

Cardiac Resynchronization Therapy - How to Overcome High Left Ventricular Pacing Thresholds and Avoid Phrenic Nerve Stimulation

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ABBREVIATIONS:

CRT: cardiac resynchronization therapy
CS: coronary sinus
LV: left ventricle
PNS: phrenic nerve stimulation

KEY WORDS: *cardiac*

*resynchronization therapy;
biventricular pacing; left ventricular
pacing; phrenic nerve stimulation;
cardiac pacing; pacing threshold;
coronary sinus lead; pacemaker exit
block*

ABSTRACT

High pacing thresholds and phrenic nerve stimulation (PNS) are not uncommon in contemporary cardiac resynchronization therapy (CRT) systems, based on our own experience as well as on other series. Whereas some cases may be resolved by programming, other cases necessitate reoperations or abandonment of the left ventricular (LV) lead. Approaches to avoid and to manage these two problems are reviewed according to our experience as divided into four phases: 1) During implantation – whereby careful selection of pacing site is required, as well as meticulous testing of thresholds and PNS, and avoidance of any site with any PNS; 2) Device and lead selection – in difficult cases with high thresholds and PNS, a system with multiprogrammable pacing configurations and bipolar leads may be preferred; 3) Programming – we found a significant advantage of systems with multiprogrammable pacing configurations and bipolar leads in dealing with PNS and high thresholds with essentially nearly 100% of those problems being resolved by reprogramming the pacing configuration in the LV lead; 4) Epicardial implantation – in cases where adequate LV pacing cannot be achieved, epicardial pacing should be considered with special emphasis on appropriate lead location.

Cardiac resynchronization therapy (CRT) using coronary sinus leads therapy has become routine in the management of patients with systolic heart failure and intraventricular conduction delays. Despite its wide use, the technique of coronary sinus pacing for left ventricular (LV) capture is far from being perfect even if compared to traditional right ventricular pacing. Higher failure rates during implantation, as we and others have shown [1,2] will not be discussed here. This paper will concentrate on increased pacing thresholds and phrenic nerve stimulation (PNS) that are frequently encountered in these systems. These complications may lead to reoperations and to LV lead abandonment [1,3].

As we have previously shown, pacing thresholds tend to be higher with left ventricular pacing, therefore even modest elevations of the thresholds over time may also lead to rapid depletion of the device battery [4]. Phrenic nerve stimulation is a common problem in CRT systems that may result from direct stimulation of the diaphragm or from phrenic nerve stimulation. Its incidence ranges between 3 to 20% in different series [1,5]. Whereas most of the cases can be resolved by programming,

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some cases may necessitate reoperation or lead abandonment. Our own experience in 150 cases is summarized in Table 1 and in ref [1].

The discussion of methods to avoid high thresholds and PNS is divided here into four parts: measures taken during implantation, system and LV pacing lead selection, programming maneuvers and epicardial lead implantation.

1. MEASURES DURING IMPLANTATION

Optimal lead positioning during implantation is the key for avoidance of high thresholds and PNS. Avoidance of scar areas with high pacing thresholds, as well as avoidance of areas lying directly over the diaphragm or near the phrenic nerve are basic principles that apply during any LV lead implantation. Albertsen et al [6] have recently characterized by simple fluoroscopy pacing sites that are more prone to phrenic nerve stimulation that should, if possible, be avoided. However, stable lead positioning and thorough testing of thresholds and of PNS are probably the key measures to be taken during implantation. If general anesthesia is being used, it is important to test for PNS when the patient is not under the influence of muscle relaxants such as curarizing agents that may mask PNS. Phrenic nerve stimulation is extremely posture-dependent and therefore cannot be completely reproduced during implantation with the patient in the recumbent position. We have noted that when any PNS occurs during testing at implantation, even if at high outputs, it is very likely to occur clinically at lower thresholds. We therefore recommend trying to avoid any location with any PNS during implantation whenever possible.

2. PACING LEAD SELECTION

We recently evaluated the acute and long term performance of different LV leads. There was no significant difference between the leads tested for LV pacing thresholds both acutely and chronically. Neither was there any significant difference in PNS (Table 1), although the Medtronic 2187 lead may have shown a tendency to lower incidence of PNS. One

may speculate that it has to do with the shape of the lead (J shape with a relatively short arm) which is usually implanted in relatively basal areas, that are far away from the diaphragm.

In another study of our group [7] we compared the results of systems with multiprogrammable configurations and bipolar leads with the results of other systems. When looking at the implantation results, the LV lead was successfully placed in a lateral or posterolateral branch in 95% of the study group, compared to only 77% of the control patient group (P=0.004). This advantage was related in part to the possibility to avoid PNS and high thresholds by changing the configuration while leaving the LV lead in its place, whereas other systems had to be repositioned or removed.

Moreover, the fact that multiprogrammability of pacing configurations, as described in the next paragraph, is beneficial also in long term management of high thresholds and PNS, may point toward the advantage of using multiprogrammable systems with bipolar LV leads for this purpose, at least in cases that are found during implantation to be problematic as far as thresholds or PNS.

3. PROGRAMMING ISSUES

Newer CRT systems that use a bipolar coronary sinus (CS) lead offer an option for programmable multiple pacing configurations. In those systems pacing of the LV may be achieved by using either the tip or the ring of the lead as either cathode or anode. When one of them encounters high thresholds or PNS, the alternative pole which is located at some distance may be used instead to avoid this problem. Noninvasive programming enables the physician to choose the lowest threshold configuration, and thus increases flexibility during CRT implantation, and help to extend battery longevity. In cases where PNS is encountered, switching to a different LV pacing configuration may overcome this problem, and prevent the need for invasive lead repositioning.

We [7] have recently shown the advantage of using multiprogrammable pacing configurations with bipolar leads, in lowering pacing thresholds and avoiding PNS. In that work, CRT systems capable of multiple LV pacing configurations

TABLE 1. Phrenic nerve stimulation with different left ventricular (LV) leads.

	Medtronic® 2187 N=30	Medtronic® 4193+4194 N=56	Easytrak® Leads (4513+ 4518) N=64	P Value
Diaphragmatic stimulation	1 (3%)	10 (18%)	8 (12%)	0.1
Intractable diaphragmatic pacing	None	1 - LVP Stopped 2 - Re-operation	1 - Reoperation	

LVP: left ventricular pacing

(Guidant models H155 and H145) were implanted in 43 patients (study group). An additional control group of 49 patients (control group) received CRT systems (Guidant, Medtronic, Biotronik, St. Jude Medical, various models) lacking this feature.

Overall, high (≥ 2.5 V/0.5 ms) LV thresholds were encountered in 13 (30%) of the study group, and 25 (50%) of control group patients ($P=0.03$). Phrenic nerve stimulation was encountered in 5 (12%) of the study group and 12 (24%) of control group patients ($P=0.13$). Notably, all cases of high LV thresholds and PNS in the study group were successfully managed by switching to a different LV pacing configuration, while high thresholds remained in control group patients, and PNS was managed by replacing the lead.

The change of threshold achieved was sometimes dramatic, and there was no single configuration that was the best. The best configuration for the individual patient had to be determined by threshold determination at all available configurations. Multiple LV pacing configurations were therefore clinically useful in a significant number of patients undergoing CRT system implantation by helping to overcome high LV pacing thresholds and PNS, and by providing more flexibility in placing the LV lead. It is reasonable to prefer those systems in patients who are found to be problematic as far as threshold and/or PNS management.

4. EPICARDIAL LV PACING

Whereas LV pacing using CS lead is currently the method of choice, in some cases this goal cannot be achieved due to high thresholds or intractable PNS despite all the maneuvers mentioned above. In those cases one may consider epicardial lead implantation on the left ventricle using thoracotomy, mini thoracotomy or thoroscopic surgery [8-10]. It is important to emphasize that in order to achieve favorable hemodynamic results, the lead has to be placed through a posterolateral approach rather than a standard lateral thoracotomy incision, and some authors have advocated mapping methods during the procedure [11]. It is also important to ensure appropriate visualization of the phrenic nerve along its course on the lateral border of the heart, in order to avoid PNS that may be obscured during the operation by muscle relaxants. Long term results of epicardial pacing are as good as CS pacing for this purpose [10]. In the few cases where implantation fails or where there are high thresholds or intractable PNS, this option should be considered as the only way to achieve CRT.

CONCLUSION

High thresholds of LV pacing and PNS are not uncommon

in contemporary CRT systems. These problems may be minimized by careful selection of electrode location during implantation and meticulous testing, by use of systems with multiprogrammable configurations and bipolar leads in difficult cases by changing pacing configurations to achieve optimal thresholds without PNS. In a few cases epicardial LV lead implantation may be necessary.

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