Technical considerations in implanting left ventricular pacing leads for cardiac resynchronisation therapy

Christoph Stellbrink*, Ole-Alexander Breithardt, Peter Hanrath

Medizinische Klinik I, Klinikum der RWTH Aachen, Aachen, Germany

Received 3 May 2004; accepted 24 May 2004

Cardiac resynchronisation therapy usually requires implantation of a left ventricular lead. The coronary venous approach is nowadays preferred for this purpose because of the less invasive nature compared to direct epicardial stimulation. Optimal hemodynamic support, accessibility of the desired vein location and adequate pacing parameters without phrenic nerve stimulation are the three most important aspects for successful left ventricular lead implantation. The highly variable anatomy of the coronary venous system can sometimes cause difficulties but in experienced hands, implant success rates of more than 95% can be achieved. In this article, the potential problems and pitfalls in implanting left ventricular leads and potential solutions to problematic cases are discussed.

© 2004 The European Society of Cardiology. Published by Elsevier Ltd. All rights reserved.

KEYWORDS
Cardiac resynchronisation therapy; Pacemaker; Electrodes; Coronary veins

Introduction

Cardiac resynchronisation therapy (CRT) has become an accepted adjunct therapy for patients with drug-refractory heart failure and ventricular conduction delay. Several studies have demonstrated acute hemodynamic benefit,1–4 chronic functional improvement5–7 and reverse remodeling of the left ventricle.8–10 All available evidence suggests pacing the left ventricle is mandatory in the vast majority of patients in order to achieve a favourable clinical outcome. Principally, this can be achieved by pacing leads introduced into the thorax via a limited thoracotomy sutured directly to the left ventricular epicardial wall, by endocardial pacing after transseptal puncture, or by using the coronary venous system. Whereas the endocardial approach is not widely accepted due to the associated potential thromboembolic risk the coronary venous approach has become the preferred approach because of its lower morbidity compared to thoracotomy. This article highlights the anatomical structures, the necessary requirements for a left ventricular lead implant and potential pitfalls in these procedures.

Coronary venous anatomy

The coronary venous system has gained increasing interest by electrophysiologists as a potential site for mapping, ablation, intracardiac defibrillation and pacing of the left atrium as well as the left ventricle. It is usually readily accessible by retrograde intubation from the low right atrium. Although left ventricular lead placement may be possible without venous angiography it is advisable in order to visualize the different vein branches that may be suitable for pacing. It is usually performed with a retrograde approach using injection of contrast dye distal to a balloon which is inflated during injection to optimize vessel opacification. The size of the coronary venous branches is usually sufficient to allow placement of pacing leads.11 There are two characteristic features of cardiac venous anatomy: the high interindividual variability of the different branches and the high amount

* Correspondence: C. Stellbrink, Medizinische Klinik I, Klinikum der RWTH Aachen, Pauwelsstrasse 30, 52057, Aachen, Germany. Tel.: +49-241-8089945; fax: +49-241-8082441. E-mail address: cstellbrink@ukaachen.de (C. Stellbrink).
of anastomoses between these branches. The latter fact is probably the reason why occlusion of a venous branch e.g. by an implanted lead usually has no clinically relevant sequelae. Several comprehensive studies on cardiac venous anatomy have been published\textsuperscript{12–14} which are the basis of the nomenclature used in the following (Fig. 1(b)). The coronary sinus (CS) begins where the oblique left atrial vein meets the great cardiac vein. It drains into the low right atrium between the inferior vena cava and the tricuspid valve. The great cardiac vein, accepting venous blood from the anterior half of the interventricular septum and anterior wall of the left ventricle, originates where the anterior interventricular vein reaches the base of the heart and terminates at the CS. One or 2 posterior veins (or one lateral and one posterior vein, respectively) drain into the CS. The middle cardiac vein, accepting blood from the posterior part of the interventricular septum, runs in the posterior interventricular groove and drains into the proximal CS or directly into the low right atrium.

**Placing the lead for left ventricular pacing**

Left ventricular lead implantation requires considerable experience with pacing lead implantation and invasive electrophysiology procedures. Expertise in coronary interventions is extremely helpful, especially if the "over-the-wire" approach is used. Several lead systems have been developed by different manufacturers for pacing

---

**Fig. 1** Coronary sinus (CS) angiography in a patient with dilated cardiomyopathy undergoing implantation of a biventricular pacemaker-defibrillator (all images are in the 30° LAO projection). Panel (a) shows the preoperative CS angiogram performed via the femoral route during a regular cardiac catheterization using an occluded balloon catheter (arrow). The great cardiac vein (GCV) and a prominent posterior vein (PV) are visualized, the anterior vein is only small and hardly visible. The PV drains at a 90° angle into the CS. Panel (b), obtained during the first implantation attempt, shows a CS ostium which was difficult to enter via the left subclavian route. Only with the help of a small inner catheter with a right coronary Judkins curve, the ostium could be identified. The right ventricular (RV) coil is already placed in the RV apex, the right atrial (RA) lead is not yet fixed. Advancement of the guiding catheter caused dissection of the proximal CS (Panel (c)), as indicated by the persistent contrast staining (*). The right-sided leads were fixated but the implant of the left ventricular (LV) lead was abandoned at this time to avoid further damage to the vessel. The patient had no clinically relevant sequelae. Three weeks later, the LV lead could be implanted deeply into the PV in a second procedure without any problems (Panel (d)). A CS dissection was no longer discernible.
from the CS tributaries. Although direct lead placement with stylet-guided pacemaker leads may be feasible in some patients, most implants require intubation of the coronary sinus with a dedicated guiding catheter. The catheter provides support for advancing the pacing leads and also allows changing the angiography catheter and different pacing leads in difficult cases. For placement of the lead through the guiding catheter, two techniques have been employed: a "conventional" stylet-guided pacing lead or an "over-the-wire" approach. For the latter, a guidewire (as used in coronary interventions) is first advanced into the desired branch of the CS and the lead then pushed into the vessel guided by the wire. While the "over-the-wire" technique offers advantages for placement in small tortuous veins, conventional leads may be preferred in large veins with a relatively straight course. Fixation of the lead may be achieved by small anchors at the tip, pre-shaped curves or helical screws.

Three aspects are important in determination of the optimal pacing site: maximal hemodynamic support, accessibility of the desired vein location and electrical measurements obtained.

In most cases, a lateral or posterior vein is the desired location for achieving optimal hemodynamic support, as this is usually the site of most delayed activation of the left ventricular wall in patients with left bundle branch block. A posterior or lateral vein is present in 99% of patients referred for regular ICD implants. In individual cases, other veins can be chosen if analysis of ventricular dyssynchrony e.g. by echocardiography suggests a different site providing optimal LV resynchronisation.

With the advancement of lead technology in recent years, accessibility of different vein branches has become a rare problem. Sharp angles between the target vein and the CS (Fig. 1(a) and (d)) can be passed by placing an angiography catheter with a narrow curve (e.g. a right Judkins catheter or an internal mammary artery catheter) through the guiding catheter and directly intubating the CS side branch. A stiff guidewire is then placed in the distal part of the vein through the angiography catheter which is then withdrawn while keeping the wire in place. In most instances, the pacing lead can then be advanced into the desired location. In our own experience, LV lead placement is eventually successful in more than 95% of patients and implant failures are more often due to insufficient support by the guiding catheter than by anatomical problems involving the anatomy of the ventricular CS branches. In fact, enlargement of the right atrium and the accompanying distortion of the CS os (Fig. 1(b)) anatomy may cause failure to cannulate the CS in up to 4% of patients.

There are rare instances in which a posterolateral vein cannot be used for pacing, either because there is no adequately sized vein present, no pacing lead can be placed for anatomical reasons or no site with an adequate pacing threshold without phrenic nerve stimulation can be identified. In this situation, epicardial lead placement by a limited thoracotomy is a useful option. In the author’s view it is preferable to implant an epicardial lead than to accept a hemodynamically suboptimal left ventricular (e.g. anterior) lead position using the CS approach.

The Thebesian valve, a fold that guards the entrance of the CS into the right atrium, may sometimes cause difficulties in advancing the guiding catheter into the CS ostium. Another valve may be found at the junction of the great cardiac vein and the CS, the valve of Vieuxsens. Both valves can be passed with some gentle manoeuvres: With the use of a steerable electrophysiology catheter the Thebesian valve can usually be passed before advancing the guiding catheter using the steerable catheter for support. The valve of Vieuxsens is only rarely a problem; it can usually be passed with a stiffer guidewire which allows enough support to advance the lead over the wire.

Once the lead is placed in the desired location, pacing threshold and local sensing are measured. Usually, a pacing threshold of $\leq 2$ V and a sensing of $\geq 5$ mV are acceptable for implantation. However, temporary stimulation at maximal output is required to rule out phrenic nerve stimulation which has been noted chronically in 1.3–2.1% of cases. It is caused by the close anatomical proximity of the phrenic nerve to lateral pacing sites. If phrenic nerve stimulation occurs during intraoperative testing, different vein locations should be tested because this adverse effect is often intolerable for the patient and is difficult to handle once the lead system is implanted. After fixation of the lead in the desired vein location, the guiding catheter is usually removed carefully avoiding dislocation of the LV lead.

### Complications

Apart from phrenic nerve stimulation, CS dissection may be caused by too vigorous advancement of the guiding catheter (Fig. 1(c)) or by injection of the contrast medium through an angiography catheter with its tip pressed against the vessel wall. The incidence of coronary sinus dissection is 2.8–5.0%. Fortunately, CS dissection usually heals well and CS perforation is exceedingly rare. However, lead placement should be abandoned and a relevant pericardial effusion be excluded by echocardiography if CS perforation is suspected. Usually, implantation of the LV lead can be safely performed several weeks later when the dissection is healed.

### Summary

The variability of coronary venous anatomy makes the implantation of left ventricular leads for cardiac resynchronisation therapy sometimes a challenging experience. Currently, several lead systems by different manufacturers allow an individualized approach to problematic cases. This allows an implant success at the hemodynamically optimal site in more than 95% of cases in experienced hands.

### References

1. Blanc JJ, Etienne Y, Gilard M et al. Evaluation of different ventricular pacing sites in patients with severe heart failure:


