Case Report

Implantation of a Permanent Tined Endocardial Electrode into Right Atrium during Open-heart Surgery: Report of 3 Cases

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Given concerns regarding electrode fixation and risk of dislodgement, transvenous implantation of a tined endocardial electrode into the right atrium is considered difficult in patients who require permanent atrial pacing following cardiac surgery. Implantation of a tined endocardial electrode into the right atrium was performed intraoperatively for 3 patients who required implantation of a permanent atrial electrode during the cardiac operation. This technique yielded excellent results during the mean follow-up period of 65 months, with low stimulation thresholds (mean 2.85 μJ), sufficiently high sensing thresholds (mean 2.23 mV) and stable lead impedances (mean 491.7 ohm). This technique offers a useful and secure method for patients with preoperative bradycardial arrhythmias who require implantation of a permanent atrial electrode during open-heart surgery.
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Key words: Direct tined electrode implantation, Atrial pacing, Cardiac surgery

Introduction

Atrial or dual-chamber pacing is considered to resemble physiological pacing, but requires implantation of an electrode into the right atrium. Several problems are associated with implantation of an atrial endocardial electrode in patients who have undergone cardiac surgery. The right atrial appendage is often used as a venous drainage site for cardiopulmonary bypass during cardiac operations, and is plicated at the end of cardiopulmonary bypass. Although screw-in electrodes have been applied, these electrodes display performance problems compared to tined electrodes, with increased late pacing thresholds and lead impedances, and decreased late sensing thresholds and durability of the screw portion.

Cases

We have encountered 3 patients (2 men, 1 woman; mean age, 69 years) with cardiac diseases requiring surgical intervention, complicated with bradycardial arrhythmias that were considered to require concomitant atrial pacing during open-heart surgery. Direct implantation of a permanent tined endocardial electrode into the right atrium was performed intraoperatively at our institution after written informed

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consent had been provided. The technique was applied to patients who met the following criteria: 1) results of preoperative electrocardiography (ECG) met the criteria for the Guidelines for Implantation of Cardiac Pacemakers for assignation to Classification I–IIb, as established by the American College of Cardiology, American Heart Association and North American Society for Pacing and Electrophysiology joint committee;[1] and 2) preoperative ECG revealed sinus rhythm, without atrial fibrillation or apparent sinus-originated P waves when the patient was in second- or third-degree atrioventricular (AV) block.

Implantation technique and parameters

A permanent tined endocardial electrode was implanted into the right atrium at the termination of cardiopulmonary bypass after removal of the venous cannula, as described below. We have improved this technique with reference to the report by Gordon et al.[2] A total of 3 non-steroid-eluting unipolar endocardial electrodes were implanted, comprising 2 Intermedics 487-07 electrodes (Intermedics/Guidant, Saint Pole, MN, USA) and 1 Ela T43F electrode (Ela Medical, Montrouge, France). We selected unipolar endocardial electrodes for implantation due to the superior durability compared to bipolar endocardial electrodes. Pulse generators employed comprised 1 Cosmos DDD pacemaker (Intermedics/Guidant) and 2 Nova II AAI pacemakers (Intermedics/Guidant). A guide wire was introduced into the right atrium through an 18-gauge needle via a purse-string suture placed onto the right atrium. Either of two methods was used on the right atrium, depending on the patient. In the first method, the existing purse-string suture was placed for venous cannulation during cardiopulmonary bypass. The second method involved placing another purse-string suture onto the right atrium and ligating the first purse-string suture for venous cannulation. A commercially available introducer for pacemaker implantation that had been curved into a J-shape was inserted into the right atrium through the guide wire. Following insertion of a tined lead into the right atrium, the tip of the electrode was positioned at an appropriate area, such as adjacent to the right atrial appendage, the Bachmann bundle indwelling area, or anywhere the atrial wall displayed adequate thickness and conditions sufficient for sensing and pacing threshold. When an appropriate position in the right atrium was obtained, atrial sensing, stimulation thresholds and lead impedances were measured using a Pacing System Analyzer (Medtronic, Minneapolis, MN, USA). When measured parameters met the criteria of: 1) sensing threshold $\geq$1.0 mV; and 2) voltage threshold at a constant pulse width of 0.5 ms to $\leq$1.5 V; the tip of the electrode was fixed to the determined position using 4-0 monofilament mattress suture with pledgets. Ligation of the mattress suture was made as gently as possible to avoid damaging the insulation or snapping of the lead (**Figure 1**). The implanted lead was installed behind the upper end of the sternum, then drawn out of anterior mediastinum into the subdermal space to the left subclavian area, or led from the anterior mediastinum to the abdominal subdermal space via the lower end of the sternum. During follow-up, sensing, stimulation thresholds and lead impedances were measured using the telemetric functions of the pulse generator. Given the presence of implanted pulse generators, sensing thresholds were estimated by reprogramming sensitivity parameters. Chronic stimulation threshold was measured at a constant pulse width of 0.5 ms at a rate above the intrinsic sinus rate, and defined as the lowest pulse energy at which continuous atrial capture would be obtained.

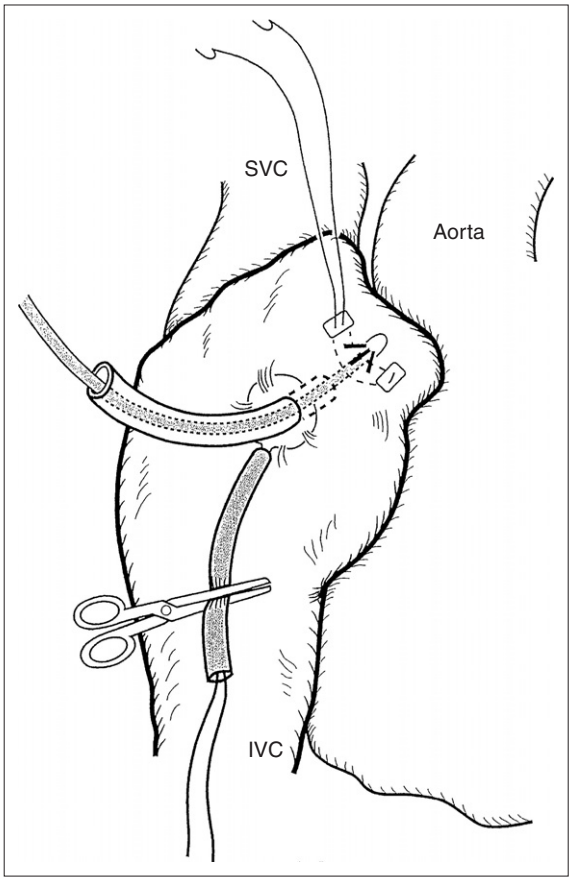

Figure 1 Introduction of a tined endocardial electrode into the right atrium using a specially designed introducer, ready for fixation using a 4-0 monofilament suture with pledget.

Table 1 Background data for patients implanted with a tined endocardial electrode into the right atrium during open-heart surgery.

case	age	gender	cardiac disease	operative procedure	preoperative ECG	electrode model	pacemaker model	interval*	duration**
1	65	male	AS	AVR	SND	Intermedics 487-07	AAI (NOVA II)	1 month	83 months
2	65	male	AS	AVR	third-degree AV block	Intermedics 487-07	DDD (Cosmos)	1 day	62 months
3	77	female	MR	MVR	SND	Ela Medical T43F	AAI (NOVA II)	11 months	49 months

AS, aortic stenosis; MR, mitral regurgitation; AVR, aortic valve replacement; MVR, mitral valve replacement; SND, sinus node dysfunction; AV, atrioventricular.
interval*: The interval from atrial electrodes implantation to connection to a pulse generator
duration**: The duration following pulse generators implantation

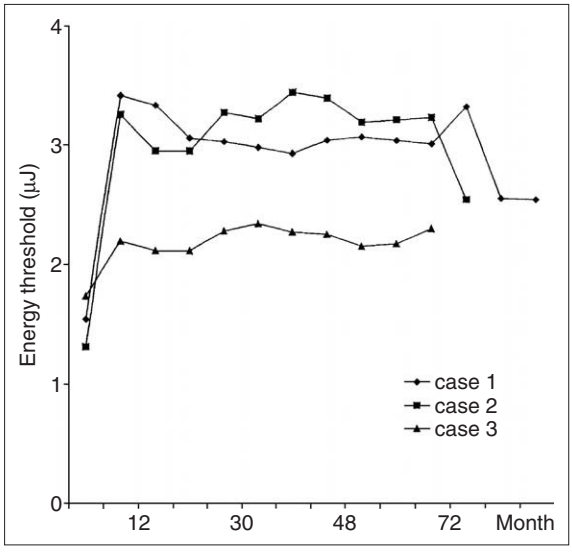

Figure 2 Changes in atrial stimulation thresholds expressed as calculated energy consumption during follow-up.

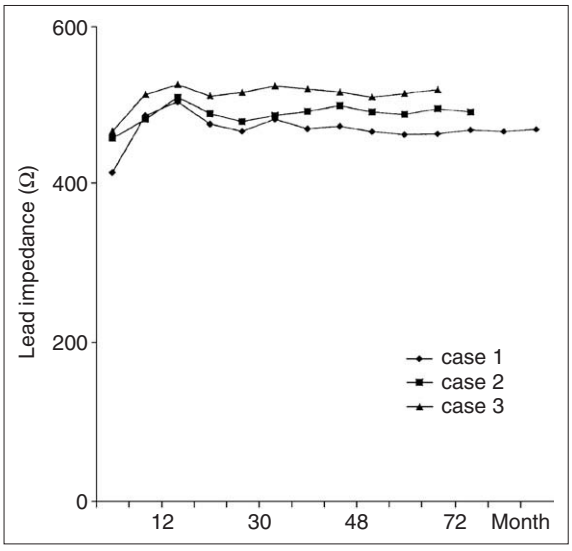

Figure 3 Changes in lead impedances in implanted atrial electrodes during follow-up.

Patients were followed routinely on an outpatient basis, and sensing and stimulation thresholds and lead impedance were measured on each visit.

Patient characteristics

The 3 patients (2 men, and 1 woman; mean age, 69 years) underwent direct implantation of tined electrode into the right atrium during open-heart surgery. Background characteristics of the patients are shown in **Table 1**. Two patients were in sinus rhythm with sinus node dysfunction. Although maximum sinus arrest times for the patients were 3.7 s and 4.2 s, both patients had no symptoms associated with bradycardia such as dizziness or lightheadedness. However, bradycardia advanced in these 2 patients postoperatively with symptoms. One patient displayed third-degree AV block, which had been treated with VVI pacemaker implantation 1 year prior to the present admission, and sinus-originated P waves were observed on preoperative ECG. Interval from atrial electrode implantation to connection to a pulse generator ranged from 1 day to 11 months postoperatively. Following pulse generator implantation, mean follow-up period was 65 months (range, 49–86 months). All implanted atrial electrodes have continued working properly.

Acute phase performance of implanted atrial electrode

During implantation, mean sensing threshold was

2.80 mV, and mean stimulation threshold was 1.07 V, with 0.5 ms of pulse width. The atrial stimulation threshold expressed as calculated energy consumption was 1.54 μJ (**Figure 2**). Mean lead impedance was 445.3 ohms (**Figure 3**).

Long-term performance of implanted atrial electrodes

During follow-up, mean sensing threshold was 2.23 mV, mean atrial stimulation threshold expressed as calculated energy consumption was 2.85 μJ (**Figure 2**), and mean lead impedance was 491.7 ohms (**Figure 3**). No serious complications such as bleeding, myocardial perforation, thrombosis, migration or snapping of the implanted electrodes were observed in the 3 patients. Pseudoinhibition due to over-sensing from myopotential was occasionally observed in 1 patient, and was dealt with by reprogramming the atrial sensitivity to not sense the myopotential.

Discussion

Since some patients with previous cardiac operations display subclinical reductions in cardiac function, maintenance of AV synchrony is important.[3] We have developed a technique for implanting tined endocardial electrodes into the right atrium during cardiac operations. The purpose of developing the present technique was to obtain atrial pacing using a tined endocardial electrode with stability and reliability for patients undergoing open-heart surgery who require permanent atrial or dual-chamber pacing due to the preoperative presence of bradycardial arrhythmias. Early and long-term performance of implanted tined electrodes have demonstrated acceptable electrode reliability, including maintenance of lead position without dislodgement, sufficiently high sensing thresholds with reasonably low stimulation thresholds and stable lead impedances. No serious complications were observed during follow-up. Due to concerns about lead fixation or dislodgement, screw-in electrodes have often been preferred to tined electrodes, in patients with a history of previous open-heart surgery who require permanent atrial or dual-chamber pacing. Several investigators have compared the long-term performance of screw-in and tined atrial electrodes in general populations of paced patients.[4–6] Closer inspection of these articles reveals a substantial number of defects in screw-in electrodes during long-term follow-up, such as increases in stimulation or sensing thresholds, loss of capture or sensing, entrapment of the tricuspid valve or chorda tendinae and lead dislodgement compared to tined electrodes, and the durability of the screw portion has been questioned.[4,5] Connelly et al. demonstrated that at implantation, sensed P-wave amplitudes were similar in both types of leads, but lead impedance and pacing threshold were significantly higher for screw-in electrodes compared to tined electrodes, and during follow-up, atrial pacing thresholds were significantly higher and sensed P-wave amplitudes significantly lower in patients with screw-in electrodes compared to those with tined electrodes. Loss of sensing occurred in 16% of patients with screw-in electrodes.[6] Connelly et al. also reported the challenge of implanting a tined electrode into the right atrium in 46 patients with previous cardiac operation. Although, a stable atrial position with satisfactory pacing and sensing thresholds was obtained in 40 of the 46 patients, 6 patients required a change to screw-in electrodes during implantation. Given these findings, implantation of a tined electrode into the right atrium for patients with previous cardiac operation is challenging, but not impossible. Another method to obtain atrial or dual-chamber pacing during cardiac operation is implantation of an epicardial electrode into the atrium and ventricle. Epicardial electrodes are useful for various kinds of patients, such as juvenile patients, patients with congenital or acquired right superior or inferior vena caval obstruction, or patients who have undergone tricuspid valve replacement. In younger patients who require atrial or dual-chamber pacing, epicardial electrodes should be selected initially. However, epicardial electrodes tend to display increases in stimulation or sensing thresholds over the long-term, due to inflammation or fibrosis in the epicardium where the electrode is attached, and general anesthesia is required for implantation. Moreover, problems with the implantation of epicardial electrodes can be encountered in patients who have undergone previous cardiac operations, due to the presence of adhesions between the pericardium and heart. We therefore, considered that the use of epicardial electrodes is beneficial in selected patients. The present technique was applied to patients who displayed preoperative ECG meeting the criteria that we have mentioned.[1] This technique displays limitations regarding patient selection, and involves putative risks such as difficulty removing the implanted electrode if electrode failure occurs. Caution is required when deciding on the method of implanted electrode installation. The method described herein involves a risk of lead damage in case of cardiac reoperation, as the implanted electrode runs just behind the sternum. To avoid lead damage

during resternotomy, the implanted electrode should be drawn out of the anterior mediastinum into the subdermal space to the right subclavian area via the intercostal space. The indications thus require caution, and younger patients would be relatively contraindicated, since the longevity of the implanted electrode would be considered shorter than the life expectancy of the patient. This technique is useful in carefully-selected patients undergoing open-heart surgery who require concomitant permanent atrial electrode implantation during cardiac operation.

Conclusion

We have applied a technique for implantation of a tined endocardial electrode into the right atrium during open-heart surgery, and reported the results of 3 patients who required permanent atrial or dual-chamber pacing during the operation. Long-term performance of implanted electrodes was stable and acceptable.

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