Inferior Myocardial Infarction
High-Risk Subgroups

Peter B. Berger, MD, and Thomas J. Ryan, MD

Inferior myocardial infarctions account for 40–50% of all acute myocardial infarctions\(^1,2\) and are generally viewed as having a more favorable prognosis than anterior wall infarctions. Data from a number of recent trials of thrombolytic therapy in acute infarction appear to support this view, with mortality rates of 2–9% reported among patients with inferior infarctions assigned to the “standard care” or control groups within these studies.\(^1–3\) It is, thus, not surprising that many of these trials have failed to demonstrate reduced mortality after thrombolytic therapy in the subset of patients with inferior infarction.\(^1,3,4\) It is important to note, however, that nearly 50% of patients suffering inferior infarction will have complications or distinguishing features associated with an increased mortality that will substantially alter an otherwise favorable prognosis. It is the purpose of this review to identify the complications most likely to occur during acute inferior infarction as defined electrocardiographically by ST-segment elevation in leads II, III, and aVF. Specifically, heart block, concomitant precordial ST-segment depression, and right ventricular infarction are discussed, their pathogenesis is reviewed, and their impact on prognosis is considered. Also, the data that exist on the impact of thrombolytic therapy on these high-risk subgroups are reviewed.

Heart Block

As summarized in Table 1, there is a 19% incidence of high-degree (second- or third-degree) heart block complicating acute inferior infarction.\(^5–20\) Approximately one half of the patients who develop heart block do so through a gradual progression of their conduction delay, whereas the remainder abruptly develop the highest degree of heart block they will attain.\(^5,9,12,15,21\) The timing of the onset of the heart block in acute inferior infarction is presented in Table 2.\(^2,9,15,16,22,23\) Roughly 8% of all patients who have an inferior infarction have high-degree heart block on arrival at the emergency department, and approximately two thirds of the patients who are eventually going to develop high-degree heart block have done so within 24 hours of admission. Virtually all the remaining patients who develop heart block do so within 3 days of admission.

The overall experience with heart block occurring in association with acute inferior infarction indicates that the heart block is responsive to atropine or isoproterenol in the majority of cases, usually does not require placement of a temporary pacemaker, and almost never requires implantation of a permanent pacemaker.\(^22\) Given the relative ease of treatment and rather short duration of the conduction abnormality, it is surprising that the development of heart block during inferior infarction is associated with an in-hospital mortality rate of more than 20%.

Virtually every study on the subject has shown a markedly increased in-hospital mortality in patients whose inferior infarctions are complicated by the development of second- or third-degree (high-degree) heart block. As shown in Table 3, the mean in-hospital mortality for patients with high-degree heart block is 23%,\(^5,9,14,17,18,21,22,24–26\) When third-degree heart block is present, the average mortality is 29% (Table 4).\(^12,13,25,27–33\) All of the studies cited were conducted in the era of coronary care units, and pacemakers were used when appropriate. It is of interest that almost none of the patients was believed to have died as a result of their heart block (although many died with persistent heart block) or from the treatment of the heart block.

It now appears that this increased mortality relates to the observation that heart block developing during inferior infarction is a marker for increased infarction size. Many studies have shown that patients with inferior infarctions associated with heart block have larger infarctions than those without heart block based on estimation of infarct size by enzyme levels,\(^9,13,34\) left and right ventricular ejection fractions determined by gated blood pool scan,\(^14,25\) and wall motion analyses of the left and right ventricles determined by echocardiography.\(^25\) While these studies serve to confirm an association between larger infarcts and atrioventricular (AV) block, they do not explain the nature of the relation or the mechanism of the heart block itself.

The two most common explanations that have been offered to explain the etiology of the heart block...
TABLE 1. Incidence of High-Degree Heart Block in Acute Inferior Infarction

<table>
<thead>
<tr>
<th>Study</th>
<th>Patients (n)</th>
<th>Second-degree (%)</th>
<th>Third-degree (%)</th>
<th>Second or third-degree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotman⁵</td>
<td>181</td>
<td>7</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>Jewitt⁶</td>
<td>128</td>
<td>16</td>
<td>12</td>
<td>28</td>
</tr>
<tr>
<td>Julian⁷</td>
<td>44</td>
<td>9</td>
<td>16</td>
<td>25</td>
</tr>
<tr>
<td>Stock⁸</td>
<td>130</td>
<td>5</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Tans⁹</td>
<td>843</td>
<td>6</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>Bassan¹¹</td>
<td>51</td>
<td>10</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>Gupta¹⁰</td>
<td>80</td>
<td>?</td>
<td>15</td>
<td>?</td>
</tr>
<tr>
<td>Brown¹²</td>
<td>160</td>
<td>?</td>
<td>8</td>
<td>?</td>
</tr>
<tr>
<td>Nicoll¹³</td>
<td>749</td>
<td>?</td>
<td>13</td>
<td>?</td>
</tr>
<tr>
<td>Kaul¹⁴</td>
<td>82</td>
<td>?</td>
<td>?</td>
<td>34</td>
</tr>
<tr>
<td>Feigl¹⁵</td>
<td>288</td>
<td>?</td>
<td>?</td>
<td>13</td>
</tr>
<tr>
<td>Brat¹⁶</td>
<td>67</td>
<td>?</td>
<td>?</td>
<td>28</td>
</tr>
<tr>
<td>Dubois¹⁷</td>
<td>447</td>
<td>?</td>
<td>?</td>
<td>20</td>
</tr>
<tr>
<td>Norris¹⁸</td>
<td>96</td>
<td>?</td>
<td>?</td>
<td>27</td>
</tr>
<tr>
<td>Coureil¹⁹</td>
<td>35</td>
<td>?</td>
<td>?</td>
<td>26</td>
</tr>
<tr>
<td>Katz²⁰</td>
<td>167</td>
<td>?</td>
<td>?</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>(101 of 1,377)</td>
<td>7</td>
<td>(283 of 2,366)</td>
<td>12</td>
</tr>
</tbody>
</table>

are 1) interruption of blood flow to the AV node and 2) high vagal tone resulting from the Bezold-Jarisch reaction.

Inferior infarctions are caused by occlusion of the dominant artery in more than 70% of cases. Because the AV nodal artery is derived from the dominant artery, it was originally believed that necrosis of the AV node caused the heart block. However, it has been shown that even complete occlusion of the AV nodal artery rarely causes necrosis of the AV node.³⁵ There are three reasons for this. First, the rate of oxygen consumption in conducting tissue is only one fifth as great as in contractile musculature, making it more resistant to prolonged hypoxia.³⁶ Second, conducting tissue has a high concentration of glycogen, allowing lesser dependence on oxidative metabolism.³⁷ The third postulate is that collateral blood flow to the AV node may be sufficient to prevent significant or irreversible ischemic damage. Ischemia without necrosis may still be an important contributing factor, and likely is. However, the AV nodal artery is a relatively distal branch of the dominant artery, arising some distance from the ostium as it bends to course along the crux of the heart. Because most infarctions are the result of occlusions of the artery proximal to the origin of the AV nodal artery, nodal ischemia would be anticipated to occur in the majority of inferior infarctions. The fact that only 20% of infarctions result in high-degree AV block suggests that factors other than ischemia must also play a role.

An alternate hypothesis invokes increased vagal tone resulting from the stimulation of afferent nerves adjacent to the AV node by ischemia. The resultant outpouring of parasympathetic stimulation via the vagus nerve produces sinus bradycardia, hypotension, and in some patients heart block. This has been called the Bezold-Jarisch reflex.³⁸ This proposed mechanism fails to explain the increased infarct size seen in patients with heart block and does not account for the cases of heart block that occur in the absence of sinus slowing, as is frequently the case.

Recently, two additional explanations for the mechanism of heart block in acute inferior infarction have been proposed that might account for the association between heart block and an increase in infarct size. The first recognizes the role of intracellular electrolytes and metabolites, in particular, potassium and adenosine, that are released from ischemic cells. It has been postulated that these chemical mediators cause the transient block seen in inferior infarction.⁶ High levels of potassium are well known to cause heart block. It has been shown by collecting blood samples in the coronary sinus during infarction that local potassium levels can be as high as 12 meq/dl.⁵⁹ Adenosine has been shown in animal models to produce AV block⁴⁰ and has been used in several human studies for this effect in the treatment of AV nodal microreentrant rhythms.⁴¹ Interestingly, aminophylline, which blocks adenosine receptors in the heart, has been demonstrated to reverse the AV block in animals⁴² and in three patients with inferior infarction whose heart block was resistant to atropine.⁴³,⁴⁴ If these chemical mediators play an important role in the development of heart block, this mechanism might serve to explain the association with larger infarcts because larger infarcts would be expected to release more intracellular potassium and adenosine.

The second theory that might explain the association of heart block with larger infarct size and increased mortality relates to the collateral blood flow to the AV node. It has been theorized that patients

TABLE 2. Onset of High-Degree Atrioventricular Block in Acute Inferior Infarction

<table>
<thead>
<tr>
<th>Study</th>
<th>Patients (n)</th>
<th>Present on admission (n) (%)</th>
<th>Present within 24 hours (n) (%)</th>
<th>Occurred after 24 hours (n) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sclarovsky²²</td>
<td>76</td>
<td>22 (29)</td>
<td>36 (47)</td>
<td>40 (53)</td>
</tr>
<tr>
<td>Feigl¹⁵</td>
<td>34</td>
<td>15 (44)</td>
<td>22 (65)</td>
<td>12 (35)</td>
</tr>
<tr>
<td>Tans⁹</td>
<td>144</td>
<td>69 (48)</td>
<td>99 (69)</td>
<td>45 (31)</td>
</tr>
<tr>
<td>Braat¹⁶</td>
<td>19</td>
<td>5 (26)</td>
<td>14 (74)</td>
<td>5 (26)</td>
</tr>
<tr>
<td>Kostuk²³</td>
<td>20</td>
<td>11 (55)</td>
<td>15 (75)</td>
<td>5 (25)</td>
</tr>
<tr>
<td>Total</td>
<td>293</td>
<td>122 (42)</td>
<td>186 (63)</td>
<td>107 (37)</td>
</tr>
</tbody>
</table>
with inferior infarctions who develop heart block may be more likely to have concomitant stenosis of the left anterior descending artery (LAD) proximal to the origin of the septal perforators, which provide a rich network of collateral vessels between the LAD and the AV nodal arteries. This would predispose the AV node to greater degrees of ischemia. To test this hypothesis, Bassan et al\textsuperscript{11} studied a consecutive series of 51 survivors of inferior infarction who underwent coronary angiography. Eleven of the 51 developed heart block. Comparing patients with and without heart block revealed a sixfold greater incidence of heart block if the LAD had a 75\% or greater stenosis before the second septal perforator. The presence of heart block had a sensitivity of 31\%, a specificity of 95\%, and a predictive value of 91\% for the presence of concomitant LAD obstruction. However, two subsequent studies produced opposite findings. An increased incidence of LAD disease was not found in the Thrombolysis in Acute Myocardial Infarction (TAMI)\textsuperscript{45} or Thrombolysis In Myocardial Infarction (TIMI)\textsuperscript{46} populations. Heart block during inferior infarction was not predictive of multivessel disease in either of these studies.

No placebo-controlled thrombolytic trial has reported specifically on the outcome of patients with inferior infarction who have high-degree heart block on presentation to the hospital. Data from the TIMI II trial, in which all patients enrolled in the study were treated with intravenous recombinant tissue-type plasminogen activator (rt-PA), reveal an in-hospital mortality of 9\% (20 of 231) for patients who developed second- or third-degree heart block.\textsuperscript{46} The TAMI investigators report a mortality of 14\% among patients with third-degree heart block after thrombolytic therapy.\textsuperscript{45} The mortality rate among patients with heart block in these trials in which thrombolytic therapy was used is less than the 23\% mortality among patients with high-degree heart block from pooled data from before the thrombolytic era. However, the relative risk of mortality associated with heart block after thrombolytic therapy (3.8 in the TIMI II trial compared with 2.6 in the prethrombolytic era) remains high. Therefore, we have no direct evidence at the present time that thrombolytic therapy is of particular benefit in this group of patients.

**Precordial ST-Segment Depression**

Acute inferior infarction is accompanied by ST-segment depression in the precordial chest leads in approximately one half of patients suffering a first, inferior infarction. However, the significance of the precordial ST-segment depression is less than clear. Initially, it was believed that the anterior ST-segment

### Table 3. Hospital Mortality in Acute Inferior Infarction Complicated by High-Degree Heart Block

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>With heart block (n)</th>
<th>Mortality (%)</th>
<th>Without heart block (n)</th>
<th>Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dubois\textsuperscript{17}</td>
<td>1986</td>
<td>88</td>
<td>24</td>
<td>359</td>
<td>4</td>
</tr>
<tr>
<td>Kaul\textsuperscript{14}</td>
<td>1986</td>
<td>28</td>
<td>27</td>
<td>54</td>
<td>6</td>
</tr>
<tr>
<td>Sclarovsky\textsuperscript{22}</td>
<td>1984</td>
<td>76</td>
<td>13</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Strasberg\textsuperscript{25}</td>
<td>1984</td>
<td>26</td>
<td>15</td>
<td>113</td>
<td>6</td>
</tr>
<tr>
<td>Tans\textsuperscript{9}</td>
<td>1980</td>
<td>144</td>
<td>22</td>
<td>699</td>
<td>9</td>
</tr>
<tr>
<td>Rotman\textsuperscript{5}</td>
<td>1973</td>
<td>45</td>
<td>24</td>
<td>136</td>
<td>16</td>
</tr>
<tr>
<td>Beregovich\textsuperscript{21}</td>
<td>1969</td>
<td>13</td>
<td>23</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Norris\textsuperscript{18}</td>
<td>1969</td>
<td>26</td>
<td>19</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Chatterjee\textsuperscript{24}</td>
<td>1969</td>
<td>65</td>
<td>23</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Friedberg\textsuperscript{26}</td>
<td>1968</td>
<td>16</td>
<td>44</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>527</td>
<td>23</td>
<td><strong>1,225</strong></td>
<td>9</td>
</tr>
</tbody>
</table>

### Table 4. Hospital Mortality in Acute Inferior Infarction Complicated by Complete Heart Block

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>With heart block (n)</th>
<th>Mortality (%)</th>
<th>Without heart block (n)</th>
<th>Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicod\textsuperscript{13}</td>
<td>1988</td>
<td>95</td>
<td>24</td>
<td>654</td>
<td>6</td>
</tr>
<tr>
<td>Rodrigues\textsuperscript{27}</td>
<td>1987</td>
<td>111</td>
<td>32</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Gould\textsuperscript{28}</td>
<td>1979</td>
<td>16</td>
<td>6</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Leth\textsuperscript{31}</td>
<td>1974</td>
<td>36</td>
<td>22</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Christiansen\textsuperscript{32}</td>
<td>1973</td>
<td>16</td>
<td>19</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Kostuk\textsuperscript{23}</td>
<td>1970</td>
<td>20</td>
<td>45</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Brown\textsuperscript{12}</td>
<td>1969</td>
<td>16</td>
<td>25</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Lassers\textsuperscript{29}</td>
<td>1968</td>
<td>32</td>
<td>27</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Gregory\textsuperscript{33}</td>
<td>1968</td>
<td>15</td>
<td>33</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Paulk\textsuperscript{20}</td>
<td>1966</td>
<td>32</td>
<td>41</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>389</td>
<td>29</td>
<td><strong>654</strong></td>
<td>6</td>
</tr>
</tbody>
</table>
depression was merely an electrocardiographic phenomenon resulting from the “reciprocal” reflection of the interior current of injury, with no anatomic or physiologic significance. It now appears that this is the case in only a minority of patients. Most studies have shown that, taken as a group, patients with precordial ST-segment depression have larger infarcts as determined by creatine phosphokinase (CPK) levels, more severe regional wall motion abnormalities, and lower left ventricular ejection fractions. In addition, they may be prone to more short- and long-term complications than patients without ST-segment depression. The two leading explanations for anterior ST-segment depression in acute inferior infarction that are believed to explain the larger infarcts and more complicated courses observed in these patients are anterior ischemia due to concomitant LAD disease or more extensive and severe inferoposterior infarction, which produces “posterior ST elevation” manifest as anterior ST-segment depression on the surface electrocardiogram.

Anterior Ischemia

It is well established that the incidence of multivessel disease among patients surviving even uncomplicated inferior infarction is high. Miller et al. catheterized 84 consecutive patients with a mean age of 52.8±2.8 years surviving uncomplicated inferior infarction and found multivessel disease in 80% of patients. This was initially believed to support the concept that anterior ST-segment depression might be due to anterior ischemia from concomitant LAD disease. Although two subsequent studies revealed statistically significant associations between precordial ST-segment depression and the presence of LAD disease, both of these studies included only those patients who underwent catheterization for clinical complications following inferior infarction and, thus, are considerably biased. There have been seven studies of consecutive series of patients undergoing catheterization after inferior infarction and only one reported a statistically significant difference in the prevalence of LAD disease between patients with and without anterior ST-segment depression.

Roubin et al. studied 84 consecutive survivors of a first inferior infarction with angiography and ventriculography. The prevalence of significant stenosis (more than 70%) in the LAD was significantly higher in the group with precordial ST-segment disease (36% vs. 3%, p<0.05), as was the prevalence of multivessel disease (53% vs. 6%, p<0.01). The peak CPK level was significantly higher in the group with ST-segment depression (1,879±935 vs. 1,122±800, p<0.01). These patients had a higher incidence of complications in the early postinfarction course, including congestive heart failure, malignant ventricular arrhythmia, and high-degree heart block, than patients without precordial ST-segment depression. The mean left ventricular ejection fraction was significantly lower in patients with ST-segment depression (48±13% vs. 56±11%, p<0.05). It is interesting to note that a comparison of the group of patients with precordial ST-segment depression and one-vessel disease (25 of 53) with those patients without precordial ST-segment depression (only two of whom had multivessel disease) reveals a significantly lower ejection fraction (51±12% vs. 56±11%, p<0.05) and a significantly higher CPK release (1,595±833 vs. 1,122±800, p<0.01.) in the group with precordial ST-segment depression and one-vessel disease. In these patients, a branch of the right coronary artery supplied the lateral wall more commonly (48% vs. 19%, p<0.05), and the distal right coronary artery more often supplied the apex (57% vs. 22%, p<0.05) than it did in patients without anterior ST-segment depression. These data provide strong evidence that precordial ST-segment depression during acute inferior infarction is a marker for larger infarction as a result of either ischemia at a distance due to the presence of multivessel disease or a greater amount of myocardium supplied by the infarct-related artery.

Shah et al. studied 44 patients after acute inferior infarction without a history of a previous infarction. These authors found that the 24 patients with anterior ST-segment depression were far more likely to have abnormal wall motion in the anteroseptal and apical segments on gated blood pool scanning than the 20 patients without anterior ST-segment depression (50% vs. 15%, p<0.05). These patients had larger infarcts as determined by CPK release, a greater degree of wall motion abnormalities in infarct-related segments, and lower left ventricular ejection fractions.

The best modality for studying the significance of anterior ST-segment depression during inferior infarction may be positron emission tomography because of its ability to detect myocardial ischemia based on the depression of metabolic activity. Billadello et al. studied 13 consecutive patients with inferior infarction, nine of whom had anterior ST-segment depression. Positron tomography revealed three of the nine patients to have anterior ischemia. All three were shown to have significant stenosis of the LAD on catheterization associated with anterior wall motion abnormalities on ventriculography. Two additional patients developed “true posterior infarction” (R>S in lead VI). Despite the small number of patients in this study, it does provide compelling evidence that at least some patients with inferior infarction and anterior ST-segment depression are undoubtedly experiencing anterior ischemia.

Posterior Transmural Infarction

Evidence supporting the concept that anterior ST-segment depression represents “reciprocal” expression of a large area of transmural infarction encompassing the posterior wall is found in the study by Gibson et al. These investigators studied 48 consecutive patients after inferior infarction with coronary angiography, submaximal thallium stress tests, and gated blood pool scans, all within 2 weeks of the acute event. The 27 patients (56%) with
precordial ST-segment depression had significantly higher peak CPK levels, significantly more severe regional wall motion abnormalities, and lower overall left ventricular ejection fractions. More patients with anterior ST-segment depression evolved electrocardiographic evidence of true posterior infarction than did patients without precordial ST depression (26% vs. 5%, p<0.05). Thallium scanning revealed more frequent and severe inferior and inferoapical perfusion abnormalities in the group with anterior ST-segment depression.

Goldberg et al. studied 25 consecutive patients after a first inferior infarction with gated blood pool scans. Thirteen of the 14 patients (93%) with anterior ST-segment depression had posterolateral akinesis on ventriculography in contrast to the 11 patients without anterior ST-segment depression, none of whom had posterior akinesis (p<0.001).

Ong et al. analyzed 70 patients with gated blood pool scans and thallium scans. The 47 patients with precordial ST-segment depression had more severely reduced inferoposterior regional ejection fractions (40% vs. 52%, p<0.005), lower left ventricular ejection fractions (45% vs. 52%, p<0.05), and more than 50% greater peak CPK levels (1,856±1,133 vs. 1,135±705 units, p<0.05). Although the mortality of the patients with precordial ST-segment depression was greater than the mortality of patients without this finding (28% vs. 4%), precordial ST-segment depression was not an independent predictor of mortality when infarct size and ventricular function were included in multivariate analysis.

In one of the largest studies examining this issue, Hlatky et al. used the Duke University Data Bank to retrospectively examine 162 consecutive patients suffering a first inferior infarction. These authors required only 0.5-mm ST-segment depression in leads V1 through V3 for inclusion into the precordial ST-segment depression group, a less-stringent inclusion criterion than other studies. The group with precordial ST-segment depression had significantly larger infarctions and a greater percentage of posterior infarctions as judged by a QRS scoring system. They also had a higher in-hospital mortality (13% vs. 4%, p<0.001) and significantly increased incidence of “urgent, nonfatal complications” (defined as reinfarction, persistent hypotension, Killip class III or IV congestive heart failure, and ventricular tachycardia or fibrillation) than those patients without precordial ST-segment depression (46% vs. 29%, p=0.026). This was one of few studies to reveal a statistically significant increase in mortality in patients with inferior infarction associated with precordial ST-segment depression. The size of the study and the method of analyzing precordial ST depression as a continuous variable rather than a dichotomous one were likely to have increased the statistical power of the study.

Not all studies investigating the significance of precordial ST-segment depression have reported it to be of clinical significance. Several studies failed to show evidence of larger infarction, greater impairment of ventricular function, or radionuclide evidence of posterior infarction in patients presenting with precordial ST-segment depression. However, many of these studies used less-stringent criteria for precordial ST-segment depression, included patients presenting with inferior ST-segment depression, or were limited by small sample size.

Nonetheless, the majority of studies have shown that patients presenting with inferior infarction associated with precordial ST-segment depression have larger myocardial infarctions than patients without precordial ST-segment depression. Despite this finding, few studies have examined the impact of thrombolyis on this high-risk group.

The Netherlands Interuniversity Cardiology Institute reported the results of 533 patients randomly assigned to either standard care (n=264) or thrombolytic therapy (n=269). These investigators found a strong relation between the amount of summed ST-segment deviation, defined for inferior infarction as the amount of ST-segment elevation in leads I, II, III, aVL, aVF, V5, and V6 combined with the amount of ST-segment depression in leads V1 through V4, and enzymatic infarct size, ejection fraction and mortality. Multivariate regression analysis revealed that the largest limitation of infarct size after thrombolytic therapy was present in patients with the greatest summed ST-segment deviation. A preliminary report by the same group on the results of a recent trial in which 721 patients were randomized to receive either rt-PA or placebo supports the finding that among those patients with inferior infarction, those with precordial ST-segment depression benefit the most from thrombolytic therapy.

Berland et al. reported on 38 consecutive patients who underwent left ventriculography, coronary angiography, and treatment with intracoronary streptokinase within 6 hours of a first inferior myocardial infarction. A second angiographic study was performed on all patients between the 12th and 15th hospital days. Pretreatment ventriculography revealed a lower mean ejection fraction in the 23 patients (60%) with precordial ST-segment depression than in the 15 patients (40%) without ST-segment depression (51±10% vs. 59±7%, p<0.01). Follow-up ventriculography revealed that patients who had successful thrombolyis and a patent coronary artery on repeat angiography had a better mean ejection fraction than those patients with an occluded vessel (56±9% vs. 47±8%, p<0.01). However, the benefit in ventricular function was confined to those patients with precordial ST-segment depression on admission electrocardiogram. There was improvement in segmental contraction in those patients who presented with anterior ST-segment depression, in whom successful recanalization resulted in a decrease in the hypokinetic surface (from 11.3±6 to 8.5±4.5 cm², p<0.05) and in the hypokinetic percentage of the ventricular perimeter (from 48±14% to 40±9%, p<0.05). In contrast, there was no signifi-
cant change in the hypokinetic zone after successful thrombolysis in the patients without precordial ST-segment depression (hypokinetic surface area from 4.7±2.4 to 6.5±3.1 cm²; p=NS; and hypokinetic percentage of the ventricular perimeter from 25±13% to 34±12%, p=NS).

Bates et al reported on the impact of thrombolytic therapy in the 159 patients with inferior infarctions treated with rt-PA and randomized to early angioplasty or deferred angioplasty in the TAMI-I trial. These investigators found that the 74 patients (47%) with precordial ST-segment depression had lower left ventricular ejection fractions before treatment with thrombolytic therapy than the 85 patients (53%) without precordial ST-segment depression (54% vs. 58%, p<0.02). Repeat ventriculography at 7 days revealed that the group with precordial ST-segment depression had a persistently lower mean left ventricular ejection fraction (53% vs. 57%, p<0.02). However, the difference in ejection fraction between the patients with and without precordial ST-segment depression in this study is less than has been reported in prior studies, leading the authors to suggest that the patients with precordial ST-segment depression benefited from thrombolytic therapy.

Little et al administered intracoronary streptokinase to 17 patients in the acute phase of inferior infarction. Fourteen of these patients had precordial ST-segment depression. Recanalization of the right coronary artery was successful in 12 of these patients and resulted in the prompt resolution of the precordial ST-segment depression, including those patients with LAD disease.

**Right Ventricular Infarction**

Only recently has the occurrence and significance of right ventricular (RV) infarction been appreciated. Previously, RV infarction was not believed to be a clinically significant entity. Starr et al, in 1943, demonstrated no adverse hemodynamic effects after cauterizing the RV free wall in open-chest dogs. Sawatani et al replaced the RV free wall in dogs with a prosthetic patch and frequently found no hemodynamic impairment. It was not until 1973 that Cohn et al first described the now classic clinical syndrome produced by acute ischemic RV dysfunction.

RV myocardial infarction is predominantly a complication of inferior infarction. Whether it is diagnosed by echocardiography, first pass, or equilibrium radionuclide ventriculography, autopsy, RV infarction has been shown to occur in approximately one third of patients suffering an acute inferior infarction. In about one half of these patients, it is of hemodynamic significance. In contrast, RV infarction occurs in association with anterior myocardial infarction in less than 10% of cases. Isolated RV infarction is rare.

It is generally believed that patients suffering inferior infarctions complicated by RV involvement have more proximal occlusions of their right coronary artery resulting in infarction of the anterolateral wall of the RV, which is primarily perfused by acute marginal branches. However, several pathologic analyses have shown that it is the posterior RV wall that is most frequently involved in RV infarction and nearly always in association with left ventricular posterior and posteroseptal infarction. The occasional development of RV infarction after occlusion of the circumflex artery in left dominant patients and in patients with occlusions of the distal right coronary artery and posterior descending artery support the significance of the posterior circulation in RV infarction. It appears that obstruction of blood flow to both the posterior circulation and acute marginal vessels increases the likelihood, and size, of RV infarction. Because most inferior infarctions result from occlusion of the right coronary artery at its proximal or middle portion before the acute marginal vessels and the posterior descending artery, it is not intuitively clear why only a minority of inferior infarctions are complicated by RV involvement. Theories postulated to explain the relative infrequency of RV infarction include 1) lower oxygen requirements of the RV due to its smaller muscle mass and work load; 2) a greater total amount of blood flow available due to greater coronary blood flow during systole; 3) more extensive collateralization of the RV, primarily from the left coronary system; and 4) diffusion of oxygen from intracavitary blood through the thin wall of the RV. Several studies have indicated that patients with RV hypertrophy are more likely to have RV infarction, whereas others have not found this association. One study shows that patients with RV involvement are more likely to have concomitant LAD lesions, reducing possible collateralization to the posterior right and left ventricles, but others have not found an increased prevalence of multivessel disease in patients with RV involvement. Therefore, it remains unclear what the predisposing factors are for RV involvement in acute inferior myocardial infarction.

The clinical sequelae of RV infarction vary widely, ranging from no hemodynamic compromise to severe hypotension and cardiogenic shock. The hypotension and shock occur when there is enough RV ischemia to decrease RV compliance, raising the diastolic filling pressure in the RV. Filling of the RV is reduced, and RV stroke volume decreases. As a result, filling of the left ventricle is impaired, cardiac output is reduced, and systemic blood pressure decreases.

Therefore, patients with hemodynamic compromise due to RV infarction will often have an elevated jugular venous pressure, usually 10 mm or more, with a positive Kussmaul’s venous sign and clear lung fields. In severe cases, systemic hypotension is present. There may also be signs of tricuspid regurgitation. Characteristic findings on physical examination may be absent despite noninvasive evidence of RV involvement.
Hemodynamic findings on catheterization typically reveal disproportionate elevation of right heart pressures, with a ratio of right atrial to pulmonary capillary wedge pressure of 0.80 or more.73,76,85,95 Because these findings may also be present in pericardial constriction and less frequently in cardiac tamponade, an accurate diagnosis may be difficult.84,96

The most reliable electrocardiographic evidence of RV infarction is ST-segment elevation of 1 mm or more in the right precordial leads and, in particular, lead V_{4R}, when there is associated ST elevation in leads II, III, and aVF. Several studies have shown this to have a sensitivity and specificity for RV infarction of more than 90%, with a positive predictive value of more than 80%.16,79,97,98 Right precordial ST-segment elevation usually resolves early in the course of inferior infarction and must be looked for promptly.

Early recognition of RV infarction is clinically important to ensure not only that appropriate treatment is instituted but also that treatments that are contraindicated are avoided. Initial therapy for a hemodynamically significant RV infarction requires the administration of volume to increase filling of the ischemic, noncomplicant RV. This is essential to raise the cardiac output and increase the preload of the underfilled left ventricle.72,80,95,99 It is critically important to avoid drugs that result in venodilation and a decrease in RV filling because these may dramatically worsen systemic hypotension. In fact, hypotension after administration of sublingual nitroglycerin in the setting of inferior infarction should immediately raise the suspicion of RV involvement. In those patients who fail to increase their cardiac output despite volume loading, dobutamine100 and dopamine82 have been shown to be effective. When treated correctly, the hypotension and shock are readily reversed in the majority of patients. In the absence of hemodynamic compromise, no specific treatment for a RV infarction is required.

Controversy exists regarding the natural history of RV wall motion abnormalities that develop in association with inferior infarction. A number of investigators have shown through the use of serial radionuclide ventriculograms that RV dysfunction often improves with time after acute inferior infarction.77,101 In contrast, others have shown that the RV wall motion abnormalities generally persist.75,102 This discrepancy may reflect the existence of two different populations of patients. In some cases, RV wall motion abnormalities detected early in the course of inferior infarction may represent stunned myocardium resulting from ischemia that does not produce substantial necrosis. Those patients in whom RV dysfunction persists presumably had had ischemia resulting in infarction.

The short-term consequences of RV infarction are not limited to the characteristic hypotension and right heart failure. Barrillon et al in 1974103 were the first to report that patients with right precordial ST-segment elevation during inferior myocardial infarction were at least threefold more likely to develop second- or third-degree heart block than patients without ST elevation. Others have found ST elevation in V_{4R} to be predictive of the subsequent development of high-degree heart block in 48–75% of patients during acute inferior infarction.16,104

The long-term clinical consequences of RV infarction are not well known. The available evidence suggests that RV infarction is not only predictive of major complications during the hospital course but also a possible independent risk factor for long-term mortality as well. Polak et al105 have shown in patients with coronary artery disease and chronic heart failure that RV dysfunction is a risk factor for mortality independent of left ventricular dysfunction. Pfitzer et al106 found that RV dysfunction is an independent risk factor for complex ventricular ectopy and sudden death in the year after a myocardial infarction. However, Gadsboll et al107 found no independent association between RV dysfunction and mortality during the year after acute myocardial infarction. Unfortunately, each of these studies failed to distinguish between true RV infarction associated with inferior infarction and RV dysfunction that occurs most commonly after anterior infarction as a result of left ventricular infarction and the secondary elevation of pulmonary pressures, increasing the RV afterload. Patients suffering RV infarction may be more susceptible to the future development of right heart failure; further studies involving long-term follow-up are needed.

There is little experimental or clinical evidence about the impact of thrombolysis on patients with RV involvement during inferior infarction. Schuler et al108 retrospectively studied 19 patients with acute inferior infarction due to proximal right coronary artery occlusion from a larger series of patients with acute inferior infarction to study the response of the RV to successful thrombolysis. All patients underwent radionuclide ventriculography before administration of intravenous streptokinase that was followed by acute catheterization, intracoronary streptokinase, and percutaneous transluminal coronary angioplasty, if needed. Patients were divided into two groups based on whether recanalization was successful (12 patients, 63%) or unsuccessful (seven patients, 37%). Radionuclide imaging repeated 4 weeks after acute infarction revealed marked improvement in RV function only in the patients in whom thrombolysis was successful (29.7±8.7% to 43.2±5.0%, p<0.01); there was no improvement in RV function in the patients without successful thrombolysis (33.4±4.8% to 32.2±6.1%, p=NS).

These findings are in contrast to those of Verani et al,77 who found that RV function improved even in those patients without successful thrombolysis. However, both of these studies suffered from small sample size. Data from the TIMI II trial support the view that successful thrombolysis reduces the incidence of RV involvement during inferior infarction.109 In the trial, 1,017 patients with acute inferior infarction underwent radionuclide ventriculography before dis-
charge. RV wall motion abnormalities were present in 62 patients (6%). Angiographic analysis of those patients undergoing protocol catheterization 18–48 hours after treatment with rt-PA reveals that patients with patency of the infarct-related artery had a much lower incidence of RV infarction (15 of 387, 4%, compared with 11 of 68, 16% incidence among patients with occluded arteries; p<0.001). In addition, patients with RV infarction were significantly more likely to have occlusion of the infarct-related artery despite thrombolytic therapy (11 of 26, 42%) than patients without RV involvement (57 of 429, 13%, p<0.001). The low incidence of RV infarction among patients with patency and the greater incidence of occlusion in patients with RV infarction provide evidence that successful thrombolysis reduces the incidence of RV infarction.

Conclusion

Patients with inferior infarction complicated by heart block, concomitant precordial ST-segment depression, and RV involvement have larger infarctions and a worse prognosis than patients without these features. The effect of thrombolysis on these high-risk groups is not well known. At the present time, there is conflicting evidence regarding the efficacy of thrombolytic therapy in patients with inferior infarction. In view of the increasing evidence that patients with the largest infarctions benefit the most from acute reperfusion, patients in these high-risk subgroups may be particularly good candidates for thrombolytic therapy.

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