Six year experience of transvenous left ventricular lead implantation for permanent biventricular pacing in patients with advanced heart failure: technical aspects

C Alonso, C Leclercq, F Revault d’Allonnes, D Pavin, F Victor, P Mabo, J-C Daubert

Abstract

Background—Biventricular pacing has been proposed as an adjuvant to optimal medical treatment in patients with drug refractory heart failure caused by chronic left ventricular systolic dysfunction and intraventricular conduction delay. Objective—To assess the technical feasibility and long term results (over six years) of transverse left ventricular pacing with the lead inserted into a tributary vein of the coronary sinus. Subjects—From August 1994 to February 2000, left ventricular lead implantation was attempted in 116 patients who were eligible for biventricular pacing (mean (SD) age 67 (9) years, New York Heart Association (NYHA) functional class III/IV, left ventricular ejection fraction < 35%, QRS duration > 150 ms). Results—The overall implantation success rate was 88% (n = 102). A learning curve was indicated by a progressive increase in success from 61% early on to 98% in the last year. The mean pacing threshold was 1.1 (0.7) V/0.5 ms at the time of implantation and increased slightly up to 1.9 (0.9) V/0.5 ms at the end of the follow up period (15 (13) months). The rate of acute and delayed left ventricular lead dislodgement decreased from 30% in the early years to 11% after 1999. During follow up, 19 patients required reoperation for delayed lead dislodgement or increase in left ventricular pacing threshold (n = 15), phrenic nerve stimulation (n = 3), or infection (n = 3). Conclusions—Transverse left ventricular pacing through the coronary sinus is feasible and safe. The rate of implantation failure and of lead related problems has decreased greatly with increasing experience and with improvements in the equipment. (Heart 2001;86:405–410)

Keywords: biventricular pacing; left ventricular pacing; heart failure; intraventricular conduction delay

Biventricular pacing was proposed in 1994 as an adjuvant to medical treatment in patients with drug refractory heart failure caused by chronic left ventricular systolic dysfunction and intraventricular delay. Following encouraging results from acute haemodynamic studies, several groups initiated pilot studies of permanent biventricular pacing. Results from those open, non-randomised trials were encouraging, revealing a significant improvement in New York Heart Association (NYHA) functional classification, exercise tolerance, and quality of life in those patients. One of the technical difficulties of this novel therapeutic approach is to achieve effective, safe, and permanent pacing of the left ventricle. Three methods have been proposed for implanting the left ventricular pacing lead. Early implantations were performed by the epicardial route, but this method requires a thoracotomy or thoracoscopy under general anaesthesia, and the complication rate is too high. Second, certain groups have proposed pacing the left ventricular endocardially. With this technique, a lead is placed in the left ventricle after trans-septal catheterisation. The technique is still being evaluated and is currently reserved for use in cases of coronary sinus implantation failure. The third method is coronary sinus implantation, initially proposed by Daubert, and this is currently the most popular. Its main advantage is a totally transvenous approach. The lead, which is inserted into the subclavian vein, is positioned in a tributary of the coronary sinus. However, the difficulties posed by this method are not negligible in view of the pronounced anatomical variation in coronary sinus anatomy from patient to patient.

We report a six year experience of biventricular pacing, where the left ventricle was paced by a lead inserted into a branch of the coronary sinus.

Methods

INCLUSION CRITERIA
All patients at our centre with consecutively implanted biventricular pacemakers were included in the study. All met the following criteria:

- severe heart failure (NYHA class III or IV) despite optimised medical treatment, featuring at least angiotensin converting enzyme (ACE) inhibitors or angiotensin receptor blockers, diuretics, and more recently β blockers;
- heart failure was related to chronic left ventricular systolic dysfunction, regardless of aetiology, with a left ventricular end diastolic diameter of > 60 mm and a left ventricular ejection fraction of < 35%;
- all had major intraventricular conduction delay, with an intrinsic QRS duration of > 150 ms.

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Anterolateral vein
Great cardiac vein
Lateral vein
Posterolateral vein
Posterior vein
Mid-cardiac vein

Figure 1  Left ventricular lead position and implant pacing thresholds.

PACEMAKER
In patients who were in permanent atrial fibrillation, the left ventricular lead was connected to the atrial port of a DDDR pacemaker and the right ventricular lead to the ventricular entry, and the atrioventricular delay was programmed to its minimum value (30 ms). The pacing mode was therefore VVIR-biventricular. In those patients, the atrioventricular junction was systematically ablated at the time of implantation to ensure full and permanent ventricular capture.

In patients in sinus rhythm and in the early period of the experiment, both ventricular leads were connected to the ventricular port of a standard dual chamber pacemaker, using a Y bifurcated adapter. Dedicated pacemakers are now available which feature two ventricular entries (Chorum MSP, ELA médical, Le Plesis Robinson, France; InSync, Medtronic Inc, Minneapolis, USA; Contak, Guidant, St Paul, Minneapolis, USA). Pacing was delivered in biventricular DDD mode, the atrioventricular delay being optimised in each patient, based on the mitral flow morphology on Doppler echocardiography.11

EVALUATION
Patients were followed up one and three months after pacemaker implantation and every six months thereafter. Follow up consisted of: a clinical examination, functional evaluation (NYHA classification, cardiopulmonary exercise test), 12 lead surface ECG recorded at 50 mm/s, frontal and lateral chest x ray for lead position analysis, pacing and sensing threshold, and lead impedance measurements through pacemaker telemetry. Finally, pacemaker related or lead related complications were listed.

Results
CLINICAL DATA
One hundred and two consecutive patients (mean (SD) age, 67 (9) years) who received biventricular pacemaker implantations between August 1994 and February 2000 were included in the study. Heart disease aetiology included ischaemic in 37 patients, idiopathic in 50, and secondary to another cause in 15. All were symptomatic and were in NYHA functional class III (n = 71) or IV (n = 31), despite optimised medical treatment. Thirty one patients (30%) had chronic atrial fibrillation. QRS duration was 185 (26) ms on average. In
Table 1  Evolution of clinical variables with biventricular pacing

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before implantation</th>
<th>After implantation</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>QRS (ms)</td>
<td>185 (26)</td>
<td>158 (19)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>QRS axis °</td>
<td>-19 (61)</td>
<td>48 (78)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>NYHA class</td>
<td>3.3 (0.5)</td>
<td>2.0 (0.6)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>V̇O₂ max (ml/kg/min)</td>
<td>12.3 (4.7)</td>
<td>16.3 (4.3)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>LVEF (%)</td>
<td>22 (6)</td>
<td>26 (8)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

LVEF, left ventricular ejection fraction; NYHA, New York Heart Association functional class; V̇O₂ max, maximum oxygen consumption.

Table 2  Evolution of left ventricular lead electrical variables during follow up

<table>
<thead>
<tr>
<th>Time of implantation</th>
<th>Month 3</th>
<th>End of follow up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T (V)</td>
<td>R (mV)</td>
</tr>
<tr>
<td>Medtronic 2188</td>
<td>1.4 (0.9)</td>
<td>12.5 (6.0)</td>
</tr>
<tr>
<td>Medtronic 2187</td>
<td>0.9 (0.7)</td>
<td>14.0 (8.0)</td>
</tr>
<tr>
<td>Recent leads</td>
<td>0.9 (0.4)</td>
<td>12.5 (5.5)</td>
</tr>
<tr>
<td>Old leads</td>
<td>1.1 (0.9)</td>
<td>14.6 (6.0)</td>
</tr>
<tr>
<td>All</td>
<td>1.1 (0.7)</td>
<td>13.0 (7.0)</td>
</tr>
</tbody>
</table>

Values are mean (SD). T (V), pacing threshold (volts). I (Ω), pacing impedance (ohms); R (mV), R wave amplitude (mV).
Finally, three patients developed infection in the pacing system, resulting in the need for explantation. These infectious complications occurred 10 days, 21 days, and three months after implantation.

In 15 cases it was necessary to remove the left ventricular lead, either because of infection or to relocate it or replace it with another one. Eight such extractions were performed. In all cases the lead had been in position for more than one month, the oldest having been in place for 41 months. In all cases it was possible to remove the left ventricular lead from the cardiac vein by simple traction with no difficulty. There were no complications from this procedure. Finally, coronary sinus angiography was performed in three patients after the left ventricular lead was removed. This showed no thrombosis, stenosis, or coronary sinus dissection.

During the follow up period, no reintervention was necessary for premature battery depletion.

Discussion

It appears from our experience that biventricular pacing is a safe technique. Indeed, no life threatening complications were observed during the course of the study. The two coronary sinus dissections—which occurred during pacemaker implantation—had no consequences for the patients. Spontaneous healing of the coronary sinus allowed successful later implantation of a left ventricular lead in these patients. With regard to infectious complications, the rate in this study was 3%—that is, slightly higher than described for standard single or dual chamber pacemaker implantation. Infections occurred early after the procedure, probably related to the long duration of the operation.

Our study also shows that left ventricular pacing using a lead placed in a coronary sinus tributary has a good success rate, though the requirement for reoperation was relatively high at 25%. Nevertheless it should be stressed that the success rate has increased and the reoperation rate linked to lead displacement has decreased with increasing experience with the technique. This improvement in outcome is probably linked to the learning curve of the implantation operators, and also to the availability of new equipment. As seen in fig 2, the success rate has increased dramatically in parallel with the overall number of implantations, from 61% at the beginning of the study to 98% in the most recent year.

Both the use of preshaped sheaths that permit stable coronary sinus catheterisation and the advent of selective angiography of the coronary sinus and branches have contributed to the increased success rate of pacemaker implantation. The saving in time that has resulted from these innovations is valuable in the light of the large anatomical differences in the coronary sinus and its branches from one patient to another.

The introduction of new leads has also reduced the number of failures. Smaller diameter leads facilitate coronary vein catheterisation and allow easier passage around tortuous vessels. They also ensure better contact and hence improved electrical properties. Some investigators have stressed the value of new leads featuring a side wire or over-the-wire technology—similar to that used in coronary angioplasty—to facilitate access to the coronary veins.

The development of new equipment has thus made it possible to increase the success rate and reduce operation time, but does it ensure optimal pacing configuration? Most teams consider that the optimal position of the left ventricular lead is in the lateral wall of the left ventricle. Some investigators have indeed reported that in dilated cardiomyopathies with conduction disorders the left

Figure 3 In this example there is a large lateral vein in which a thick conventional lead could easily be introduced. LV, lateral vein; RA, right atrial lead; RV, right ventricular lead; LV, left ventricular lead.
ventricular lateral wall often shows delayed contraction. After analysing the acute haemodynamic effects of BiV pacing, others have concluded that the best configuration includes pacing of the left ventricular free wall. However, achieving the optimum configuration is subject to certain limitations linked to the anatomical variability of the coronary sinus and its branches. Indeed, even though the mid- and great cardiac veins are constantly present, no lateral or posterior branches can be found in around 1% of patients. In addition, the diameter of the branches and the angles they make with the coronary sinus also vary between patients, making these vessels hard to access. In figs 3, 4, and 5 we show the anatomical variability of the coronary sinus and branches. Figure 3 is an example where the gauge and angle made by the coronary sinus with a lateral branch make the branch readily accessible to a pacing lead. In fig 4, however, angiography shows the presence of a good calibre posterolateral branch, but its angle with the coronary sinus may create difficulty in introducing a lead. Leads featuring angioplasty-type guidewires here prove their worth. Finally, in the example shown in fig 5 there is no lateral or posterior branch. In that particular case, a choice had to be made between the great cardiac vein, which is small in diameter, and the mid-cardiac vein. In our study, 70% of left ventricular leads were positioned in a lateral, anterolateral, or posterolateral branches of the coronary sinus. The lack of a lateral branch or the presence of a high pacing threshold forced us to select other locations in some cases.

It should be noted that pacing and sensing electrical properties did not vary significantly with the position of the lead (fig 1). Electrical resynchronisation also appeared to be satisfactory, because QRS duration was reduced by 15% on average and the QRS axis tended to normalise. The pacing mode induced a significant functional improvement in our patients, as reflected by the downgrading of the NYHA classification (by one class on average), improved exercise tolerance, and an increase in average VO_2 peak of 32%.

**CONCLUSIONS**

Transvenous biventricular pacing is a feasible technique with a low complication rate. There have been no serious complications in our patients. An initially high rate of implantation failure because of difficulties with the left ventricular lead has decreased greatly with the increasing experience of the operators and with the development and introduction of new leads and equipment. Further improvements are likely, in parallel with ongoing technological advances.

Aortic recoarctation as the source of arterial embolism 32 years after synthetic patch angioplasty

A 44 year old man presented with intermittent claudication of the right lower leg and a history of surgical repair for aortic coarctation at the age of 12 years. Right popliteal and pedal pulses were diminished, and a 3/6 mesosystolic heart murmur was most clearly audible over the posterior part of the thorax. Systolic blood pressure was slightly raised equally in both arms, and a systolic ankle/arm pressure gradient that was higher on the right than on the left side (75 mm Hg and 45 mm Hg, respectively) was found. Ultrasound showed a mass in the right popliteal artery causing severe stenosis. Angiography revealed two structures in the middle and just before the bifurcation of the popliteal artery (far left). Based on these findings, a subacute popliteal artery embolism was suspected. No irregularities were found in the lower aorta and iliac/femoral arteries. Other causes of the embolism, such as atrial fibrillation, endocarditis or patent foramen ovale, were excluded.

Transoesophageal echocardiography showed high grade aortic recoarctation with an extensively protruding and partly mobile sclerotic structure (left) at the site where the patient had undergone corrective surgery with Dacron patch angioplasty 32 years previously. Resection of the restenosed aortic segment with interposition of a synthetic vascular tube graft was performed. The preoperative systolic pressure gradient of 40–50 mm Hg greatly improved, but intermittent claudication remained unchanged. The claudication was resolved only after subsequent balloon angioplasty of the right popliteal artery.

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