Autopsy Findings with Permanent Pervenous Pacemakers

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SUMMARY
Of 130 patients who received permanent pervenous pacemakers in the last 2 years at the Massachusetts General Hospital, 21 have died; complete postmortem data are available on seven who died 5 days to 18 months after insertion of the pacemaker. No deaths were related to pacemaker malfunction. No patient received routine anticoagulant therapy. The intracardiac portions of all pacemaker electrodes were 30 to 80% endothelialized. In three cases tiny, organized mural thrombi formed on these sheaths, but none appeared to give rise to pulmonary emboli. All pacemaker electrode tips were wedged firmly beneath the trabecular system of the right ventricular apex and elicited varying degrees of local fibrous tissue reaction. Further focal fibrotic attachments occurred in the right atrium and superior vena cava. Although in four cases the electrodes adhered to the chordae tendineae, the long-term presence of an electrode did not appear to compromise tricuspid valve function. Late removal of an electrode may be hazardous because of its firm attachments to the endocardium and tricuspid valve.

Additional Indexing Words:
Atrioventricular block Pathology Heart block
Neo-endocardium Tricuspid valve Endocardial electrode
Pulmonary emboli Fibrosis

PERMANENT endocardial pacing is an effective means of preventing Stokes-Adams attacks and an aid in the treatment of congestive heart failure associated with atrioventricular block. The mechanical and technical complications common with this form of pacemaker system are well known and include generator failure, electrode breakage, displacement, and septicemia. In contrast, the biologic reaction of the cardiovascular system to the electrode, a foreign body, are less well known. This paper describes the necropsy findings of seven patients with permanent pervenous pacemaker systems.

Methods
During the past 2 years, 130 patients at the Massachusetts General Hospital underwent implantation of Medtronic or Cordis pervenous pacemakers. Twenty-one of these patients have since died. Data concerning the seven autopsied at this hospital are reported herein. Two of these seven cases have been reported previously. The technic by which the pacemaker and electrode are inserted, the complications encountered, and the clinical data about the above 130 patients are reported elsewhere.

Results
The clinical and autopsy findings for the seven patients are presented in table 1. The
## Table 1

### Clinical and Autopsy Data

<table>
<thead>
<tr>
<th>Case and unit no.</th>
<th>Age (yr)</th>
<th>Type of pacemaker and interval from implant to death</th>
<th>Clinical diagnosis*</th>
<th>Autopsy findings*</th>
<th>Coronary artery atherosclerosis</th>
<th>Cause of 3° block</th>
<th>Fibrous tissue reaction at tip</th>
<th>Electrode adherent to tricuspid valve</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1172483</td>
<td>81</td>
<td>Medtronic</td>
<td>Diabetes mellitus; uremia</td>
<td>Acute bronchopneumonia; intercapillary glomerulosclerosis (nodular form); portal cirrhosis</td>
<td>Moderate</td>
<td>Calcified mitral annulus</td>
<td>Slight</td>
<td>Yes</td>
</tr>
<tr>
<td>2 1354708</td>
<td>81</td>
<td>Medtronic</td>
<td>Hypertension, unknown years (max, 260/130 mm Hg); MI, terminal admission</td>
<td>Acute MI with mural thrombus and renal infarcts</td>
<td>Moderate</td>
<td>Not studied</td>
<td>Slight</td>
<td>Yes</td>
</tr>
<tr>
<td>3 0640132</td>
<td>64</td>
<td>Medtronic</td>
<td>None</td>
<td>Acute bronchopneumonia; idiopathic myocardial hypertrophy with numerous fibrotic foci; cerebral infarcts; infarcts, embolic, old</td>
<td>None</td>
<td>Fibrosis of atrio-ventricular node</td>
<td>Slight</td>
<td>Unknown</td>
</tr>
<tr>
<td>4 889853</td>
<td>85</td>
<td>Cordis</td>
<td>Calcific aortic stenosis</td>
<td>2 days after aortic valve replacement; fibrosis, focal, subendoocardial, and interventricular septum</td>
<td>None</td>
<td>Calcified mitral annulus</td>
<td>None</td>
<td>Yes</td>
</tr>
<tr>
<td>5 1334963</td>
<td>75</td>
<td>Medtronic</td>
<td>Diabetes mellitus; MI, multiple, 1962-65; MI, terminal admission</td>
<td>Acute and healed MI with mural thrombi; pulmonary infarct, tiny, recent</td>
<td>Severe</td>
<td>Fibrosis of bundle of His and interventricular septum</td>
<td>20 × 10 × 1 mm</td>
<td>No</td>
</tr>
<tr>
<td>6 1471839</td>
<td>73</td>
<td>Cordis</td>
<td>Renal and mesenteric emboli, terminal admission</td>
<td>Mural thrombus occluding aortic lumen with renal infarct, massive, recent; healed MI</td>
<td>Severe</td>
<td>Infarct of subendocardium and interventricular septum; atrioventricular node not studied</td>
<td>Slight</td>
<td>No</td>
</tr>
<tr>
<td>7 1531479</td>
<td>82</td>
<td>Medtronic</td>
<td>MI, old</td>
<td>Acute MI with mural thrombus and renal infarct; healed MI</td>
<td>Severe</td>
<td>Absence of musculature approach to atrioventricular node</td>
<td>Fibrin only</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* MI = myocardial infarct.
PERMANENT PERVENOUS PACEMAKERS

Figure 1

Patient 1. Electrode, in situ. A fibrin sheath covers 70% of the electrode; an organizing thrombus is present where the electrode passes through the tricuspid valve. The tip has elicited a slight fibrous tissue reaction (arrow).

Figure 2

Patient 2. Electrode ensheathed in fibrin and adherent to tricuspid valve. Extensive postmortem clot is present.

Figure 3

Patient 4. Electrode adherent to tricuspid valve. The electrode tip is buried in the myocardium rather than normally wedged beneath the trabeculae carneae. Fibrin ensheathes the entire intraventricular portion of the electrode and to a much lesser extent, the portions in the atrium and superior vena cava.

The reaction of the cardiovascular system to the electrode was extensive and consisted of a youngest patient was 64 years old; the oldest, 85. All patients were white, and only one was female (case 2). Each patient received pacemaker systems because of Stokes-Adams attacks or severe congestive heart failure. Five patients experienced symptomatic improvement; they died 4 to 18 months after receiving the pacemakers. Of the two patients who showed no improvement one (case 4) had severe calcific aortic stenosis (valve area, 0.6 cm²), and one (case 7) died unexpectedly 5 days after pacemaker implantation. At postmortem examination all pacemakers functioned normally. The autopsies showed that three patients died from noncardiac diseases, three from acute myocardial infarcts, and one shortly after cardiac surgery. The atrioventricular conduction systems in five patients were examined by the method outlined by Lev and associates.7

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Patient 5. Electrode highly ensheathed with fibrin in both right atrium and ventricle. Two organizing mural thrombi adhere to the electrode, one in the atrium and one near the atrioventricular valve. Fibrous adhesions bind the intra-atrial portion of the electrode to the atrial wall. A marked fibrous tissue reaction is present about the electrode tip.

Fibrin sheath which formed about the electrode, multiple points of attachment of the fibrin sheath to the endocardium, fibrosis about the electrode, and adherence of the electrode to the tricuspid valve structures (figs. 1 to 8). In each case including that of the patient who died 5 days after receiving the pacemaker, an extensive coat of fibrin en- sheathed 30% to 80% of the electrode (figs. 1 and 4). This coat, called "neo-endocardium" by others,\(^8\) forms within 12 hours after insertion of the pacemaker.\(^9\) At autopsy the electrode could be made to slide within this nonadherent sheath. However, traction on the electrode itself resulted in tearing its fibrous attachments to the endocardium while the electrode remained undisturbed within the sheath. In four patients the electrode adhered to the tricuspid valve. In each of these patients the electrode passed between two lateral chordae tendineae (figs. 1 to 3) and thereby was fixed deep in a valve commissure (fig. 7). In two patients the electrodes did not pass between the chordae tendineae and were not adherent to the valve structure. In no patient was there a suggestion of insufficiency of the tricuspid valve. The degree of the fibrous tissue reaction of the heart to the electrode tip varied roughly with the time the electrode was in place. The most extensive fibrosis occurred in the patient whose pacemaker system was present for 18 months (fig. 4). Extensive fibrin deposition but no fibrosis was present when the electrode tip was in place for only 5 days (fig. 8). Patient 4 whose pacemaker system was present for 6 weeks lacked fibrosis about the electrode tip (fig. 3). All other patients had slight fibrosis (figs. 1, 2, and 5). Figure 6 is a photomicrograph through this reactive region.
PERMANENT PERVENOUS PACEMAKERS

No differences were observed in the fibrous tissue reactions to the Medtronic and Cordis electrode tips.

Three patients had single asymptomatic pulmonary emboli at autopsy. The emboli in patients 1 and 3 were highly organized; 2 years before receiving the pacemakers both patients experienced documented bouts of pulmonary embolism. In addition, in patient 1 a tiny organizing thrombus adhered to the electrode sheath (fig. 1). Patient 5, who had multiple old myocardial infarcts with mural thrombi and an acute myocardial infarct at autopsy, also had a recent 1.5-cm pulmonary infarct; organizing thrombi adhered to the electrode sheath (fig. 4). None of these three patients received anticoagulants.

Discussion

The results of this study show that the reaction of the cardiovascular system to the pacemaker electrode is extensive. Although several investigators have remarked on the various modes of attachments, namely, fibrin sheaths, fibrous adhesions, fibrosis about the electrode tip, and adherence to the tricuspid valve, our results indicate that the extent is far greater than generally appreciated. Thus damage to the heart, tricuspid valve, and superior vena cava may occur if for some reason a defective electrode is removed.

The electrodes in four patients adhered to the chordae tendineae of the tricuspid valve. Furman and Escher reported a similar occurrence in two patients and illustrated this phenomenon clearly in their figure 4. Lagergen and co-workers, although they did not find this adherence in any of 21 necropsies, observed one case in which the electrode passed through the valve leaflet itself. We have noted at postmortem examination that if the electrode is pulled with moderate force, the fibrous adhesions binding the sheath to the endocardium will rip and cause marked damage to the heart. These findings corroborate a recent report in which Furman and

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Figure 6

Patient 6. Photomicrograph through fibrous tissue reaction about electrode tip. Elastic-van Gieson stain; reduced from ×32.

Figure 7

Patient 7. Tricuspid valve. The fibrin sheath adherent to the chordae tendineae fixes the electrode deep in the valve commissure (arrow).
Escher\(^8\) attempted but could not remove two defective electrodes which had been inserted 10 and 19 months before; in each case a new electrode had to be inserted and the old one left in place.

Pulmonary embolism occurring as a complication of the pacemaker is often mentioned. Recent data, however, indicate that except for a rare case,\(^11\) pulmonary embolism is not seen.\(^2, 9, 12-14\) Three of our patients had clinically asymptomatic pulmonary emboli. Two patients whose emboli were organized and months old had each clinically significant pulmonary embolism 2 years before receiving the pacemakers. The patient whose pulmonary infarct was recent had an acute, and several healed, myocardial infarcts and a large mural thrombus in the left ventricle. The possibility of an associated right ventricular mural thrombus as a source for the pulmonary infarct can not be ruled out even though none was found at autopsy. None of our patients received anticoagulants routinely.

An anatomic cause of death was found in each patient. Other series have reported no anatomic cause of death for as many as one third of the patients\(^14\) despite autopsy.\(^13\) The relation of competitive pacing to sudden death has been widely contested. In a case report of a woman with an acute inferior myocardial infarct and third degree heart block, the electrocardiogram was continuously recorded from admission until death occurred 5 hours later.\(^15\) Ten minutes before death competitive pacing appeared and resulted in arrhythmias. The terminal arrhythmia was ventricular fibrillation. Patients 2, 4, 5, and 7 in our study died of acute myocardial infarcts or after cardiac surgery; all had fixed-rate pacemakers. Anoxia and irritability related to the postinfarction or postoperative state may have rendered these patients more vulnerable to arrhythmias induced from competitive pacing. Whether or not the ultimate cause of death in these patients was induced arrhythmias remains uncertain.

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Announcement of An Operation

The following day at noon, the students came in, hurrying up the great stair. At the  
first landing-place, on a small, well-known blackboard, was a bit of paper fastened by  
wafers, and many remains of old wafers beside it. On the paper were the words: "An  
operation today. J. B. Clerk."

Up ran the youths, eager to secure good places; in they crowded, full of interest and  
talk. "What's the case?" "Which side is it?"

Don't think them heartless; they are neither better nor worse than you or I; they get  
over their professional horrors, and into their proper work,—and in them pity, as an  
emotion, ending in itself or at best in tears and a long-drawn breath, lessens, while pity  
as a motive is quickened, and gains power and purpose. It is well for poor human na- 
ture that it is so.—John Brown (1810-1882): Rab and His Friends. New York, Dodge  
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