

Use of a quadripolar left ventricular lead to achieve successful implantation in patients with previous failed attempts at cardiac resynchronization therapy

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Aims

Problems with implanting a left ventricular (LV) lead during cardiac resynchronization therapy (CRT) procedures are not uncommon and may occur for a variety of reasons including phrenic nerve stimulation (PNS) and high capture thresholds. We aimed to perform successful CRT in patients with previous LV lead problems using the multiple pacing configurations available with the St Jude Quartet model 1458Q quadripolar LV lead to overcome PNS or high capture thresholds.

Methods and results

Four patients with previous failed attempts at LV lead implantation underwent a further attempt at CRT using a Quartet lead. In all four cases, successful CRT was achieved using a Quartet lead placed in a branch of the coronary sinus. Problems with PNS or high capture thresholds were seen in all four patients but were successfully overcome. Satisfactory lead parameters were seen at implant, pre-discharge, and at short-term follow-up (8.5 ± 5 weeks).

Conclusion

The Quartet lead allows 10 different pacing vectors to be used and may overcome common pacing problems because of the multiple pacing configurations available. Problems with either PNS or unsatisfactory pacing parameters experienced during CRT may be resolved simply by changing the pacing configuration using this quadripolar lead system.

Keywords

CRT • Quadripolar lead • Phrenic nerve stimulation (PNS) • Failed implant

Introduction

Cardiac resynchronization therapy (CRT) improves heart failure symptoms and reduces hospitalizations and risk of death in patients with left ventricular (LV) dysfunction and a broad QRS.^{1–3} Failure to implant an LV lead during attempted CRT occurs in ~5–15% of cases.^{4–6} This may be because of an inability to cannulate the coronary sinus (CS) ostium, an inability to pass the LV lead into a CS branch, unsatisfactory pacing parameters, or phrenic nerve stimulation (PNS). In a study of 197 consecutive patients undergoing CRT, Biffi *et al.* showed that

clinically relevant PNS occurred in 22% of patients at CRT implant or follow-up and that its occurrence was highest in those patients for whom the LV lead was placed at pacing sites most associated with reverse remodelling. In the aforementioned study, 7% of patients required an LV lead revision or CRT to be turned off and cathodal programmability (the capability to program either the proximal or the distal LV lead electrode as cathode) was described as a possible solution to the problem of PNS.⁷ Indeed, other studies^{8,9} have shown that the availability of multiple pacing configurations may overcome problems with high pacing capture thresholds and PNS.

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The Quartet LV lead model 1458Q (St Jude Medical, Sylmar, CA, USA) is a multipolar LV lead with three ring electrodes in addition to the tip electrode. The three ring electrodes are located 20, 30, and 47 mm from the tip that has a 4.0 Fr diameter. The maximum lead body diameter is 4.7 Fr and the lead is easily manoeuvrable. The Quartet lead allows all four of the electrodes on the lead to act as the cathode and two also as an anode. In

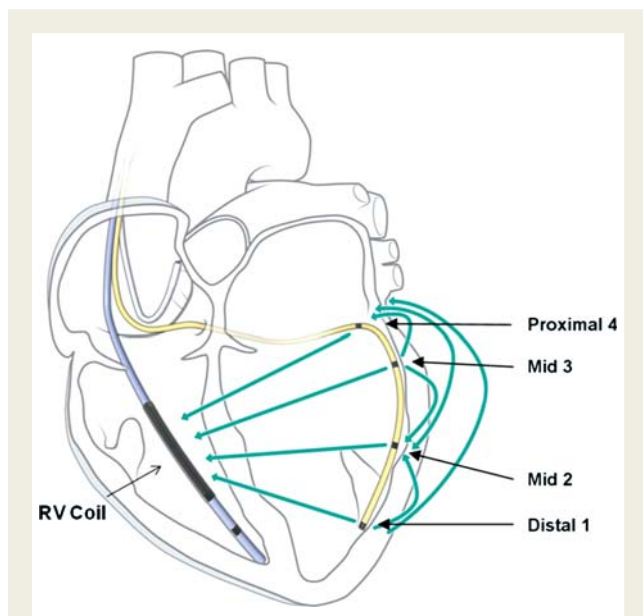


Figure 1 Ten vectors are available using the three ring electrodes and distal tip of the Quartet lead and the RV coil: 1. distal 1 (D1) to mid 2 (M2); 2. D1 to proximal 4 (P4); 3. D1–RV coil; 4. M2–P4; 5. M2–RV coil; 6. mid 3 (M3) to M2; 7. M3–P4; 8. M3–RV coil; 9. P4–M2; and 10. P4–RV coil (image courtesy of St Jude Medical).

addition, the right ventricular (RV) coil of the shocking lead may act as an anode thus giving 10 possible bipolar and unipolar pacing configurations (see *Figure 1*). Theoretically, a change in pacing vector may allow problems not only with PNS to be overcome but also with unsatisfactory pacing capture thresholds. In the temporary setting, Thibault *et al.*¹⁰ reported that problems with PNS could be overcome with ‘electronic repositioning’ of the Quartet lead by changing the pacing vector. Forleo *et al.*¹¹ have compared the Quartet lead with conventional bipolar leads and found it to be associated with a reduced need for lead revision or reprogramming. We report a series of four patients, all of whom had previously had a failed LV lead implantation attempt and who went on to have successful CRT using a Quartet lead.

Methods

Four patients, two males and two females with mean age 55 ± 21 years, underwent re-attempt at LV lead implantation at our institution between March and May 2010 (see *Table 1*). All the four patients had New York Heart Association (NYHA) class III symptoms of heart failure of a non-ischaemic aetiology. The mean left ventricular ejection fraction (LVEF) was $28 \pm 8.7\%$ prior to reattempt at LV lead implantation. Three patients were in sinus rhythm and one was in atrial fibrillation. In our institution, we aim to place the LV lead in an optimal CS vein for resynchronization and this usually means a postero-lateral or lateral position. In these four difficult cases, the main determinant of LV lead position was a pacing configuration that gave the best pacing parameters (lowest capture threshold with good R-wave) without PNS.

Results

In all four cases, a Pacesetter St. Jude Quartet lead model 1458Q and Promote Q Model CD3221-36 generator (St Jude Medical) were

Table 1 Patient characteristics pre-Quartet lead implant

Case	Age	Sex	ECG	NYHA	LVEF (%)	Cardiomyopathy aetiology	Patient characteristics
1	72	F	Sinus rhythm; LBBB; QRSd 140 ms	III	25	Non-ischaemic	Two previous attempts at CRT with two different bipolar leads but PNS or high capture thresholds in all target veins
2	60	M	Sinus rhythm; LBBB; QRSd 160 ms	III	20	Non-ischaemic	Previous attempt at CRT in referring center but implanter unable to pass guide catheter into CS. Only one suitable CS vein found at our center but PNS seen using conventional bipolar lead
3	24	M	AF; LBBB (paced); QRSd 160 ms	III	20	Non-ischaemic	Previous AVSD repair and dual-chamber pacemaker for severe sinus and AV node disease. At CRT-P upgrade only two suitable veins seen and PNS found in one of these. LV lead placed in the other CS branch (without PNS at implant) but PNS found at follow-up and LV lead switched off
4	64	F	Sinus rhythm; LBBB; QRSd 170 ms	III	35	Non-ischaemic	One previous attempt at CRT with two different bipolar leads but PNS or high capture thresholds in all target veins

M = male; F = female.

Table 2 Pacing parameter data

Pacing parameter	
Mean implant LV capture threshold at 0.5 ms pulse width	2.0 ± 1.6 V
Pre-discharge LV capture threshold at 0.5 ms pulse width	1.4 ± 0.7 V
LV capture threshold at latest (8.5 ± 5 weeks) follow-up at 0.5 ms pulse width	1.3 ± 0.2 V
LV lead impedance at implant	1057 ± 254 Ω
Pre-discharge LV lead impedance	912.5 ± 394 Ω
LV lead impedance at latest (8.5 ± 5 weeks) follow-up	872 ± 387 Ω

successfully implanted. The mean procedure time for the four cases was 157.5 ± 42.1 min. The fluoroscopy time was 18.2 ± 19.8 min with a radiation dose of 1178 ± 1417.2 cGy cm². Pacing parameters were stable at pre-discharge pacing check and latest follow-up of 8.5 ± 5 weeks (see Table 2).

Case 1

A 72-year-old female with a non-ischaemic cardiomyopathy, LVEF of 25%, left bundle branch block (LBBB), QRS duration (QRSd) 140 ms, and NYHA class III symptoms of heart failure was referred to our centre for consideration of an epicardial surgical approach to LV lead placement following two previous failed transvenous attempts at CRT. The referring centre had cannulated all possible target veins during the two previous attempts at LV lead placement, but PNS or unsatisfactory pacing parameters were found in all branches using Attain Ability 4196 (Medtronic Inc., Minneapolis, MN, USA) and Easytrak 2 (Boston Scientific Corp., Natick, MA, USA) LV leads. The patient elected to have a further attempt at trans-venous LV lead implantation at our institution before considering an epicardial surgical approach.

We placed a Quartet lead via the left subclavian vein in posterior, lateral, postero-lateral and antero-lateral branches of the CS. High capture thresholds or PNS were found in all CS branches. The lead was finally positioned in a lateral branch with a capture threshold of 1.75 V at 0.8 ms pulse width (3.75 at 0.5 ms pulse width) and an impedance of 950 Ω using the vector from the distal tip of the LV lead to the coil of the RV shocking lead, vector D1–RV coil (see Figure 2). A new Pacesetter St Jude Durata model 7122 (St Jude Medical) shocking lead was placed in the RV apex. The old pace/sense lead was capped and the three remaining leads attached to a Promote Q Model CD3221-36 generator that was placed in a subcutaneous pocket.

Pre-discharge capture thresholds for the 10 possible pacing vectors were tested at a pulse width of 0.5 ms—D1–M2: 1.25 V; D1–P4: 1.0 V; D1–RV coil: 1.0 V; M2–P4: 7 V; M2–RV coil: 5.25 V; M3–M2: no capture; M3–P4: no capture; M3–RV coil: no capture; P4–M2: no capture; and P4–RV coil: no capture. The large range of thresholds seen here using different pacing configurations may be because of differing levels of contact between each lead pole and the surrounding tissue. Variations in pacing

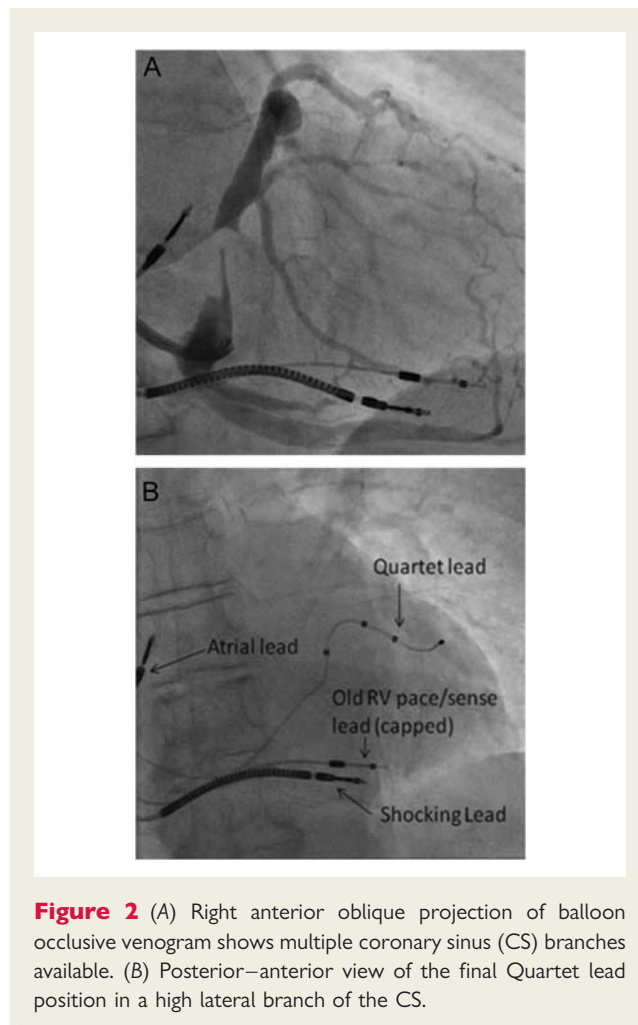


Figure 2 (A) Right anterior oblique projection of balloon occlusive venogram shows multiple coronary sinus (CS) branches available. (B) Posterior–anterior view of the final Quartet lead position in a high lateral branch of the CS.

parameters between different poles may also be caused by varying levels of tissue fibrosis or scar.

At latest follow-up, 16-week post-implant, the patient was symptomatically much improved in NYHA class I and her LVEF had improved to 50%. Her latest pacing check at 16-week post-implant showed that the threshold on the LV lead was 1.25 V at 0.5 ms pulse width with an impedance of 1300 Ω.

Case 2

A 60-year-old male with non-ischaemic cardiomyopathy, LBBB (QRSd 160 ms), LVEF 20%, and NYHA class III dyspnoea was referred to our centre for a further attempt at LV lead implant. Cannulation of the CS had proved difficult at the referring centre and although the implanter was able to place a 0.032 in. diameter terumo wire (Terumo Medical Corp., Somerset, NJ, USA) into the CS, he was unable to pass three different guide catheters over the wire. As the patient had received over 25 min of fluoroscopy, a dual-chamber CRT-D was left *in situ* (St Jude Medical Promote RF Model 3213-36 generator, Pacesetter St Jude Durata 7120 shocking lead in the RV apex and Pacesetter St Jude Tendril ST 1888TC in the right atrial appendage) and the LV port was plugged. The implanter felt that there may have been a Thebesian valve at the CS ostium hindering cannulation

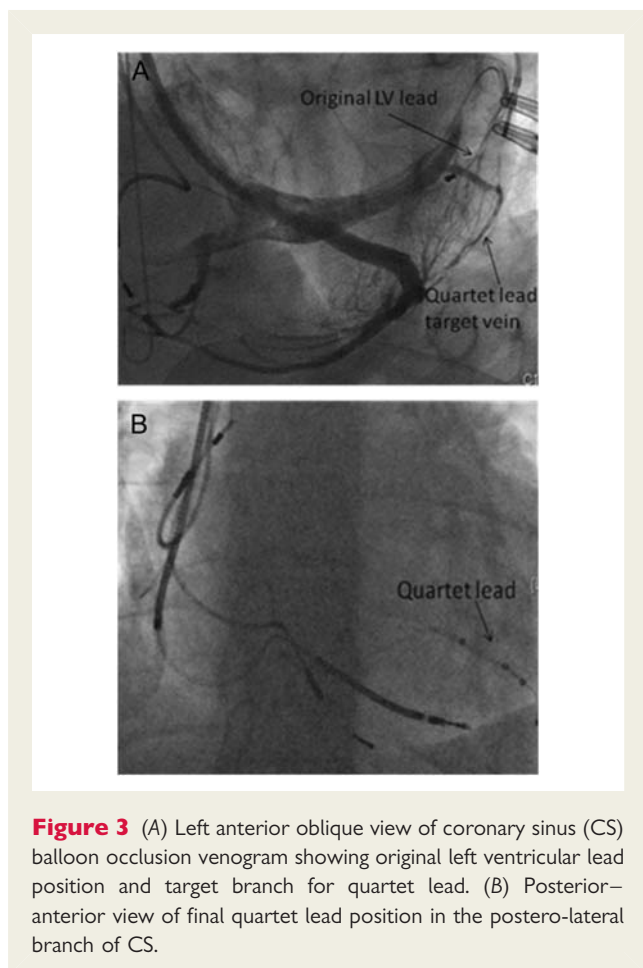


Figure 3 (A) Left anterior oblique view of coronary sinus (CS) balloon occlusion venogram showing original left ventricular lead position and target branch for quartet lead. (B) Posterior–anterior view of final quartet lead position in the postero-lateral branch of CS.

and the patient was referred to our centre for a further attempt at transvenous LV lead implant followed by a surgical approach if unsuccessful.

At our centre, the CS was successfully cannulated and a St Jude Quicksite Model 1056 LV lead passed into a posterior branch of the CS. Phrenic nerve stimulation was seen, however. As this was the only suitable vein, we removed the LV lead and replaced it with a Quartet lead to take advantage of the multiple vectors available to overcome PNS. The Quartet lead was placed in a similar position to the discarded LV lead but satisfactory pacing parameters (threshold 0.75 V at 0.5 ms; impedance 740 Ω) and no PNS was found when pacing using the M3–M2 vector.

Six weeks later, the patient's LVEF had improved to 35–40% and symptomatically he was in NYHA class II. Left ventricular lead parameters were stable (threshold 1.5 V at 0.5 ms, impedance 850 Ω). The QRSd on electrocardiogram (ECG) had reduced to 104 ms.

Case 3

A 24-year-old male with a previous history of a partial atrioventricular septal defect (AVSD) repair, severe sinus, and AV node disease with left bundle branch block had previously had a dual-chamber pacemaker implantation 10 years earlier. This was upgraded to a CRT-P device 5 years later as he was found to have a non-ischaemic cardiomyopathy and NYHA class III symptoms. He developed persistent atrial fibrillation 2 years ago and

suffered a stroke. He was admitted with worsening heart failure and found to have intermittent PNS even with a low LV lead output (2.5 V). The LV lead was therefore programmed off and he was listed for extraction of the lead with re-implant of a new LV lead and RV shocking lead. His echocardiogram pre-procedure confirmed an LVEF of 20% with moderate–severe mitral regurgitation and moderate tricuspid regurgitation. At his device upgrade 5 years previously, it had been noted that he had PNS in the only other vein suitable for an LV lead. It was therefore decided that the re-implant should be with a Quartet lead to overcome any potential problems with PNS (see Figure 3).

The original LV lead (Medtronic Attain model OTW 4193) was successfully extracted and a new Pacesetter St Jude Durata model 7120 shocking lead placed in the RV apex. A Quartet lead was positioned in the postero-lateral branch of the CS that was not used 5 years earlier because of PNS. Phrenic nerve stimulation was again found in this CS tributary when pacing using conventional bipolar LV pacing (D1–M2 vector). The problem was overcome, however, with a switch to the M3–M2 vector (threshold 0.5 V at 0.5 ms pulse width, impedance 997 Ω). The old RV pace/sense lead (Medtronic Viatron model IMD 49B) and atrial lead (Medtronic Viatron model IMX 49 JB) were capped and the remaining leads attached to a Promote Q model CD3221-36 generator placed in a new sub-pectoral pocket.

Lead parameters were stable at pre-discharge pacing check and at 6-week follow-up (threshold 1 V at 0.5 ms pulse width; impedance 1100 Ω). His LVEF was found to have improved to 40–45% at this time.

Case 4

A 64-year-old female with non-insulin-dependent diabetes, non-ischaemic cardiomyopathy, and previous history of hypertension and stroke was found to have non-sustained ventricular tachycardia on Holter monitoring, LBBB (QRSd 170 ms), LVEF 35%, and NYHA class III symptoms underwent attempted CRT. A Medtronic Attain Ability model 4196 LV lead was placed in a high lateral CS branch but a high pacing capture threshold was found. The implanter was unable to pass the lead into a lower (small) lateral branch and the middle cardiac vein had PNS distally with no capture when pulled more proximally. This LV lead was discarded and a St Jude QuickSite model 1056T LV lead was placed in the middle cardiac vein but a capture threshold >5 V was found distally and again no capture proximally. It was not possible to pass this lead into the high lateral branch. This lead was also discarded and no further attempts at LV lead implantation were made on this occasion. A Pacesetter St Jude Tendril model 1788T atrial lead was placed in the right atrial appendage and a Pacesetter St Jude Durata model 7120 was placed in the RV apex.

The patient returned to our institution 9 months after the original attempt at CRT for a further attempt at LV lead placement. A Quartet LV lead was successfully implanted in a postero-lateral branch of the CS (vector D1–M2; capture threshold 3.1 V at 0.5 ms pulse width; impedance 1344 Ω). The lead was attached to a Promote Q model CD3221-36 generator and placed in the old pre-pectoral pocket. Pacing parameters had improved at pre-discharge pacing check (threshold 1.75 V at 0.5 ms pulse width,

impedance 510 Ω) and were better still at 6-week pacing check (threshold 1.25 V at 0.5 ms, impedance 540 Ω).

Discussion

We have demonstrated that the Quartet lead can be implanted successfully in patients who have previously had failed attempts at LV lead placement. We have also shown that problems with PNS and high capture thresholds can be overcome simply by changing the pacing vector. Our short-term follow-up data on this small cohort of patients suggest that the Quartet lead pacing parameters remain satisfactory at pre-discharge and at latest follow-up.

A significant number of patients are found to have PNS or unsatisfactory LV lead parameters at CRT implant or during follow-up. Indeed, as PNS may be posture dependent and thus not manifest at implantation, it may be an underreported complication. Techniques for overcoming PNS include reducing the LV pacing output, repositioning the LV lead, surgical placement of an epicardial LV lead, or turning off LV pacing altogether. Cathodal programmability offers an excellent non-invasive alternative solution to the problem.

Several LV leads offer cathodal programmability and thus the ability to change pacing vector if conventional bipolar LV pacing is not satisfactory. The Quartet LV lead with an appropriate CRT device has the ability to pace from any of its four LV lead electrodes as cathode. Anode choices include two LV electrodes as well as the RV coil thus giving 10 possible pacing configurations. The use of bipolar leads that allow the pacing configuration to be altered if problems occur with PNS or high capture thresholds may resolve these problems without the need to resort to high LV pacing outputs, lead repositioning, or surgical approaches to LV lead placement. Indeed, in our case series, the programmability of the quartet lead obviated the need for an epicardial surgical approach to CRT in at least two patients.

The advantage of the Quartet lead over other leads with cathodal programmability is the number of vectors available. Thus, if problems with PNS or high capture thresholds are encountered, it offers more pacing configurations than other CRT systems and may allow patients with previous failed attempts at LV lead implantation the potential to have a successful transvenously placed LV lead rather than the options of either an epicardial surgical approach to CRT or no CRT at all. In this study, the M3–M2 vector used as the final configuration in two of our patients is not available with other bipolar LV leads but the D1–M2 and D1–RV coil vectors used in the other two patients can be programmed with other CRT systems. The fact that we

were also successful in these cases using conventional bipolar configurations suggests that the handling characteristics and lead geometry of the Quartet lead may have allowed us to attain a position in the CS that was different from the bipolar leads previously used.

This study is limited by its small size, non-randomized nature, and lack of control group. Further studies looking at how different pacing configurations affect dyssynchrony indices and LV volumes are required.

Conflict of interest: C.A.R. has consultancy agreements with St Jude Medical and Medtronic.

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