Difficulty of Extraction of Chronically Implanted Tined Ventricular Endocardial Leads

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The dislodgment rate of permanent pacing ventricular and atrial endocardial leads has significantly decreased with the incorporation of tines as a fixation device. In contrast, transvenous manual extraction of chronically implanted endocardial leads is, at times, clinically indicated, particularly when pacemaker system infection is present. The success rate of such extraction attempts for ventricular endocardial leads over the past 5 years was reviewed. Extraction was usually successful (six of seven attempts) in patients with silicon-rubber nontined (or short-tined) older ventricular endocardial leads (Group A). However, in patients with newer urethane long-tined ventricular endocardial leads (Group B), extraction was unsuccessful in three of four attempts. Because of entrapment of the distal electrode tip in the right ventricular apex, manual traction of these leads resulted in permanent conductor material stretching with resultant urethane insulator material breakage in the region of the joints with the proximal and distal electrodes. The one successful extraction in Group B was technically difficult and appeared to create a significant risk of intracardiac lead separation.

This experience indicates that with improved pacemaker lead design decreased lead dislodgment has been obtained at the cost of increased difficulty of ventricular endocardial lead extraction. Such difficulty should be anticipated when a clinical decision is made to attempt to extract the new urethane long-tined ventricular leads.

Tined atrial and ventricular endocardial pacemaker electrodes are now used routinely for permanent cardiac pacing. The incorporation of tines as a fixation device onto the distal electrode tip (Fig. 1) has resulted in a marked decrease in the early lead dislodgment rate of both atrial and ventricular leads after endocardial implantation (1–4). In contrast, the ability to remove chronically implanted endocardial leads by transvenous manual extraction is also important, particularly when infection of the pacing system is present. Previous reports (5–7) have described satisfactory transvenous manual extraction of chronically implanted ventricular leads. These reports, however, relate to leads of older design without long tines as a fixation device. Extraction of these older leads has frequently been rapidly accomplished although, at times, continuous traction for a few hours using a pulley system with weights has been necessary (7–10). Special retrieval devices have also been used occasionally for transvenous removal of endocardial lead fragments (11–13). The failure of such extraction attempts can have important clinical implications. Surgical removal of endocardial leads with the use of cardiopulmonary bypass has been necessary, particularly in patients with an infected pacemaker system or right ventricular lead perforation (14–17).

No previous report, however, has reviewed the success rate of attempted transvenous manual extraction of chronically implanted long-tined ventricular endocardial leads. Because we have recently noted marked difficulty in the extraction of such leads, we reviewed our experience of the past 5 years in all attempted transvenous extractions of ventricular endocardial leads (both tined and nontined leads).

Methods

The data were retrospectively reviewed on all patients in whom manual extraction of a permanent chronically implanted transvenous ventricular lead had been attempted in the previous 5 years at the University of Missouri Health Sciences Center, Columbia and the Harry Truman Veterans Administration Hospital, Columbia, Missouri. Chronic lead
implantation was defined as a lead implantation occurring at least 3 months before attempted extraction. An assessment was made as to whether the attempted extraction was successful or not; in addition, the type of lead, reasons for removal and potential complications of the procedure were evaluated. All attempted removals were performed by at least one of the authors (N.P.M. or J.F.S.) and were undertaken using controlled manual traction under fluoroscopic observation in the cardiac catheterization laboratory. If this procedure was unsuccessful, no chronic traction procedures using pulley systems were attempted.

**Study patients.** For the purpose of analysis, the patients were classified into two groups: Group A consisted of patients with either nontined or short-tined (2.7 mm) ventricular endocardial leads, and Group B comprised patients with long-tined (5 mm) ventricular endocardial leads.

During the study period, 11 patients underwent attempted transvenous ventricular lead extraction. Five of the 11 patients had evidence of lead fracture (either insulator or conductor material) and the remaining 6 had an infected pacemaker system. Only one of these patients with an infected pacemaker system had their pacemaker implanted at our institution. The remaining patients had been referred to us for treatment from other hospitals because of their infection. Results

**Group A (nontined or short-tined leads).** Group A comprised the seven patients with either nontined or short-tined leads (Table 1). The two patients with a fractured lead in this group had conductor material breakage. Six of the seven extraction attempts were successful and uncomplicated (Patients 1 to 6). Where present, infection was completely eradicated after removal of the pacemaker system and appropriate antibiotic therapy. The period of manual traction necessary for removal ranged from 5 to 60 minutes. In the remaining patient in Group A (Patient 7) extraction was unsuccessful. This patient had been referred from another hospital because bacterial endocarditis had developed as a consequence of pacemaker infection. Before the extraction procedure, echocardiography and right ventricular cineangiography had demonstrated a large vegetation on the proximal electrode of the ventricular endocardial lead. Because of concern that too forceful extraction could result in either dislodgment of this vegetation or avulsion of the tricuspid valve, only a brief limited attempt at extraction was performed. This patient subsequently underwent successful surgical removal of the lead and vegetation under cardiopulmonary bypass. Corynebacterium on the proximal electrode was confirmed bacteriologically.

Of the seven ventricular endocardial leads in Group A patients, five had no tines on the distal tip (Table 1); the remaining two leads had short (2.7 mm) tines as a fixation device. All seven leads had silicone rubber as the insulating material. No conductor material uncoiling or insulator material breakage occurred during extraction with these leads.

**Group B (long-tined leads).** Group B consisted of the remaining 4 of 11 patients; all had a urethane long-tined (5 mm) Medtronic 6972 (18) endocardial ventricular lead (Table 1). In this group, three of the four removal attempts were unsuccessful. A consistent pattern emerged with manual traction of these leads that was entirely different from that seen in Group A. It was noted that all electrodes were entrapped in the apex of the right ventricle. No resistance to extraction occurred in the fibrous tissue beneath the clavicle. With traction, the position of the distal electrode remained unchanged but the lead conductor material was
Table 1. Results of Attempted Transvenous Manual Extraction

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yr) &amp; Sex</th>
<th>Diagnosis</th>
<th>Pulse Generator</th>
<th>Ventricular Lead Type</th>
<th>Reason for Extraction</th>
<th>Extraction Successful</th>
<th>Time From Implant to Extraction (mo)</th>
<th>Tines on Lead</th>
<th>New System</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>89F</td>
<td>AVB</td>
<td>VVI</td>
<td>Medtronic 6904</td>
<td>Infection</td>
<td>Yes</td>
<td>102</td>
<td>None (straight tip)</td>
<td>Endocardial</td>
</tr>
<tr>
<td>2</td>
<td>70F</td>
<td>SSS</td>
<td>VVI</td>
<td>Medtronic 6962</td>
<td>Infection</td>
<td>Yes</td>
<td>4.5</td>
<td>Short (2.7 mm)</td>
<td>Epicardial</td>
</tr>
<tr>
<td>3</td>
<td>75M</td>
<td>SSS</td>
<td>VVI</td>
<td>Medtronic 6904</td>
<td>Infection</td>
<td>Yes</td>
<td>46</td>
<td>None (straight tip)</td>
<td>Refused</td>
</tr>
<tr>
<td>4</td>
<td>72M</td>
<td>SSS</td>
<td>VVI</td>
<td>Medtronic 6901</td>
<td>Fracture</td>
<td>Yes</td>
<td>55</td>
<td>None (flanged tip)</td>
<td>Refused</td>
</tr>
<tr>
<td>5</td>
<td>78F</td>
<td>CSH</td>
<td>VVI</td>
<td>Medtronic 6901</td>
<td>Fracture</td>
<td>Yes</td>
<td>14</td>
<td>None (flanged tip)</td>
<td>Endocardial</td>
</tr>
<tr>
<td>6</td>
<td>84M</td>
<td>SSS</td>
<td>VVI</td>
<td>Medtronic 6962</td>
<td>Infection</td>
<td>Yes*</td>
<td>32</td>
<td>Short (2.7 mm)</td>
<td>Epicardial</td>
</tr>
<tr>
<td>7</td>
<td>62M</td>
<td>SSS</td>
<td>VVI</td>
<td>GE A207</td>
<td>Infection</td>
<td>No†</td>
<td>51</td>
<td>None (straight tip)</td>
<td>Epicardial</td>
</tr>
</tbody>
</table>

Group A (non- or short-tined silicone rubber ventricular endocardial leads)

Group B (long-tined urethane ventricular endocardial leads)

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yr) &amp; Sex</th>
<th>Diagnosis</th>
<th>Pulse Generator</th>
<th>Ventricular Lead Type</th>
<th>Reason for Extraction</th>
<th>Extraction Successful</th>
<th>Time From Implant to Extraction (mo)</th>
<th>Tines on Lead</th>
<th>New System</th>
</tr>
</thead>
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<tr>
<td>8</td>
<td>38M</td>
<td>AVB</td>
<td>VDD</td>
<td>Medtronic 6972</td>
<td>Fracture</td>
<td>No</td>
<td>16</td>
<td>Long (5 mm)</td>
<td>Endocardial</td>
</tr>
<tr>
<td>9</td>
<td>70M</td>
<td>AVB</td>
<td>DVI</td>
<td>Medtronic 6972</td>
<td>Fracture</td>
<td>No</td>
<td>10</td>
<td>Long (5 mm)</td>
<td>Epicardial†</td>
</tr>
<tr>
<td>10</td>
<td>85M</td>
<td>AVB</td>
<td>VVI</td>
<td>Medtronic 6972</td>
<td>Fracture</td>
<td>No</td>
<td>25</td>
<td>Long (5 mm)</td>
<td>Endocardial</td>
</tr>
<tr>
<td>11</td>
<td>70M</td>
<td>SSS</td>
<td>VVI</td>
<td>Medtronic 6972</td>
<td>Infection</td>
<td>Yes</td>
<td>14</td>
<td>Long (5 mm)</td>
<td>Endocardial</td>
</tr>
</tbody>
</table>

*Post-traumatic (only infected pacemaker placed at our institution); †Subsequently surgically removed with total cardiopulmonary bypass; ‡Unable to place new endocardial system because of chronic, subclinical subclavian vein thrombosis. AVB = atrioventricular block; CSH = carotid sinus hypersensitivity; DVI = atrioventricular sequential; SSS = sick sinus syndrome; VVI = ventricular demand; VDD = atrial synchronous ventricular inhibited.

found to permanently stretch and uncoil (Fig. 2). This resulted in considerable difficulty in maintaining the traction force (tension) on the distal tine tip necessary for successful removal.

This stretching phenomenon gave the initial impression that extraction was being successfully accomplished; however, in reality, the whole lead was being stretched irreversibly without any effect on the distal tip. Fluoroscopy revealed an increased distance between the proximal and distal electrodes (Fig. 3 and 4). This stretching of the conductor material resulted in separation of the insulation material from both the proximal and the distal electrodes (Fig. 3 and 5). In light of the potential for complete intracardiac lead separation, these attempts at manual extraction were abandoned. Because all three leads had insulator material fracture, rather than infection, they were cut, capped and left in situ. Evidence of polyurethane degradation was not specifically sought in the lead remnants.

The subsequent implications of the inability to extract these leads was significant, particularly in the two patients with a dual chamber pacing system (Patients 8 and 9). In Patient 8, the second dual chamber pacing system was placed by way of the opposite subclavicular venous system. Because the originally implanted atrial lead was also not successfully extracted, the patient thus has four endocardial leads, two atrial and two ventricular (Fig. 6). In Patient 9, an attempt was made to pass another ventricular lead by the same subclavicular venous system originally used. However, because of a probable subclinical right subclavian vein thrombosis, this was unsuccessful. This patient subsequently underwent successful epicardial ventricular lead replacement.

The remaining patient in Group B (Patient 11) was referred to us from an outside institution because of an infected pacemaker system. During the attempted removal, initial gentle traction resulted in conductor material stretching and insulator material tearing with the same pattern noted previously. Because this was an infected pacemaker system, we persisted in our extraction attempts to avoid the need for cardiopulmonary bypass and surgical removal. A number of transvenous retrieval devices were introduced in unsuccessful attempts to dislodge the electrode tip from the
right ventricular apex (Fig. 4B). After these prolonged efforts failed, by pulling on a forcep clamped tightly across the exposed lead (Fig. 7), we placed further traction on the lead despite our concern about possible intracardiac lead separation. Increased conductor material stretching occurred with increased electrode and insulator material separation. The lead subsequently appeared to reach a maximal length that was more than double the original lead length (Fig. 8). At this point of maximal lead length, further traction finally resulted in successful extraction of the lead from the right ventricular apex without complications.

**Discussion**

**Endocardial lead removal.** The decision to attempt removal of a defective, chronically implanted endocardial ventricular lead is often difficult to make clinically. Because of the fibrous tissue reaction in the trabecular network of the right ventricle, chronically implanted leads are clearly more difficult to remove than acutely implanted leads (< 3 months). Complications that occur after chronic lead extraction attempts have been reported (19,20) and noninfected leads can frequently remain safely in situ (21,22). However, the ability to remove endocardial leads safely by transvenous extraction can be clinically important.

The major indications for endocardial lead removal are:

1) *Infect ed pacemaker systems:* without removal of the pulse generator and endocardial lead or leads, which act as foreign bodies, eradication of the infection is probably not possible (7).

2) *Lead breakage:* this can be either a conductor fracture or defective insulator material. Although, in this situation,
removal is usually not essential, three potential reasons for extraction exist:

a) For the assessment of long-term lead reliability: analysis of extracted leads is important, particularly for those leads of recent design showing evidence of premature malfunction.

b) To restrict the number of endocardial leads implanted in an individual patient to a minimum: as this number increases, the risk of venous thrombosis (in the veins utilized for insertion) probably also increases (23–26). With the evolving use of dual chamber pacing systems, this situation has gained in importance.

c) To avoid abnormal pacemaker sensing. Intermittent intracardiac metal contact between the functioning and non-functioning electrodes can potentially generate false electrical signals. Such false signals have been reported to create pacemaker sensing problems from either false inhibition or false triggering (27).

Removal of tined leads. Recent changes in design have clearly resulted in improved lead characteristics. These changes have included a decrease in diameter for improved ease of transvenous insertion, greater lead flexibility with longer “flex life,” a lower electrical resistance and improved electrode design resulting in more efficient myocardial stimulation (18). In addition, with the incorporation of tines close to the distal electrode acting as a fixation device, endocardial lead dislodgment rates have decreased markedly (1–4,18,28). However, there appears to be a potential cost for improved fixation; our experience indicates that long-tined urethane ventricular endocardial leads are significantly more difficult to extract than the older nontined (or short-tined) Silastic leads. Such difficulty appears to be present only for chronically implanted leads (>3 months); easy repositioning in patients (3) and extraction in dogs (18) have been reported for acutely implanted leads (≤3 months). Urethane triggers less of a fibrous reaction on the endocardial surface than silicone rubber so that fibrous attachment to the tricuspid valve and the trabeculations of the right ventricle should be less likely (29). Therefore, extraction of chronically implanted urethane ventricular endocardial leads should be theoretically easier than that of older silicone rubber leads. However, in practice, the other factors discussed next appear to outweigh this theoretical advantage.

Possible reasons for greater difficulty in extraction of long-tined leads include:

1) The greater fixation by the long tines results in a greater force needed for extraction (with resulting lead conductor coil stretch and insulator material separation from its joints in the area of the distal and proximal electrodes). In addition to the role of the tines, this greater fixation possibly occurs also because of design changes in the electrode-lead junction. Compared with the older silicone leads, the urethane leads in Group B have a greater “shoulder” at this junction so that the lead suddenly narrows to the diameter of the main shaft.

2) A different structural relation exists between the conductor wires and the insulation material. In the older leads, with silicone rubber as the insulator material, the construction was such that the conductor wires were embedded in a comparatively thick layer of silicone rubber. In the long-tined leads, the conductor material is sheathed in a thinner layer of urethane and freely movable within the insulation.

Figure 4. Example of lead stretching noted on fluoroscopy. A, Lead before stretching. B, Result of stretching. Note the abnormally increased distance between the proximal and distal electrodes (the retrieval device in the atrium is also demonstrated).
Figure 5. Lead conductor material stretching with insulator material breakage. The right arrow indicates the proximal electrode where the urethane has torn away. The left arrow indicates the position to which the torn urethane sheath has been retracted (this occurred within the heart).

Thus, traction on the older nontined silicone leads results in the tension being distributed to both conductor and insulator material. However, for the long-tined leads, the tension appears to be mainly on the inner conductor material.

Clinical implications. In our experience this inability to remove long-tined ventricular leads has important clinical implications. In patients with premature lead malfunction, adequate lead analysis cannot be performed. With pacemaker system infection, transvenous manual extraction appears to expose the patient to the potential risk of intracardiac lead separation. With infection, if all the lead is not removed, subsequent surgical removal with cardiopulmonary bypass is necessary (30). In order to avoid such a surgical procedure, it has to be accepted that conductor coil stretching and insulator material separation will occur before sufficient force can be exerted onto the entrapped distal electrode which is necessary for successful removal. In our experience, such sufficient force occurs when the lead has been stretched to a maximal length (approximately 2.5 times normal). The risk of this procedure, however, is unknown at present because of the limited available experience.

Figure 6. X-ray film from Patient 8 demonstrating two atrial and two ventricular leads. Note the uncoiling of the conductor material of the long-tined urethane lead.

Figure 7. Extracted long-tined lead in Patient 11. Note the forceps clamped for extraction, conductor coil stretching and insulation breakage.
The solutions to these problems lie in a number of possible areas. First, the decision to remove an endocardial long-tined lead should be made carefully because of anticipated difficult or even impossible extraction. Second, all removal attempts should be performed under constant fluoroscopic guidance. Third, a new lead should be fully evaluated for its removal characteristics after chronic implantation. For example, a lead with shorter tines and isodiametric distal tip may provide continued excellent fixation but be easier to remove with transvenous manual traction. Finally, gradual pulley traction (not attempted by us) could be an alternative approach but results of this procedure with urethane long-tined leads have not been reported. Although our experience in long-tined leads was only with a single manufacturer's lead type, we anticipate that similar problems of extraction would occur with all currently available long-tined ventricular endocardial leads.

References

17. Perelman MS, Shiu MF. Migration of redundant pacing electrode. Am Heart J 1980;100:594–2