Implantable cardioverter defibrillator lead placement in the middle cardiac vein after tricuspid valve surgery

J. Alberto Lopez*

Department of Cardiology and Electrophysiology, Texas Heart Institute at St Luke’s Episcopal Hospital and Baylor College of Medicine, 6624 Fannin Street, Suite 2780, Houston, TX 77030, USA

Received 19 July 2011; accepted after revision 16 January 2012; online publish-ahead-of-print 14 February 2012

Aims

Pacing and defibrillation with an implantable cardioverter defibrillator (ICD) after tricuspid valve surgery can be challenging if right ventricular (RV) lead placement is contraindicated or safe lead placement in the RV apex is impossible.

Methods and results

In six patients for whom RV lead placement and repeat thoracotomy were contraindicated, ventricular pacing and sensing were achieved with bipolar leads placed in the lateral branch of the coronary sinus or in the atrialized portion of the RV or without helix exposure of the pace-sense electrodes of the defibrillator leads. After cannulation of the middle cardiac vein (MCV), a defibrillator coil lead was delivered there and placed in the farthest apical position. An ‘active can’ pulse generator was implanted in the left retromammary region. Biphasic shocks were delivered between the MCV coil, SVC coil, and the ‘active can’, or between the MCV coil, azygous vein coil, and the ‘active can’.

All six patients underwent successful implantation. All patients had a defibrillation safety margin of at least 10 J (at least two successful shocks at 25 J). During follow-up, one patient received a successful internal shock for ventricular fibrillation, and two received successful overdrive ventricular pacing for ventricular tachycardia. Three patients underwent defibrillation threshold testing to evaluate safety margins. No late complications have been reported at 60 months’ follow-up.

Conclusion

Defibrillator coil lead placement in the MCV is a safe alternative to epicardial lead placement via a thoracotomy in selected patients for whom RV lead placement is contraindicated or impossible.

Keywords

Atrioventricular pacing • Transvenous endocardial approach • Cardiac defibrillation

Introduction

Implantable cardioverter defibrillators (ICDs) provide protection against sudden cardiac death (SCD) in high-risk patients and have been proven superior to antiarrhythmic drugs in many clinical studies [the Antiarrhythmics Versus Implantable Defibrillators (AVID) trial,1 the Multicenter Automatic Defibrillator Implantation Trial (MADIT),2 MADIT II,3 and the Sudden Cardiac Death in Heart Failure Trial (SCD-HeFT)4]. Thus, many patients now are being referred for ICD therapy. Despite investigators testing a variety of non-thoracotomy lead configurations in the early days of transvenous defibrillation, placement of a transvenous defibrillator coil near the right ventricular (RV) apex and close to the interventricular septum emerged as and has remained the recommended position for one of the defibrillator coil leads.5

Pacing and defibrillation therapy after tricuspid valve surgery remains a challenge, because patients may have an absolute or relative contraindication to lead placement through the prosthetic valve or their anatomy may be unsuitable for safe and stable lead positioning. In these patients, epicardial placement of the defibrillator and pacing/sensing (p/s) leads has become the routine or most common alternative. Placement of pacing leads in the coronary veins for chronic ventricular pacing has been reported since 1994.6 Since then, leads specifically designed for left ventricular (LV) pacing have been designed, making it our placement technique.

* Corresponding author. Tel: +1 713 790 9401; fax: +1 713 790 0353. Email: jalopez@bcm.tmc.edu

Published on behalf of the European Society of Cardiology. All rights reserved. © The Author 2012. For permissions please email: journals.permissions@oup.com.
of choice in patients with prosthetic tricuspid valves. Conversely, placement of defibrillation coil leads via a transvenous approach after tricuspid valve surgery rarely has been attempted.

Reported here are the long-term results of a series of patients who underwent successful pacing and cardiac defibrillation via a transvenous, minimally invasive approach, which avoids the use of general anaesthesia and the morbidity and mortality associated with surgical epicardial lead placement. This alternative approach is particularly useful in patients who have undergone multiple, previous cardiac surgeries and for whom further invasive surgical procedures are contraindicated.

Methods

From February 2007 to December 2009, we evaluated six patients for ICD therapy (four women, two men; aged 38–65 years) for the primary or secondary prevention of SCD. Table 1 lists all medical conditions that precluded RV lead implantation in these patients. The transvenous approach was indicated, because all patients were either high-risk or poor candidates for a repeat thoracotomy.

The technique has been described in detail elsewhere. Briefly, after patients were under conscious sedation, a left axillary venous approach was used to catheterize the coronary sinus (CS). Angiography of the CS was performed with balloon occlusion either as distal as possible or in the anterior cardiac vein to document the middle cardiac vein (MCV) (by antegrade contrast flow) and its relationship to the proximal CS (Figure 1). Because of the need for continuous and reliable ventricular pacing due to AV block, specifically designed bipolar pacing leads were placed in one of the lateral branches, and adequate sensing and capture of the LV were obtained. In one patient without a pacing indication, sensing was obtained from the MCV lead: in this position, the R-wave sensing was excellent and capture threshold acceptable (2.8 V at 0.5 ms; diaphragmatic stimulation only occurred at an output of 7.5 V at 0.5 ms).

In another patient with Ebstein’s anomaly and atrioventricular (AV) block, CS branch lead placement was not possible. Ventricular pacing and sensing were obtained with an active fixation lead in the atrialized portion of the RV.

To place a second lead delivery system in the CS, selective cannulation of the MCV was performed, and a catheter delivery system (Attain Deflectable Catheter Delivery System, Medtronic, Minneapolis, MN, USA, for 7-Fr leads or SafeSheath CSG Introducer System, Pressure Products, Inc., San Pedro, CA, USA, for 9-Fr leads) was advanced into the vein (Figure 2). A single-coil defibrillator lead (Model 6937, Medtronic), a dual-coil pacing/defibrillator lead (Model 0185, Boston Scientific, Natick, MA, USA), or a 7-Fr dual-coil lead (1580 St Jude Medical, St Paul, MN, USA) was then advanced through the catheter delivery system and placed in the farthest apical position (Figure 3). To lessen the difficulty of removal, passive fixation leads were not used. In addition, the helix was not exposed on the active fixation leads, because it can result in vein perforation.

When indicated, atrial pacing and sensing were obtained at the interatrial septum by placing a standard bipolar active fixation lead at the ostium of the CS (Figure 4A) or using an Attain Deflectable Catheter Delivery System (Medtronic) to place a SelectSecure bipolar lead (Model 3830, Medtronic) at the region of Bachmann’s bundle to improve the diastolic filling time by avoiding an abnormally prolonged intra-atrial conduction time (Figure 4B). An ‘active can’ pulse generator was implanted in the left infraclavicular or retromammary position. Ventricular fibrillation (VF) was induced, and an adequate safety margin was documented (at least two successful defibrillations at 25 J). One of the patients with a severely enlarged LV required a coil be placed in the azygous vein before an acceptable safety margin was achieved.

Results

All procedures were performed in the electrophysiology suite using local anaesthesia while patients were under conscious sedation. All patients underwent successful procedures, without acute complications. All patients had at least a 10 J defibrillation safety margin (Table 2).

During the follow-up period, three of the six patients received appropriate therapy for ventricular tachyarrhythmia (one patient received one successful shock for an episode of VF and two patients received successful overdrive pacing for ventricular tachycardia). Three of the patients required 100% atrial pacing because of sick sinus syndrome and three of the patients received 100% ventricular pacing because of complete or advanced AV conduction block. Routine follow-up at 1 week, 1 month, and every 3 months thereafter indicated stable and adequate pacing and

**Table 1** Patient characteristics

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Sex</th>
<th>Clinical diagnosis</th>
<th>Previous surgeries</th>
<th>Previous thoracotomies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43</td>
<td>F</td>
<td>ToF, VT, AVB III</td>
<td>PVR, TVR, AVR, MVR</td>
<td>Ao root enlargement</td>
</tr>
<tr>
<td>2</td>
<td>57</td>
<td>F</td>
<td>RhHD, CMP, VT, A-fib</td>
<td>AVR, MVR, TVR</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>57</td>
<td>M</td>
<td>RVCMP, VT, SSS, AVB, A-fib, CAD, CABG, recurrent RV lead fracture (lead removal × 2)</td>
<td>TVR, MAZE, CABG</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>59</td>
<td>F</td>
<td>Ebstein’s, syncope, LV CMP, VSD, PFO closure, AFL, SSS</td>
<td>TV repair, VSD</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>65</td>
<td>M</td>
<td>Carcinoid, CMP, VT, A-fib</td>
<td>MV repair, TVR</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>F</td>
<td>Ebstein’s, ASD, AVB, VT, AF, LBBB, LV CMP</td>
<td>TV repair, ASD, MVR</td>
<td>2</td>
</tr>
</tbody>
</table>

A-fib, atrial fibrillation; AFL, atrial flutter; Ao, aortic; ASD, atrial septal defect; AVB, atrioventricular block; AVB III, atrioventricular block (third degree); AVR, aortic valve replacement; CABG, coronary artery bypass grafting; CAD, coronary artery disease; CMP, cardiomyopathy; LBBB, left bundle branch block; LV CMP, left ventricular cardiomyopathy; MVR, mitral valve replacement; PFO, patent foramen ovale; PVR, pulmonary valve replacement; RhHD, rheumatic heart disease; RVCMP, right ventricular cardiomyopathy; SSS, sick sinus syndrome; ToF, tetralogy of Fallot; TV, tricuspid valve; TVR, tricuspid valve replacement; VSD, ventricular septal defect; VT, ventricular tachycardia.
sensing thresholds, no dislodgements, and no post-implant complications. Patients continued to receive follow-up care every 3 months, as recommended.

At 1- to 5-year follow-up (minimum 13 months), there have been no late complications, no incidences of lead migration, and no need for re-intervention. One patient died of metastatic cancer complications 13 months after implantation. Three patients have undergone VF induction and defibrillation safety margin evaluation—two of them after 3 weeks of amiodarone therapy for the treatment of atrial fibrillation and the other for follow-up of the safety margin after requiring an azygous vein coil.

**Discussion**

Providing permanent pacing and transvenous cardiac defibrillation for patients with previous tricuspid valve surgery is a difficult task, but the excellent results from the long-term follow-up in these six patients demonstrate that defibrillator coil lead placement in the MCV is a safe alternative in patients for whom RV lead placement is either contraindicated or impossible.

Surgical implantation of epicardial defibrillator lead patch electrodes requires a thoracotomy and is associated with longer hospital stays, higher morbidity and mortality, and a higher incidence of
lead failure, which is more common in patients who have undergone previous cardiac surgery. Epicardial defibrillator lead malfunction or failure has been as high as 7.5% at 4 years for the only currently available patch. Alternatives to epicardial patch electrode placement have emerged, whereby subcutaneous defibrillator leads are placed in the pericardial space via a subxiphoid approach or in the subcutaneous tissue of the chest wall. Although acceptable results have been achieved in both adult and paediatric populations, these alternative methods do not address atrial or ventricular pacing therapy needs. Even though the newer steroid-eluting leads for epicardial ventricular pacing have a failure rate that approaches that of endocardial leads, the 5-year atrial lead failure rate is as high as 26% for steroid-eluting sutured atrial leads (a very difficult task from the subxiphoid approach) and 40% for non-steroid atrial screw-in leads.

A transvalvular coil lead placement approach through the bioprosthetic valve has been used as an alternative, but this approach has been associated with valve stenosis and insufficiency, valve leaflet damage during lead implantation or removal, and lead fracture and should be avoided, if possible. Furthermore, the transvalvular approach is absolutely contraindicated in patients with tilting-disc valves.

Subcutaneous coil leads gained popularity before the availability of biphasic waveform ICDs as a way to reduce the defibrillation threshold (by as much as 45%) in selected patients and thus avoid a thoracotomy. A new, totally subcutaneous implantable defibrillator (Cameron Health, Inc., Auckland, New Zealand) is currently undergoing clinical validation studies in the USA, with approval already granted in Europe. The new device is an attractive option, but it does not address the needs of patients who require pacing therapy.
The use of available defibrillator coil leads in the CS or the azygous vein has been shown to be another safe and effective way of obtaining an adequate defibrillation safety margin via a non-thoracotomy approach.\footnote{et al.} Unfortunately, when used without an RV coil, the CS lead to left intraclavicular ‘active can’ or the superior vena cava (SVC) ‘active can’ configurations are inadequate for achieving defibrillation, because most of the RV and LV free wall and the interventricular septum are outside the current field vector. Abdominal positioning of the ‘active can’ could possibly solve the current vector problem, as reported by Cohen et al.\footnote{et al.} Abdominal positioning of the ‘active can’ could possibly facilitate lead extraction, if necessary.\footnote{et al.} but such positioning requires tunnelling the leads to the abdominal pocket and the possible use of general anaesthesia, resulting in a significantly more complex implant procedure. Again, this approach does not address the need for ventricular pacing or tachycardia detection.

To the author’s knowledge, four other single case reports with no follow-up report have been published in the scientific literature that describe alternative lead configurations for avoiding a thoracotomy in patients who require ICD therapy after tricuspid valve surgery. Leng et al.\footnote{et al.} report a non-thoracotomy approach to implant a defibrillation system in a patient with a mechanical tricuspid valve and a persistent left SVC; however, subcutaneous coils were required to obtain an adequate safety margin, and a bipolar lead was needed in the MCV to obtain ventricular sensing. Schreiber et al.\footnote{et al.} report using a previously implanted epicardial ventricular pacing and sensing lead and obtaining defibrillation with a floating double-coil lead with a distal electrode in the inferior vena cava. Biffi et al.\footnote{et al.} report using a bipolar lead in a lateral CS branch for tachycardia detection and obtaining defibrillation with a single-coil active fixation lead screwed to the lower septal region of the right atrium. Finally, Cohen et al.\footnote{et al.} used a previously placed ventricular epicardial pacing lead for pacing and tachycardia detection and achieved defibrillation by placing a lead in the CS, tunnelled to the abdominal ICD pocket and using a CS to ‘active can’ configuration.

We prefer to place a defibrillator coil lead in the MCV and a conventional LV bipolar lead in a lateral branch. With the defibrillator lead in the MCV, the current vector is similar to what it would be in the conventional RV apical position. Positioning the coil lead electrode in the MCV, epicardially located and in contact with the LV inferior wall, increases the amount of myocardium within the current field and creates a favourable potential gradient over the interventricular septum, resulting in defibrillation of a greater mass of ventricular myocardium (Figure 1). A review of the scientific literature shows that others have evaluated this configuration—in animal models—as a way to decrease defibrillation energy requirements and ICD size. Arruda et al.\footnote{et al.} used a canine model to evaluate the feasibility and safety of an MCV electrode and its effect on the defibrillation threshold. They found that an MCV-to-SVC configuration resulted in lower defibrillation thresholds than did an RV-to-SVC configuration (22 vs. 35 J). They also studied the pathological effects of shocks delivered in the MCV and found no significant pericardial or coronary damage.

In follow-up experiments, Roberts et al.\footnote{et al.} using an MCV electrode is an effective, feasible, and safe alternative to the conventional epicardial approach when there is no access to the RV. The availability of a small-profile, over-the-wire defibrillator coil lead would make this approach much easier,\footnote{et al.} as would a coil or electrode covering of polytetrafluoroethylene to prevent the formation of scar tissue and facilitate lead extraction, if necessary.\footnote{et al.}

The chronic effects of electrode placement within the MCV or another CS branch should be carefully evaluated. Because long-term experience with this alternative configuration is lacking, the possibility of thrombosis and fibrosis, and the mortality and morbidity associated with future lead removal, if needed, should be weighed against the risks of other procedures.

In conclusion, we believe that the possible risks associated with this alternative approach compare favourably with those of the epicardial approach, which is a more invasive procedure with higher morbidity and mortality, particularly in patients who have previously undergone multiple cardiac surgeries. Further randomized, prospective studies of this approach are needed.

### Acknowledgements

J.A.L. is on the Regional Advisory Board, Cardiac Rhythm Management, for Medtronic and the National Advisory Board, Cardiac Rhythm Management, for Boston Scientific.

### Conflict of interest

none declared.

### References


