SUMMARY  Real-time, two-dimensional echocardiographic studies were performed in 10 patients with acute myocardial infarction who had clinical features suggestive of right ventricular involvement. All patients showed right ventricular wall motion abnormalities. In the four-chamber view, seven patients showed akinesis of the entire right ventricular diaphragmatic wall and three showed akinesis of segments of the diaphragmatic wall. Segmental dyskinetic areas involving the right ventricular free wall were identified in four patients. One patient showed a large right ventricular apical aneurysm. Other echocardiographic features included enlargement of the right ventricle in eight cases, paradoxic ventricular septal motion in seven cases, tricuspid incompetence in eight cases, dilatation of the stomach in four cases and localized pericardial effusion in two cases. Right ventricular infarction was confirmed by radionuclide methods in seven patients, at surgery in one patient and at autopsy in two patients.

RIGHT VENTRICULAR INFARCTION may frequently complicate left ventricular infarction and represents an important clinical syndrome whose recognition may have vital therapeutic implications.

Isolated infarction of the right ventricle is uncommon, occurring in only 2.2% of Wartman and Hellerstein’s 160 autopsied patients. Right ventricular infarction more often occurs as an extension of left ventricular infarction and involvement of the right ventricle may exist in as many as one-third of the patients with inferior myocardial infarction. Confirmation of right ventricular infarction has been limited to autopsy studies, but newer methods of noninvasive assessment suggest that accurate antemortem diagnosis is possible. We describe the real-time, two-dimensional echocardiographic features noted in 10 patients with clinical features of right ventricular myocardial infarction.

**Methods**

As part of ongoing clinical and echocardiographic studies in the coronary care unit, 10 patients with clinical features of right ventricular infarction were studied by real time, two-dimensional echocardiography. The diagnosis of acute myocardial infarction was based on a history of characteristic chest pain, electrocardiographic evidence of myocardial injury with subsequent evolutionary changes and positive creatine kinase isoenzyme assay. Patient characteristics are presented in table 1.

Right ventricular infarction was proved at autopsy in two patients, at surgery for repair of a ruptured ven-
Table 1. Patient Characteristics

<table>
<thead>
<tr>
<th>Pt</th>
<th>Age (years)</th>
<th>Sex</th>
<th>ECG</th>
<th>Chest x-ray</th>
<th>MB</th>
<th>Technetium pyrophosphate scan</th>
<th>Blood pressure (mm Hg) RA PA PCW</th>
<th>Mean right-heart pressures (mm Hg)</th>
<th>Cardiovascular complications</th>
<th>Autopsy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>54</td>
<td>M</td>
<td>DMI</td>
<td>Clear</td>
<td>+</td>
<td>+</td>
<td>94/60</td>
<td>10 — —</td>
<td>Sinus bradycardia</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>82</td>
<td>F</td>
<td>DMI</td>
<td>Clear</td>
<td>+</td>
<td>—</td>
<td>90/50</td>
<td>15 — —</td>
<td>Complete AV block</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>58</td>
<td>F</td>
<td>DMI/PMI</td>
<td>Clear</td>
<td>+</td>
<td>+</td>
<td>70/0</td>
<td>8 — —</td>
<td>Sinus bradycardia</td>
<td>NA</td>
</tr>
<tr>
<td>4</td>
<td>78</td>
<td>F</td>
<td>DMI</td>
<td>Clear</td>
<td>+</td>
<td>Technically inadequate</td>
<td>90/60</td>
<td>20 22 17</td>
<td>Complete AV block</td>
<td>NA</td>
</tr>
<tr>
<td>5</td>
<td>64</td>
<td>M</td>
<td>DMI</td>
<td>Clear</td>
<td>+</td>
<td>Not done</td>
<td>60 palpation</td>
<td>15 21 16</td>
<td>Varying AV block Cardiogenic shock</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>M</td>
<td>DMI/PMI</td>
<td>Clear</td>
<td>+</td>
<td>Not done</td>
<td>182/110</td>
<td>12 16 16</td>
<td>Ventricular septal rupture (surgical repair)</td>
<td>NA</td>
</tr>
<tr>
<td>7</td>
<td>62</td>
<td>M</td>
<td>DMI/ALMI</td>
<td>Clear</td>
<td>+</td>
<td>+</td>
<td>90/0</td>
<td>21 21 21</td>
<td>Frequent ventricular ectopy</td>
<td>NA</td>
</tr>
<tr>
<td>8</td>
<td>58</td>
<td>F</td>
<td>DMI</td>
<td>Clear</td>
<td>+</td>
<td>+</td>
<td>60/0</td>
<td>19 20 18</td>
<td>Complete AV block</td>
<td>NA</td>
</tr>
<tr>
<td>9</td>
<td>58</td>
<td>M</td>
<td>DMI/APMI</td>
<td>Clear</td>
<td>+</td>
<td>+</td>
<td>90/55</td>
<td>17 22 18</td>
<td>1° AV block</td>
<td>NA</td>
</tr>
<tr>
<td>10</td>
<td>61</td>
<td>M</td>
<td>DMI</td>
<td>Clear</td>
<td>+</td>
<td>+</td>
<td>96/60</td>
<td>10 16 8</td>
<td>Ventricular tachycardia Not obtained</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: DMI = diaphragmatic myocardial infarction; PMI = posterior myocardial infarction; ALMI = anterolateral myocardial infarction; APMI = apical myocardial infarction; MB = creatine kinase MB fraction; RA = right atrium; PA = pulmonary artery; PCW = pulmonary capillary wedge; AV = atrioventricular; NA = not applicable.

tricular septum in one patient and with technetium pyrophosphate scans in six patients. One patient with a technically inadequate myocardial scan but a characteristic clinical presentation and subsequent first-pass technetium pertechnetate scan that showed a right ventricular aneurysm is also included. Coronary artery disease was confirmed by standard pathologic techniques in the two autopsied patients, by coronary angiography in the patient operated on for repair of the ruptured ventricular septum and in one patient electively catheterized after infarction. Only one patient had a history of myocardial infarction.

Myocardial scanning with 15 mCi of technetium-99m stannous pyrophosphate was performed within 96 hours of admission in seven patients and on the fifth hospital day in one patient (no. 4). Infarct scintigrams were obtained in the anteroposterior, 45° left anterior oblique and left lateral projections and interpreted by an independent observer without knowledge of clinical or laboratory data. Right ventricular infarction was considered present if abnormal radionuclide uptake was observed in the right ventricle in the anteroposterior and left anterior oblique views.

Real-time, two-dimensional echocardiography was performed in eight patients within 48 hours of admission and on the fourth hospital day in two patients. A commercially available Advanced Technology Laboratory wide-angle 90° mechanical sector scanner with a 3-MHz transducer was used. All patients were studied in the supine and in various left lateral decubitus positions. Images were recorded on videotape in standard long-axis, parasternal short-axis and four-chamber planes from the apical and subcostal positions.

For the purpose of analyzing wall motion abnormalities, the right ventricle was considered to have three walls: the diaphragmatic or inferior wall, the ventricular septum and the free wall. The diaphragmatic portion represented the right ventricular wall in contact with the diaphragm and was demarcated and identified by the presence of underlying echoes from liver tissue. The free wall represented the remaining right ventricle with the exception of the ventricular septum. Each wall was then divided into segments (fig. 1).

In addition to the standard planes, we could obtain four other planes in some of the patients (fig. 1B). An inferobasal right ventricular plane was obtained in patients 6, 9 and 10 by angling the transducer inferiorly from the apical four-chamber view such that the sector exited from the posterobasal portion of the right ventricle near the junction of the basal free wall with the diaphragmatic surface of the right ventricle (fig. 2). This plane was used to evaluate the motion of the basal aspect of the diaphragmatic and free walls of the right ventricle. A subcostal short-axis view was obtained in patients 4, 5 and 10 by rotating the transducer from the subcostal four-chamber position; another subcostal plane was imaged in patient 4 by directing the transducer such that the tricuspid valve apparatus, right ventricular apex and the pulmonary valve could be visualized simultaneously (RV inflow-apex-outflow plane) (fig. 1B). A right-heart apical two-chamber view was obtained in patients 9 and 10 from the apical four-chamber position by rotating the sector until the left ventricular chamber disappeared and the sector imaged the anterior and diaphragmatic surfaces of the right ventricle and exited through the right atrium (fig. 3).

Maximal right and left ventricular dimensions were measured at end-diastole in both the long- and short-axis views obtained from the parasternal transducer positions. Right ventricular enlargement was considered present when the end-diastolic ratio between
the right and left ventricles was greater than 0.5 in both views.

Wall motion of the right ventricle was categorized as akinetic, dyskinetic or normal. Wall motion was considered akinetic when no inward motion or thickening was noted during systole with respiration held. Dyskinesia was defined as a paradoxical aneurysmal bulging of the right ventricular wall during systole. An aneurysm was considered present when there was a diastolic wall shape deformity with akinesis or dyskinesis during systole. All other segments were considered to have normal motion if inward motion or thickening was observed during systole. No subjective judgment of hypokinesia was made for this study.

Echocardiographic contrast studies were performed using 5-ml bolus injections of 5% dextrose solution in nine of 10 patients. These injections were made in the right atrial chamber through a #7 triple-lumen Swan-
Ganz catheter that had been inserted at the antece-
tubal fossa in six patients and through an upper-extrem-
ity peripheral i.v. line in two. Tricuspid regurgitation
was judged to be present if a to-and-fro motion of con-
tast echoes across the tricuspid valve or a prominent
and persistent reflux of contrast material from the
right atrium into the inferior vena cava and hepatic
veins was observed.\(^7\)\(^8\)

All echocardiograms were analyzed by two inde-
pendent observers. Patients gave informed consent for
all invasive procedures.

**Results**

Two-dimensional echocardiographic records suit-
able for analysis were obtained in all patients. Nine pa-
ients were adequately studied from the parasternal,
apical and subcostal positions. In one patient, who
had a history of chronic obstructive pulmonary dis-
ease, only the subcostal view was adequate. No dif-
ferences were noted in the findings of the two
observers who analyzed all echocardiograms in-
dependently.

All patients had right ventricular wall motion ab-
normalities (tables 2 and 3). In the subcostal four-
chamber plane, the most striking abnormality was
akinesia of the entire diaphragmatic wall of the right
ventricle in seven patients and of segments of the
diaphragmatic wall in three patients. In the parasternal
or subcostal short-axis plane, six of nine patients had

**Table 2. Two-dimensional Echocardiographic Findings in Standard Planes**

<table>
<thead>
<tr>
<th>Pt</th>
<th>Parasternal long-axis</th>
<th>Parasternal short-axis</th>
<th>Apical four-chamber plane</th>
<th>Subcostal four-chamber plane</th>
<th>Ventricular septal motion</th>
<th>Tricuspid regurgitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normal</td>
<td>FW normal</td>
<td>Normal</td>
<td>Akinetic</td>
<td>Normal</td>
<td>Absent</td>
</tr>
<tr>
<td>2</td>
<td>PS normal</td>
<td>FW normal</td>
<td>Normal</td>
<td>PS normal</td>
<td>Normal</td>
<td>Paradoxical</td>
</tr>
<tr>
<td>3</td>
<td>Normal</td>
<td>FW normal</td>
<td>Akinetic</td>
<td>Normal</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>PS dyskinetic</td>
<td>PS dyskinetic</td>
<td>PS akinetiC</td>
<td>Paradoxical</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Normal</td>
<td>Not visualized</td>
<td>Akinetic</td>
<td>Paradoxical</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Normal</td>
<td>Not visualized</td>
<td>PS normal</td>
<td>Normal</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>PS normal</td>
<td>PS normal</td>
<td>PS normal</td>
<td>Akinetic</td>
<td>Paradoxical</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Normal</td>
<td>PS normal</td>
<td>MS dyskinetic</td>
<td>Akinetic</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Normal</td>
<td>PS normal</td>
<td>MS dyskinetic</td>
<td>Akinetic</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>PS normal</td>
<td>PS normal</td>
<td>PS normal</td>
<td>Absent</td>
<td>Paradoxical</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: RV = right ventricle; FW = free wall; DW = diaphragmatic wall; PS = proximal segment; MS = middle segment; AP = apical segment.
posterior portion of the ventricular septum was noted at autopsy in patients 2 and 10, who had abnormal ventricular septal motion; both died within a few days after admission. Both had severe proximal obstructive lesions of the left anterior descending coronary artery and right coronary artery.

Echocardiographic assessment of tricuspid insufficiency was performed in nine of 10 patients. Tricuspid regurgitation was judged present in eight patients and absent in one patient.

Eight of nine patients who could be imaged from the parasternal positions had a right ventricular/left ventricular end-diastolic ratio greater than 0.5 both in the long- and short-axis planes suggestive of right ventricular chamber enlargement (table 3). Patient 6, who had a ratio of less than 0.5, probably represented a false-negative due to an aneurysmal bulging of the ventricular septum adjacent to an easily visualized ventricular septal defect. At surgery this was proved to be a dissecting hematoma, which extended along the ventricular septum and posterior ventricular wall until it communicated to the right ventricle at the apex.

Other echocardiographic features included a dilated stomach in four patients; in three it was best imaged by placing the transducer near the cardiac apex with the patient in the left lateral decubitus position, and in the fourth it was imaged from the subcostal transducer position. Confirmation that this space represented the stomach was obtained by generation of an echocardiographic contrast effect by the patient sipping a small quantity of water (fig. 6). Two patients had a localized 8-10-mm echo-free space anterior to the right ventricular wall that increased in size to 12-13 mm over the next 48 hours, indicative of a small-to-moderate pericardial effusion. One patient who had a pacing catheter had tricuspid valve prolapse that involved the septal leaflet. Perforation of the right ventricular apex by a temporary pacing catheter was also diagnosed echocardiographically in this patient.

**Discussion**

Although the right ventricular involvement was anatomically confirmed in only three of our patients, clinical features in the other seven patients are consistent with right ventricular infarction. Six of these seven patients had positive technetium stannous pyrophosphate scans, which correlate well with transmural myocardial infarction. This method has been successfully applied to the diagnosis of right ventricular involvement in acute myocardial infarction. In the remaining patient, the clinical and hemodynamic evidence of right ventricular involvement in acute myocardial infarction is supported by the abnormal radionuclide scan, which demonstrated right ventricular aneurysmal formation. This patient did not have a history of myocardial infarction.

Experimental studies have shown that areas of periinfarct ischemia or possible myocardial infarction
with some preservation of contractile function may be echocardiographically visualized as hypokinesis adjoining akinetic segments. The quantitative description of hypokinesis relative to normal right ventricular wall motion, however, is not possible. Although many segments of the right ventricular wall showed motion thought to represent hypokinesis, the inclusion of these segments as normal in the present study would tend to underestimate observed wall motion abnormalities and increase the specificity of observed akinesis of right ventricular infarction.

Paradoxical ventricular septal motion would be expected in an acutely volume-overloaded dilated right ventricle with tricuspid regurgitation, and this abnormality was noted in seven of 10 patients. No conclusion can be drawn, however, about the ability of right ventricular infarction alone to cause paradoxical ventricular septal motion because all patients in this study had coexisting left ventricular infarction.

To our knowledge, echocardiographic description of an aneurysm of the right ventricle has not previously been reported. Such entities are rare and represent no more than 5% of all cardiac aneurysms. Imaging a diastolic wall shape deformity with systolic akinesis or dyskinesis, such as that seen in patient 10, is consistent with this diagnosis (fig. 4). Patients 4 and 6, who had localized dyskinetic right ventricular segments, were proved to have aneurysms at surgery and by radionuclide scanning. The echocardiographic findings in these patients may represent acute aneurysm formation, as none had a history of myocardial infarction.

The gastric dilatation observed in four patients is of uncertain origin. The echocardiographic appearance is such that it may mimic a left ventricular pseudoaneurysm. It is interesting to speculate about a relationship between gastric distention and the gastrointestinal and vasovagal symptoms commonly associated with inferior left ventricular or right ventricular myocardial infarction. Tricuspid valve prolapse seen in patient 5 may have been related to the presence of a pacing catheter across the tricuspid valve. In the same patient, the echocardiographic diagnosis of ventricular perforation (proved at autopsy) illustrates the possible hazard of placing a temporary right ventricular pacemaker when the right ventricle is involved in acute myocardial infarction.

In summary, our preliminary study indicates that
echocardiographic asynergy of the right ventricle is observed when right ventricular involvement occurs in acute myocardial infarction. Echocardiographic features of such infarctions commonly include paradoxical ventricular septal motion, which may result from right ventricular volume overload or severe ischemia of the ventricular septum, right ventricular chamber enlargement and tricuspid regurgitation as evidenced by echocardiographic contrast studies. Dilatation of the stomach and localized pericardial effusion may also be observed (table 3). Echocardiographic study is most helpful when the subcostal plane is used to image the diaphragmatic right ventricular wall and additional newer planes may also contribute to this evaluation. Further studies are necessary to determine the specificity of these results and their potential role in the clinical evaluation and decision to proceed with invasive monitoring in patients with acute myocardial infarction.

Acknowledgment

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References

4. Isner JM, Roberts WC: Right ventricular infarction complicating left ventricular infarction secondary to coronary heart disease. Frequency, location, associated findings and significance from analysis of 236 necropsy patients with acute or healed myocardial infarctions. Am J Cardiol 42: 885, 1978

Figure 6. Dilatation of the stomach (ST). The large echo-free space (ST) was imaged by placing the transducer near the cardiac apex. Swallowing sips of water resulted in progressive opacification of this space (arrow), confirming its relationship to the gastrointestinal tract.
Two-dimensional echocardiographic features of right ventricular infarction.
B D'Arcy and N C Nanda

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