads and clinical manifestations. Recently, there have been many reports dealing with hemodynamic features of MI-RV. Predominant hemodynamic features of MI-RV were reported to be; (1) low cardiac output, (2) normal left ventricular filling pressure and (3) right atrial pressure elevated more than left ventricular filling pressure. Ueda et al analyzed aged patients with acute MI and noted a high incidence of patients showing a low cardiac output without an elevation of the left ventricular filling pressure (subset III of Forrester’s classification) in posterior MI. They attributed it to the associated interventricular septal MI and/or MI-RV which was supported by an autopsy study. Cohn et al reported on the clinical and hemodynamic features of MI-RV with autopsy studies in 2 cases. They recognized a syndrome of low output and hypotension, which they attributed to the fact that the right ventricle was unable to maintain adequate left ventricular filling.
We analyzed the clinical features of MI-RV. Only 2 of the 7 cases, whose clinical and pathologic data were studied in detail, showed hypotension without pulmonary congestion. However, we could not find any of the so-called characteristic clinical findings of MI-RV, including isolated right heart failure.

From echocardiographic\(^8\)-\(^{11}\) and radioisotopic examinations,\(^9\),\(^{14}\),\(^{15}\) right ventricular dilatation (RVD) has been suggested as playing an important role in the compensatory mechanisms which may augment right ventricular ejection. The ratio of the echocardiographic end-diastolic dimension of the right ventricle to left ventricle was significantly greater in patients with MI-RV than those without. We studied the gross morphology of MI-RV in relation to right ventricular changes.

The cases with MI-RV had RVD more frequently than those without MI-RV. Among the cases with posterior MI, the cases with only a posterior septal infarction had RVD more frequently than those without septal infarction but less than those with MI-RV. Thus, RVD was the important morphologic feature distinguishing the cases with MI-RV from those without MI-RV. As for the extent of MI-RV, most cases with RVD showed involvement of 1/3 to 2/3 or more of the right ventricular free wall. The patients who had an MI-RV and no RVD had MI-RV of a mild degree. RVD is assumed to be associated with advanced right ventricular dysfunction due to severe myocardial injury. The elevated right ventricular end-diastolic pressure and compensatory mechanisms including Frank-Starling’s law might play important roles in RVD.

Right ventricular hypertrophy (RVH) has been thought to play an important role in the development of MI-RV,\(^{17}\),\(^{27}\) but our observation is not consistent with this speculation. In this study, only 2 cases (15%) with MI-RV showed RVH. Seven (8%) of the 93 cases with left ventricular MI showed RVH. Therefore, RVH was not significantly more frequent among the cases with MI-RV than those without MI-RV.

Coronary artery findings of MI-RV were assessed. A high frequency of severe atherosclerosis of the RCA in cases with MI-RV has been noted,\(^{18}\)-\(^{20}\) but the frequency of atherosclerosis of RCA has not been compared with the frequency of either LAD or LCx in most reports. There are a few reports on MI-RV with detailed examination of the coronary arteries. Isner et al\(^{18}\) reported that the percentage with significant narrowing of the RCA was similar in cases with and those without MI-RV among the cases of posterior MI, but Hiraoka et al\(^{20}\) considered that severe narrowing of the proximal RCA is characteristic of MI-RV. Among our cases with posterior MI, the degree of narrowing of the RCA in cases with MI-RV was greater than that
in those without MI-RV. This observation is not consistent with Isner's report, and the percentage of cases with significant narrowing of the RCA was significantly greater than that of the LAD.

In conclusion, the results suggest that the incidence of right ventricular dilatation and significant narrowing of the RCA was greater in cases with posterior MI-RV than those with posterior MI only.

REFERENCES

18. Isner JM, Roberts WC: Right ventricular infarction complicating left ventricular infarce-