Left ventricular pacing with a new quadripolar transvenous lead for CRT: Early results of a prospective comparison with conventional implant outcomes

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BACKGROUND: Flexible left ventricular (LV) pacing configurations are a useful component of cardiac resynchronization therapy (CRT) systems for preventing high LV pacing thresholds and phrenic nerve stimulation (PNS). A quadripolar LV lead has recently been designed with the purpose of allowing more choices in lead placement location and programming capability.

OBJECTIVE: To verify the effectiveness of quadripolar LV leads compared to conventional bipolar LV leads implant outcomes.

METHODS: Forty-five consecutive patients underwent implantation with either the quadripolar (n = 22; quadripolar group) or a conventional bipolar LV lead (n = 23; bipolar group). The primary outcome of the study was LV lead failure, defined as the need for lead revision or reprogramming during the first 3 months after implantation. Additionally, operative and follow-up data were prospectively noted and checked for significance between groups.

RESULTS: The implantation success rate in both groups was 100%. Baseline characteristics, procedure duration, and fluoroscopy time did not differ significantly between groups. Two lead dislodgments (requiring reoperation) and 4 clinical PNS were reported in the bipolar group; reprogramming of the device was sufficient to prevent PNS in 3 patients, the fourth is pending solution. One PNS successfully managed noninvasively occurred in the quadripolar group. By Kaplan-Meier analysis, event-free survival for the combined primary outcome was significantly lower in patients with quadripolar leads (P = .037).

CONCLUSION: This prospective, controlled study provides strong evidence that CRT with the quadripolar LV lead results in low rates of dislocations and phrenic nerve stimulation.

KEYWORDS Cardiac resynchronization therapy; Lead performance; Left ventricular lead; Left ventricular pacing configurations; Phrenic nerve stimulation

ABBREVIATIONS CS = coronary sinus; CRT = cardiac resynchronization therapy; LV = left ventricular; RV = right ventricular; PNS = phrenic nerve stimulation

Cardiac resynchronization therapy (CRT) is well established as a treatment for heart failure in patients with severely impaired left ventricular (LV) systolic function and evidence of ventricular dyssynchrony.1,2 Although advances in technology and improving expertise have increased the success rate for biventricular system implantation, the placement of a coronary sinus (CS) lead is a technically challenging procedure owing to variable vein anatomies, and lead stability still remains problematic.

Combined results of over 2,000 patients from a multicenter study showed a need for reoperation in 8% of patients during a 6-month follow-up period.3 The reasons for revision included mainly LV lead dislodgment with loss of capture, phrenic nerve stimulation (PNS), or increased LV pacing threshold without obvious lead dislocation. The principal obstacles to the successful implementation of CRT involve limited anatomic choices for the placement of the LV lead and difficulties in obtaining a stable pacing site free of extracardiac (phrenic nerve) stimulation. Most LV leads are preshaped and curved in one or multiple dimensions to ensure passive fixation in the target vein. Special LV leads using different fixation techniques (stent implantation, leads with retractable tines, screw-in leads) were designed to ensure successful CRT in patients with challenging coronary vein anatomy.4-6

Recently, a quadripolar CS lead (Quartet 1458Q, St Jude Medical, Sylmar, CA) has been designed to provide more options for LV pacing. The goal of this design, which integrates multiple pacing options, was to minimize the effects of lead dislodgment and give the implanters more choices in implantation location and in device programming, as compared to the configurations available with traditional bipolar LV leads.

In this report, we compare for the first time different bipolar CS leads with this newly developed lead in terms of
safety, procedural course of implantation procedures, and LV leads’ performance.

Methods

Patients and study protocol
This was a single-center, prospective, controlled, nonrandomized study performed in a tertiary care university hospital. Consecutive patients who were scheduled for the implantation of a CRT device according to current guidelines at time of implantation were prospectively enrolled. Patients were included regardless of whether the implant was performed as a first-device implantation procedure or whether the CS lead was placed as part of an upgrade procedure in patients who already had either a permanent pacemaker or an implantable defibrillator. Patients participating in the study had to be willing to attend the follow-up control visits in the outpatient clinic. The study was approved by the local ethics committee, and all patients gave written informed consent.

Over a period of 6 months, eligible patients underwent implantation either with a quadripolar LV lead (n = 22; quadripolar group) or with a conventional bipolar LV lead (n = 23; bipolar group). The choice of lead type was not made according to patient clinical characteristics, but was related to the availability on the day of implantation. Devices were individually programmed according to arrhythmia and patient characteristics.

Procedural and fluoroscopic time at implantation, as well as lead measurements, handling characteristics, and any complications or clinical events, were noted at implantation, discharge, and follow-up visits. In addition, physicians were asked to rate handling characteristics of the LV pacing leads as excellent, good, adequate, or difficult.

LV pacing leads
The quadripolar pacing lead used in this study (quadripolar group) was the Quartet lead, a 4.7-F, over-the-wire, steroid-eluting LV lead with a 4-electrode in-line connector (Figure 1). Connected to an appropriate CRT-D device (Promote Q or Promote Quadra, St. Jude Medical Inc., Sylmar, CA), it enables delivery of pacing stimuli using any of the 4 electrodes as the cathode in 10 bipolar pacing configurations.

Five different types of LV lead by 3 manufacturers were used in the control group: Easytrak 3 and Acuity Steerable (Boston Scientific Corp., Natick, MA), Attain Ability 4196 (Medtronic Inc., Minneapolis, MN), Quickflex 1156T and 1258T (St. Jude Medical Inc., Sylmar, CA). All CRT-D devices implanted in the bipolar group were capable of at least 4 different LV pacing configurations, including LV tip to either LV ring or right ventricular (RV) coil, and LV ring to either LV tip or RV coil.

Implant procedure
All procedures were performed under local anesthesia by 2 electrophysiologists (G.B.F. and L.S.) who were experienced in CRT implantation. Pacing leads were implanted via cephalic vein or by subclavian vein puncture. The defibrillation lead was positioned first, followed by the atrial

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Figure 1  View of the quadripolar left ventricular lead with a detailed representation of the multiple pacing vectors. The 3-ring electrodes (M2, M3, P4) are located 20, 30, and 47 mm from the 4.0-F–tip electrode (D1). Maximum lead body diameter is 4.7-F. In conjunction with an appropriate device, it enables delivery of pacing stimuli using any of the 4 electrodes in 10 pacing configurations. Bottom: final lead location at implantation from the right anterior oblique projection. RV = right ventricular.
lead. The implantation of the LV lead was preceded by an angiography of the CS in every patient, then a target vein was identified.

The LV leads were positioned in the most optimal available anatomic branch of the CS. The preferred position was a lateral or posterolateral vein. Implanters selected secondary targets only when venous anatomy, stimulation threshold, stability, or extracardiac (diaphragmatic) stimulation prevented lead delivery to the primary site. Final lead position and pacing configuration was determined at the discretion of the operator based on acceptability of pacing thresholds, absence of diaphragmatic stimulation, and anatomic position. PNS was tested in all patients starting from maximum pacing system analyzer output, 10 V at 0.5 ms. The inability to deliver an LV lead into any venous branch defined a failed implantation attempt. The final position of the LV pacing lead was assessed with cine fluoroscopy. Implantation duration was defined as the time between skin incision until suture. Measurements were repeated within 24 hours of implantation using the implanted pulse generator and pacemaker programmer.

Follow-up
Clinical evaluation and device testing were carried out at each follow-up visit scheduled at 1 and 3 months after implantation. For the purpose of this study, follow-up was terminated 3 months postimplantation.

Pacing thresholds were determined in volts at a pulse width of 0.5 ms. The lead impedance was measured at an output setting of 2.5 V and 0.5 ms. PNS and LV pacing threshold were measured by a step-down protocol starting from maximum device output in all of the pacing configurations available according to lead type and device programming capability. PNS threshold was evaluated during respiratory changes in several body positions: supine, left lateral, right lateral, sitting, and standing. In the event that patients had PNS during follow-up, they were evaluated for symptom assessment and problem solving. We defined PNS as regular sensations reported by the patient and confirmed by the physician on physical examination of the patient during follow-up.

At each visit, the final biventricular pacing configuration was determined at the physician’s discretion, based on acceptability of pacing thresholds, absence of PNS, and after evaluating the effects of different configurations on hemodynamic parameters as assessed by a comprehensive numerical model to improve biventricular pacing temporization.

Statistical analysis
The primary outcome of the study was LV lead failure, defined as the need for lead revision or reprogramming. The rate of CS lead failure was determined using the Kaplan-Meier estimates.

Categorical data are summarized using absolute values (percentage). Continuous data are presented as mean (SD) or, where shown, as median (interquartile range). Continuous variables were tested for normal distribution by the Kolmogorov–Smirnov test. Noncontinuous variables expressed as proportions were compared using chi-square analysis or Fisher exact test. Comparison between groups was performed with either the Student t-test or, when data were not normally distributed, the Wilcoxon rank sum or signed rank test. All P values were 2-sided, and a P value of .05 was considered to indicate statistical significance.

Results
Patient demographics
A total of 46 subjects having CRT implantation attempts (defined as skin incision made) were evaluated. One implant failure occurred because of inability to cannulate the CS ostium, reducing the sample size to 45 patients. The cohort was 75.5% male, and ages ranged from 46 to 87 years. Of these 45 patients, 22 underwent an implantation attempt with the quadripolar LV lead (quadripolar group), and 23 were attempted with a conventional bipolar LV pacing lead (bipolar group). Baseline characteristics of the whole study population and of the 2 study groups are described in Table 1.

All patients had severe drug-refractory cardiomyopathy with a left bundle branch block or trifascicular block. Biventricular defibrillators were implanted in all cases. Of the enrolled patients, 40 had not been previously implanted with a pacemaker or defibrillator. The remaining 5 patients (11%) were receiving a new LV lead to upgrade an existing pacemaker or defibrillator system. At the time of device implantation, 35 (77.8%) patients were in synus rhythm and 10 (22.2%) presented with permanent atrial fibrillation. The baseline clinical characteristics were similar between the 2 treatment groups.

Implantation data
The implantation success rate in both groups was 100%. Final LV lead location determined at the time of implantation from the left anterior oblique 30° view was midlateral in 42.2% (19 of 45), anterolateral in 24.5% (11 of 45), and posterolateral in 33.3% (15 of 45). No LV leads were placed in the true anterior CS branch. The desired values for pacing threshold, R-wave amplitude, and impedance were obtained in all patients.

In 33 patients (73.3%), the LV lead successfully engaged the predefined ideal side branch. Significant PNS requiring a retraction or a repositioning of the catheter in a different vein was detected in 5 patients of the bipolar group (21.7%). Seven patients in the quadripolar group presented significant PNS by pacing from the distal bipolar configuration (D1-M2) that probably would have required lead retraction or a repositioning if a bipolar-designed LV lead was implanted instead of a quadripolar one. Six of those patients were managed by pacing from proximal electrodes, and there were no further problems; the other patient required lead repositioning in a different vein.

In 3 patients it was necessary to replace the initial bipolar catheter with a different-shaped pacing lead before reaching the final position. For 1 of these patients, in whom we could not reach a stable lead position, a shift to an active-fixation
Table 1 Baseline characteristics, procedural data, and outcomes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall</th>
<th>Quadripolar group</th>
<th>Bipolar group</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>45</td>
<td>22</td>
<td>23</td>
<td>-</td>
</tr>
<tr>
<td>Age, yrs</td>
<td>70.2 ± 10</td>
<td>69.1 ± 10.1</td>
<td>71.2 ± 10.3</td>
<td>NS</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>34 (75.5)</td>
<td>16 (72.7)</td>
<td>18 (78.2)</td>
<td>NS</td>
</tr>
<tr>
<td>LV ejection fraction (%)</td>
<td>26.0 ± 8.4</td>
<td>26.2 ± 6.3</td>
<td>25.9 ± 10.0</td>
<td>NS</td>
</tr>
<tr>
<td>QRS duration, ms</td>
<td>152 ± 26</td>
<td>152 ± 29</td>
<td>151 ± 22</td>
<td>NS</td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>44 (97.8)</td>
<td>22 (100)</td>
<td>22 (95.6)</td>
<td>NS</td>
</tr>
<tr>
<td>History of AF, n (%)</td>
<td>6 (13.3)</td>
<td>4 (18.1)</td>
<td>2 (8.7)</td>
<td>NS</td>
</tr>
<tr>
<td>Diabetes, n (%)</td>
<td>14 (31.1)</td>
<td>7 (31.8)</td>
<td>7 (30.4)</td>
<td>NS</td>
</tr>
<tr>
<td>Coronary artery disease, n (%)</td>
<td>24 (53.3)</td>
<td>11 (50.0)</td>
<td>13 (56.5)</td>
<td>NS</td>
</tr>
<tr>
<td>Procedural data</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procedural time, min</td>
<td>107.8 ± 23.0</td>
<td>106.3 ± 23.5</td>
<td>109.5 ± 23.0</td>
<td>NS</td>
</tr>
<tr>
<td>Fluoroscopy time, min</td>
<td>15.9 ± 6.7</td>
<td>15.1 ± 5.8</td>
<td>16.6 ± 7.4</td>
<td>NS</td>
</tr>
<tr>
<td>LV lead implant time, min</td>
<td>16.1 ± 13.9</td>
<td>14.0 ± 11.5</td>
<td>17.9 ± 15.7</td>
<td>NS</td>
</tr>
<tr>
<td>LV pacing threshold, V*</td>
<td>1.09 ± 0.55</td>
<td>0.99 ± 0.57</td>
<td>1.17 ± 0.54</td>
<td>NS</td>
</tr>
<tr>
<td>Outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS lead failure</td>
<td>7 (15.6)</td>
<td>1 (4.5)</td>
<td>6 (26.1)</td>
<td>.037</td>
</tr>
<tr>
<td>PNS</td>
<td>5 (11.1)</td>
<td>1 (4.5)</td>
<td>4 (17.4)</td>
<td>NS</td>
</tr>
<tr>
<td>CS lead dislodgment</td>
<td>2 (4.4)</td>
<td>0 (0.0)</td>
<td>2 (8.7)</td>
<td>NS</td>
</tr>
<tr>
<td>CS lead failure requiring repositioning</td>
<td>2 (4.4)</td>
<td>0 (0.0)</td>
<td>2 (8.7)</td>
<td>NS</td>
</tr>
</tbody>
</table>

Values are mean ± SD unless otherwise specified.
CS lead failure was defined as the need for lead revision or reprogramming.

At the optimal pacing configuration.
AF = atrial fibrillation; CS = coronary sinus; LV = left ventricular; NS = not significant; NYHA = New York Heart Association; PNS = phrenic nerve stimulation.

Table 2 Electrical characteristics of the quadripolar lead and outcomes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Quadripolar group</th>
<th>Bipolar group</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS lead failure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pacing threshold, V*</td>
<td>1.09 ± 0.55</td>
<td>0.99 ± 0.57</td>
<td>NS</td>
</tr>
<tr>
<td>Impedance</td>
<td>500 ± 100</td>
<td>500 ± 100</td>
<td>NS</td>
</tr>
<tr>
<td>Electrical characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| LV lead failure, defined as the need for lead revision or reprogramming, occurred in 1 patient (4.5%) in the quadripolar group and in 6 patients (26.1%) in the bipolar group. By Kaplan-Meier analysis, event-free survival for the combined primary outcome of LV lead failure was significantly lower in patients with quadripolar leads (Figure 2).

Four patients in the bipolar group had PNS, and 2 of those occurred within 1 week of implantation. In 3 patients, diaphragmatic stimulation was prevented by reprogramming pacemaker output and/or the polarities, the fourth patient was pending for a solution at the end of the 3-month follow-up. Another 2 patients in the bipolar group required re-intervention for overt LV lead dislodgment (1 had lead dislodgment after the lead was pulled back to a mid-basal position at implantation).

One patient in the quadripolar group experienced clinical PNS 2 months after the implantation. Interestingly, in this patient PNS was evocable in 8 of the 10 LV pacing configurations, and this condition was successfully managed by reprogramming of the device in a pacing configuration (P4-RV coil) free of PNS during 7.5-V pacing.

Discussion
Despite considerable advances, LV lead placement remains a technically challenging and cumbersome procedure in
CRT. The difficulties include reliably obtaining CS access, efficiently selecting CS branch vessels, maintaining lead stability, and avoiding both PNS and lead dislodgment. To overcome these technical problems, several manufacturers have developed various LV leads with different structures, designs, and delivery systems.\(^4\)\(^6\)\(^1\)\(^1\)\(^3\)\(^1\) This task has been limited by many factors, mostly the intrapatient and interpatient variability of the CS anatomy.

The most important goal when implanting a CRT system is to reach a stable LV lead position in a suitable CS tributary associated with a low capture threshold and no extracardiac stimulation. Flexible LV pacing configurations are a useful feature of CRT systems for preventing high LV pacing thresholds and PNS.\(^1\)\(^4\)\(^1\)\(^5\) A lead with multiple pacing electrodes is a potential alternative to physical adjustment of the lead or discontinuing CRT when PNS occurs. The Quartet lead integrates multiple pacing options to minimize the effects of lead dislodgment and give the implanter more choices in implantation location, as compared with the configurations available with traditional bipolar LV leads. To the best of our knowledge, no previous experience has been reported with this innovative design, apart from a recent experimental work performed in 1 patient with an investigational quadripolar lead.\(^1\)\(^6\) Our prospective, controlled study represents the first clinical series so far published describing in detail the use of a quadripolar LV lead in a significant number of patients undergoing CRT system implantation.

**LV lead stability**

Postoperative LV lead dislodgment represents a limitation of transvenous CRT systems in comparison to established right atrial and RV lead performance. Various studies report an LV lead dislodgment rate between 6% and 14%.\(^2\)\(^1\)\(^7\)\(^1\)\(^8\) Other studies have shown a significant proportion of patients who required a surgical intervention to restore LV capture or to correct extracardiac stimulation.\(^1\)\(^9\)\(^2\)\(^0\) Failure to ensure LV stimulation at the appropriate site because of a high pacing threshold and PNS are important causes of failure to deliver CRT. Patients with high pacing thresholds require significantly higher energy to pace the heart; this may reduce the device’s battery life or cause pacing failure.

Both high pacing thresholds and phrenic nerve or diaphragmatic stimulation are often due to the location of the pacing lead electrode. During implantation, many leads are moved more proximally in the target vein deemed optimal for CRT due to distal PNS. This may pose a stability issue with an increased risk of subsequent lead dislodgment. A multipolar LV catheter has the potential to solve PNS without moving the LV lead to a suboptimal site that may prevent the clinical benefit of CRT.\(^1\)\(^6\) Because of the relatively small diameter and electrode choices of the Quartet lead, it is possible to advance the distal tip (4.0-F) more toward the apex to ensure lead stability, while retaining the ability to program the lead to pace from middle or proximal electrodes in a mid-basal or basal location. This technical aspect could also explain the relatively higher dislodgment rate in the bipolar group; in some cases the lead could not be

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**Table 2** Electrical characteristics of quadripolar pacing leads

<table>
<thead>
<tr>
<th>Lead Configuration</th>
<th>LV Capture at 7.5 V (%)</th>
<th>Pulse Threshold (V)</th>
<th>Impedance (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1–M2</td>
<td>100</td>
<td>2.4 ± 1.8</td>
<td>1,085 ± 267</td>
</tr>
<tr>
<td>D1–P4</td>
<td>100</td>
<td>2.1 ± 1.6</td>
<td>1,016 ± 235</td>
</tr>
<tr>
<td>D1–RV coil</td>
<td>100</td>
<td>1.6 ± 1.5</td>
<td>672 ± 164</td>
</tr>
<tr>
<td>M2–P4</td>
<td>86.4</td>
<td>2.1 ± 1.7</td>
<td>880 ± 163</td>
</tr>
<tr>
<td>M2–RV coil</td>
<td>100</td>
<td>2.0 ± 1.6</td>
<td>532 ± 126</td>
</tr>
<tr>
<td>M3–M2</td>
<td>90.9</td>
<td>2.6 ± 2.3</td>
<td>903 ± 219</td>
</tr>
<tr>
<td>M3–P4</td>
<td>90.9</td>
<td>3.1 ± 2.2</td>
<td>851 ± 182</td>
</tr>
<tr>
<td>M3–RV coil</td>
<td>95.5</td>
<td>2.4 ± 2.1</td>
<td>497 ± 119</td>
</tr>
<tr>
<td>P4–M2</td>
<td>81.8</td>
<td>3.0 ± 2.3</td>
<td>911 ± 171</td>
</tr>
<tr>
<td>P4–RV coil</td>
<td>95.5</td>
<td>2.9 ± 2.4</td>
<td>429 ± 85</td>
</tr>
</tbody>
</table>

Values are mean ± SD or percentages. Pacing thresholds were determined in Volts at a pulse width of 0.5 ms.

Abbreviations as in Figure 1.

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![Figure 2](image)  
A Kaplan-Meier estimate of the rate of left ventricular (LV) lead failure (revision or reprogramming). After 3 months, freedom from LV lead failure was significantly higher in the quadripolar group.
advanced to a sufficiently distal position due to PNS, and therefore it slipped out into the CS with heart movement.

**Phrenic nerve or diaphragmatic stimulation**

Biffi et al. documented a clinically relevant PNS in 22% of CRT patients at implantation or follow-up occurring most frequently at the same pacing sites where reverse remodeling occurs after CRT delivery. Bipolar LV leads allow pacing from either LV tip or ring as cathode, with various choices of anode. The Quartet lead can pace from any of the 4 electrodes as cathode, and anode choices include LV electrodes and RV coil. Importantly, because PNS may be posture-dependent, the detection of PNS at implantation has a poor sensitivity. Consequently, more pacing configurations at implantation are helpful to identify the pacing site less likely to develop clinical PNS.

In this study, it is notable that LV lead failure (revision or reprogramming) was significantly lower in patients implanted with the quadripolar lead. Program flexibility allows pacing in a configuration free of PNS or with the most convenient safety margin for PNS (difference between PNS and LV threshold). In all patients who exhibited PNS at implantation, we were able to avoid PNS by programming LV quadripolar leads in a pacing configuration free of PNS at maximum device output and as far away as possible from the site of PNS. On the other side, 6 patients in the bipolar group (26%) had detectable PNS at the best performing pacing configuration at implantation. Hence patients implanted with quadripolar leads had an enhanced possibility to avoid subsequent PNS. It should be noted that the choice of the optimal configuration has been reassessed at each follow-up visit; therefore, the incidence of clinical PNS may have been dramatically decreased as a result of an intensive follow-up on a case-by-case basis.

**LV reverse remodeling: Potential advantages of a multipolar LV catheter**

The pacing site is crucial for improving ventricular mechanics. Thus, it can be postulated that nonresponder patients are paced at a suboptimal site. In a substantial proportion of patients, the anatomically selected pacing site does not always coincide with ventricular regions having a large mechanical delay. Recently, Merchant et al. showed that compared with basal or midventricle LV lead position, apical lead position is associated with worse clinical outcomes during CRT, including significantly higher mortality rates. This issue might have important implications for LV lead implantation strategies. The quadripolar lead may facilitate targeting of more proximal coronary venous branches, to consistently and safely target basal and midventricle pacing sites with adequate long-term stability. Therefore this programming flexibility might theoretically improve CRT outcomes while maintaining a more distal and stable final lead position.

The proportion of nonresponders (estimated at about 40%) is likely to be reduced by choosing the best pacing site. The most common LV pacing site selected for delivering CRT is the free lateral wall. A potential reason for nonresponse to CRT may be the presence of extensive scar tissue in the region of the tip of the LV pacing lead (usually the posterolateral LV region). In addition, many LV leads are placed outside the target vein deemed optimal for CRT due to PNS. This new system has 2 potential advantages over traditional ones: first, by maintaining lead stability in case of distal PNS; second, by having more options to avoid pacing from within scar areas by selecting a near-site stimulation. The latter feature can be selected by evaluating sensing and impedance values of the sites. Whether a multielectrode catheter has a higher likelihood of improvement after CRT, especially in patients with large areas of scar tissue, remains to be determined. Future developments of this catheter will introduce the possibility of simultaneous LV pacing from all the electrodes, leading to both depolarization of more cardiac tissue and production of flatter and more homogeneous wave-front propagations.

**LV lead performance**

The present study shows that the newly designed system can safely be used for cardiac pacing with good pacing thresholds and stability, comparable to traditional catheters. The strength of this study is the number of patients studied and the presence of a control group concurrently enrolled and followed up. The implantation success rate in the study was 100%, and the data obtained during implantation were comparable between groups. Pacing thresholds and R-wave amplitudes for leads have been found to be stable during follow-up. Despite somewhat higher procedural times in the bipolar group, the difference between the 2 groups did not reach significance. At implantation, we managed to solve PNS by changing lead placement in 5 patients (22%) in the bipolar group. We believe that the electronic repositioning to alternative electrodes without adjusting lead position might reflect the shorter time needed for lead implantation (lead insertion to fixation) observed in the quadripolar group (14.0 ± 11.5 minutes vs. 17.9 ± 15.7 minutes; \( P = .32 \)).

**Study limitations**

The study has some potential limitations: (1) This is a single-center nonrandomized study and has the inherent limitations of this design. However, it is important to note that there was no selection bias between the systems, and the initial choice of the implanted system was based on the availability at the time of implantation, rather than on patient-specific or procedure-specific variables. (2) The small sample size of patients might account for the failure to detect differences between groups. (3) Follow-up in our study was limited to 3 months after implantation; however, in subsequent long-term follow-up, LV leads are unlikely to dislodge and lead stability should be expected to be excellent. (4) As lead technology becomes more complex and sophisticated, the new systems present new challenges and more complex modes of failure, and this study, which is strictly limited by the follow-up of 3 months, does not
exclude the possibility of an increased risk of failure that can be attributable to newer lead design.

**Conclusions**

This prospective, controlled study is the first experience reported with the quadrupolar LV lead and provides strong evidence that this new lead might avoid common LV pacing complications through more choices of the best-performing pacing configuration and by enhancing the possibility to achieve a stable lead placement in the target coronary vein. Future development and technology should include a multielectrode LV lead design that offers several configurations for programming flexibility. Nevertheless, additional supporting clinical studies with longer surveillance data will be needed to establish the long-term performance and hemodynamic effects of this newly designed LV lead.

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**References**