Clinical Evaluation of Myocardial Perforation as a Complication of Permanent Transvenous Pacemakers*

Melvyn Rubenfire, M.D.;** Daniel T. Anbe, M.D.;† Ellet H. Drake, M.D.;‡ and Robert S. Ormond, M.D.¶

A simple and reliable radiographic method to aid in the detection of penetration or perforation of the myocardium by permanent transvenous pacemaker electrodes is described. The “epicardial fat-pad sign” was clearly positive in three “symptomatic” patients in whom electrodes had perforated the myocardium and in eight of 28 “nonsymptomatic” patients with pacemakers implanted as long as three years. The incidence, management, and clinical implications of myocardial perforation as a complication of transvenous pacemakers are discussed. It is suggested that patients in whom pacemaker electrodes have perforated be closely observed, and that repositioning of the pacemaker electrode be performed when an adequate cardiac escape mechanism is thought to be lacking.

Materials and Methods

Patients

Thirty-one patients with permanent transvenous pacemakers were evaluated radiographically and by other diagnostic techniques. Three patients had been admitted to the hospital with clinical symptoms which suggested myocardial perforation; 28 others had remained asymptomatic for one to 36 months following pacemaker insertion and comprised a representative sample of 150 such asymptomatic patients observed at this hospital over a three-year period. All pacemakers were Medtronic models, approximately 80 percent being of the “demand” type. Medtronic endocardial electrodes (no 5816, no 12 French with a relatively broad and flat tip diameter of 4 mm) had been used in all instances.

Epicardial Fat-Pad Sign

As reported by Ormond et al the epicardial fat which defines the limit of the myocardium may easily be visualized by employing radiographic techniques. On a spotfilm, the epicardial fat appears as a fine, lucent stripe. Perforation or penetration of the myocardium by the electrode is indicated when a distance of less than 3 mm, that is, a distance less than the average thickness of the right ventricle separates the electrode tip from the epicardial fat. Although there is a variable distribution of epicardial fat from patient to patient, the stripe was well seen on all patients evaluated.

Radiographic Technique

By fluoroscopic means the diaphragm was examined for unusual contractions and the position of the electrode was
carefully evaluated. The patient was then placed in the right lateral decubitus position and examined with an image intensifier having an image orthicon television and monitor. When the epicardial fat was visualized on the monitor, a spot film was made with the patient in the position in which the electrode appeared closest to, or anterior to, the epicardial fat. Two spot films were taken, one at the peak of deep inspiration and the other with the patient breathing quietly.

Other Diagnostic Procedures

To verify the relationship of the electrode tip to the endocardium and fat pad, right ventricular cineangiograms were obtained in six patients. Contrast medium was injected into the right atrium or ventricle, and 35 mm cineangiograms were obtained with a six-inch image orthicon. Simultaneous electrocardiograms (ECG) carotid pulse tracings, and phonocardiograms were obtained in three patients in whom precordial extracardiac clicks were audible. Phonocardiograms were obtained using Cambridge 1-176 heart sound amplifiers and Leatham-type heart sound microphone.

Results

Epicardial Fat-Pad Sign

The preliminary diagnosis of pacemaker perforation in three patients admitted with clinical symptoms was confirmed radiographically by the epicardial fat-pad sign.

Figure 1A demonstrates pacemaker catheter penetration; the electrode tip lies within 1 mm of the epicardial fat. Figure 1B illustrates this schematically. A frame from a 35 mm cineangiogram obtained in the same patient (Fig 2) depicts the catheter tip lying outside the contrast media. The cineangiogram demonstrated that the patient had a small aneurysm at the site of penetration. In Figure 3, the electrode tip may be seen lying within the epicardial fat-pad, the lucent stripe which encircles the heart. In two of these patients in whom exploratory surgery was performed, the electrode tip was found in the pericardial cavity. Epicardial electrodes were implanted and the transvenous catheters removed through the perforation site without hemorrhage.

Of the 25 clinically asymptomatic patients, the electrode had penetrated or perforated the myocardium in eight cases (29 percent). One of the eight patients in whom perforation was found on a routine screen, developed sudden pacing failure six months later. Cineangiography then confirmed perforation and surgery was performed. The tip of the pacemaker electrode was seen lying on the epicardial fat.

The right ventricular cineangiogram verified the results of the epicardial fat-pad sign in all of the six patients who were studied.

Clinical Findings in 31 Patients

As shown in Table 1, 6 of the 31 patients had
undergone repositioning of the electrode following the initial insertion and four perforations subsequently occurred. Pericardial friction rubs occurred in four patients shortly after pacemaker insertion; there was perforation in two of these. Of three who had a precordial extracardiac click, two had perforations. One patient with symptomatic diaphragmatic contractions was found to have a perforated pacemaker electrode which probably was stimulating the phrenic nerve.

**Duration of Pacemaker Implantation and Incidence of Myocardial Penetration**

The relationship between the duration of pacemaker implantation and perforation (or penetration) was evaluated in the 28 asymptomatic patients (Table 2). Six months following insertion, there was a trend toward the occurrence of perforation. In the asymptomatic group, perforations were not documented earlier than six months postinsertion. However, in two of three clinically symptomatic patients, perforation had occurred within three months of insertion. Both of these patients had undergone repositioning of the catheter electrode during the week following initial insertion.

**Sequence of Ventricular Depolarization and Electrode Penetration**

Among the 31 cases, there was no correlation between the direction of pacemaker spike vector and either perforation or penetration of pacemaker electrodes. There was perforation in one patient whose ECG changed from a left to a right bundle-branch block pattern.

**Discussion**

Previously it had been difficult to evaluate and confirm pacemaker electrode perforation in patients who remained asymptomatic. Simple penetration of the myocardial wall has not been clinically documented but observed only at postmortem examinations. Rather, findings such as pericardial friction rubs, pacemaker clicks, changes in chest x-ray films, changes in the ECG from a left to a right bundle-branch block, failure to pace, cardiac tamponade, and diaphragmatic pacing had variously led to a diagnosis of pacemaker electrode perforation. Although contraction of the left and right hemidiaphragms has been linked to pacemaker perforation, up to 10 percent of all patients with endocardial right ventricular pacemakers have some diaphragmatic contractions so that this finding does not necessarily imply perforation. The pattern of right or left bundle-branch block and the pacemaker spike in the scale electrocardiogram are also relatively unreliable unless there is an obvious change.

Failure to pace or to capture usually implies

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**Table 1—Clinical Findings in 31 Subjects with Implanted Transvenous Pacemakers**

<table>
<thead>
<tr>
<th>Finding</th>
<th>Total Patients</th>
<th>No. Having Diagnosis of Perforation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repositioning of electrode</td>
<td>6/31</td>
<td>4</td>
</tr>
<tr>
<td>Pericardial friction rub</td>
<td>4/31</td>
<td>2</td>
</tr>
<tr>
<td>Precordial “click”</td>
<td>3/31</td>
<td>2</td>
</tr>
<tr>
<td>Diaphragmatic contraction</td>
<td>1/31</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 2—Duration of Pacemaker Implantation in 28 Asymptomatic Patients; Incidence of Myocardial Penetration**

<table>
<thead>
<tr>
<th>Duration of Pacemaker Implantation, Mo</th>
<th>Patients, Total</th>
<th>Penetration/Perforation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-6</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>6-12</td>
<td>7</td>
<td>2</td>
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<tr>
<td>12-18</td>
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<td>2</td>
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<td>18-24</td>
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<tr>
<td>24-30</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>30-36</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>8</td>
</tr>
</tbody>
</table>

*Excludes three symptomatic patients.
battery depletion, exit-block (fibrosis at the electrode site), fractured wire, displaced electrode tip or perforation. It is interesting, however, that perforated catheters usually continue to pace because of the proximity to the epicardium. In fact, in our series, in only one patient of the 31 did pacing cease and that was intermittent for a short period. That patient (Fig 2) was found to have a penetrating electrode six months earlier and was shown to have an aneurysm by cineangiography at the electrode site.

**Incidence of Perforation**

In large series of permanently implanted transvenous pacemakers, incidences of perforation have been relatively rare. Perforation by temporary pacemaker electrodes has varied from 4 to 20 percent. On the other hand, permanent pacemaker perforation has been thought to occur in approximately 5 to 7 percent of the patients. The small electrode tip of 2 and 4 mm seem to have a higher incidence of perforation.

Autopsies have been performed on very few patients with endocardial electrodes. In one study of six cases, no perforations were found postmortem. No comment was made by the authors regarding penetration of the electrode into the myocardium, although the catheters were buried in the trabeculae and had been covered by a fibrous sheath.

Our findings suggest that the incidence of perforation is much higher than previously reported. Although this higher incidence could be due to our technique of pacemaker insertion, a similar high incidence of perforation will likely be found by others in asymptomatic patients if they are studied with the epicardial fat-pad sign. The usual posterior, anterior and lateral chest x-ray film is totally inadequate in attempting to determine perforation or penetration.

**Contributory Factors in Perforation**

Repositioning of pacemaker electrodes, positioning of electrodes with guide wire left in place, and small electrode tips are all apparently significant factors related to the increased incidence of perforation. The size of the electrode tip is very significant in that the force exerted is inversely proportional to the area over which it is exerted. The force exerted on the endocardium rises fourfold when stylets are left in place. The latter is unrelated to the source of manufacture.

**Clinical Significance of Perforation and Clinical Management of Patients**

The significance of myocardial perforation by pacemaker electrode is somewhat questionable. We have now accumulated data on 11 patients with a perforated or penetrated myocardium, of which only four were clinically symptomatic. Our results, as well as the experience of others, suggests that if repositioning becomes necessary because of penetration with subsequent failure to pace, it should be conducted under fluoroscopic control with an eye towards surgical exploration and insertion of an epicardial pacemaker electrode when necessary.

Although cardiac tamponade must be guarded against, it is unlikely and repositioning of the endocardial catheter electrode will likely suffice. Patients with asymptomatic perforated electrodes and a diagnosis made by the epicardial fat-pad sign or other methods should be closely observed. Repositioning should likely be performed when an adequate cardiac escape mechanism is not likely.

Considering our findings and those of others with large series of permanent transvenous pacemakers, it is suggested that the epicardial pacemaker electrode should not be abandoned too rapidly.

**References**