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First Report of Super-Response After Left Bundle Branch Area Pacing for Cardiac Resynchronization Therapy (LBBAP-CRT) Utilizing a Stylet-Driven Lead

Short Title: Super-Response after LBBAP Using a Stylet-Driven Lead

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Introduction

The deleterious effects of electrical dyssynchrony on myocardial health and function have been firmly established, whether the dyssynchrony is caused by left bundle branch block (LBBB)\(^1\) or by right ventricular pacing (RVP). \(^2\) In patients with heart failure with reduced ejection fraction (HFrEF), correction of electrical dyssynchrony with biventricular (BiV) pacing to achieve cardiac resynchronization therapy (CRT) with the implantation of a left ventricular (LV) lead via the coronary sinus (CS) system is a class I guideline-directed therapy. \(^3\) However, in some patients, patient-specific anatomy and technical factors preclude successful implantation of a CS lead. Furthermore, despite successful implantation of a BiV pacing system, there is a consistently observed approximately 30% non-response rate to CRT in modern clinical trials despite attempts at optimization. \(^4\) \(^5\)

His bundle pacing (HBP) has been described as a means to preserve or restore physiologic activation with conduction system pacing (CSP), and as alternative means to deliver CRT in heart failure. \(^5\) Recently, pacing at the proximal left conduction system (LCS) via left bundle branch pacing (LBBP) or left bundle-branch area (LBBAP) have been advocated as alternative strategies to achieve CSP in CRT patients with lower and more stable thresholds. \(^6\) \(^7\) Prior case series of CSP for CRT, however, have exclusively reported on the use of fixed-helix, lumen-less lead (Medtronic 3830; Medtronic Inc, Minneapolis, MN) supported by the delivery catheter (C315His; Medtronic Inc). Multiple vendors have now introduced sheath systems utilizing standard stylet-driven leads, designed for CSP. To our knowledge, we report the first case of super-response or
normalization of left ventricular ejection fraction (LVEF) with LBBAP, utilizing a new delivery sheath system and a standard stylet-driven lead.

Case

A 71-year-old man with chronic systolic heart failure secondary to ischemic heart disease with left ventricular ejection fraction (LVEF) of 20% (Movie 1) and NYHA class III symptoms was referred for CRT. He had LBBB for greater than 4 years; he developed declining LVEF 5 months before referral and had been started on appropriate goal directed medical therapy on carvedilol and losartan and had achieved target dosages for greater than 3 months. Nonetheless he had persistent severe LV dysfunction and we proceeded with device implantation. The CS demonstrated a markedly posterior take-off and was unable to be cannulated stably despite multiple attempts (Supplementary Figure 1, Panels A and B). Conduction system pacing with targeting of the left bundle branch area was pursued as a bail-out strategy. A stylet-driven pacing lead with an extendable helix (Boston Scientific Ingevity+, Model 7842; Marlborough, MA, USA) was delivered through a fixed curve sheath (Site Selective Pacing C3, Boston Scientific, Marlborough, MA, USA) (Figure 1, Panel A). The lead helix was deployed at the right ventricular (RV) septum (Figure 1, Panel B) and then tunneled to the left conduction system (LCS) by rotating the lead 6-7 times (Figure 1, Panel C). Left septal position was demonstrated by contrast injection through the sheath (Figure 2, Panel A). The capture threshold was excellent at 0.4 V @ 0.4 ms. Post-implant chest radiograph is shown (Figure 2, Panels B-C). At baseline, the patient
demonstrated left bundle branch block (LBBB) pattern with QRS duration of 182 ms (Figure 3, Panel A). Paced QRS duration narrowed with LBBAP (measured from stimulation-artifact to QRS-end $^{\text{QRSst}} = 156$ ms; measured from intrinsicoid deflection in V2 to QRS-end $^{\text{QRSid}} = 122$ ms). The patient demonstrated a left axis deviation suggestive of non-selective left posterior fascicular capture. Left ventricular activation time, defined as the time from stimulus to the peak of the R wave in the lateral precordial leads (V4-V6), was 84 ms when measured to V6 (Figure 3, Panel B).

On post-operative day 1, the patient underwent echocardiogram which demonstrated acute improvement of LVEF from 20 to 41% (Movie 2). Quantitative markers of synchrony using strain imaging also improved with time to peak strain from basal septum to basal lateral wall, shortening from 402 ms to 36 ms. The mechanical index (standard deviation of time to peak strain for 12 basal to mid segments) decreased from 150 ms to 60 ms. Four months later, the patient’s LVEF had completely normalized to 62% (Movie 3). Lead parameters remained stable, with pacing threshold of 0.6 V @ 0.4 ms. He reported marked improvement in clinical symptoms from NYHA III to NYHA I-II.

Discussion

To our knowledge, this is the first report of super-response after left bundle branch area pacing for cardiac resynchronization therapy (LBBAP-CRT) utilizing a stylet-driven lead. Zanon et al recently reported their initial experience on LBBAP using a stylet-driven lead through a new delivery sheath (Biotronik Selectra 3D, Biotronik SE
Both patients in the case series had a normal QRS duration and LBBAP was performed to preserve physiologic activation versus to deliver CRT, as in our case. In a 50-patient comparison of lumen-less lead versus stylet-driven lead system (Biotronik Selectra 3D) for LBBAP, only 3 patients underwent LBBAP in the setting of HFrEF and LBBB. There was a trend towards improved LVEF in this group from 37% to 45% over 1 month of follow-up; whether any particular patients had an acute super-response and complete normalization of LVEF was not reported. Our case is distinct in reporting a super-response and using the Boston Scientific Ingevity+ lead. With the availability of sheath systems from multiple vendors (e.g., Boston Scientific Site Selective Pacing, Biotronik Selectra 3D, and Abbott Agilis HisPro), opportunity for LBBAP with stylet-driven leads will undoubtedly rise.

Briefly, the procedure is performed as follows using the Boston Scientific system and is similar across vendors with minor variations. A Wholey wire is used to introduce the long fixed curved sheath (Figure 1, Panel A) into the RV. The wire is exchanged for a stylet-driven lead and the RV septum can be mapped in a unipolar fashion. A site for initial tunneling is chosen based on fluoroscopic location, distance from His potential if one has been found, and paced morphology. This step is similar to finding an appropriate site when using the traditional lumen-less lead system, as has been described previously. The sheath can be re-shaped as necessary. Once an appropriate location has been chosen, with slight forward pressure on the sheath, the lead helix is deployed using the pinch-on tool (Figure 1, Panel B). The tool is kept attached to the lead so that the helix does not retract during tunneling and the stylet should be at the tip of the lead. The entire lead is then rotated clockwise to advance the
lead through the septum towards the LV endocardial surface. Pacing and sensing can be performed during lead advancement by attaching electrodes to the stylet. Once a satisfactory position is found, the stylet is withdrawn (so as not to advance lead further during spit), and the sheath is then split with careful attention towards sufficient slack (Figure 1, Panel C). Lead advancement is monitored under fluoroscopy. End points for successful LBBAP have been described elsewhere and are similar whether using a stylet-driven lead or a traditional lumen-less lead. These include R’ on paced V1 QRS morphology, presence of a left bundle potential (if intact), drop in pacing impedance suggestive of approach towards the LV endocardium, presence of fixation beats or PVCs with a morphology suggestive of LBB ectopy, and lack of change between very high (10V) and programmed pacing output (suggestive that changes in the size of the virtual electrode do not lead to intermittent capture of the conduction system at a distance from the lead tip). Importantly, however, output-dependent changes during threshold testing may show loss of anodal capture of the septum by the ring, and is more apparent in patients with narrow QRS or right bundle branch block (RBBB), in which it may be utilized to facilitate QRS narrowing.

In our case, the final site of pacing was likely a left septal position with some secondary recruitment of the left-sided conduction system or non-selective left bundle branch pacing. Given the prominent left axis deviation (LAD) and the fluoroscopic position, the posterior fascicle is likely the site of conduction system capture and the final QRS axis may also reflect the underlying cardiomyopathy. Though our paced QRS morphology in lead V1 does not have an R’ (Figure 3, Panel B), the significantly shortened or partially corrected QRS duration and the relatively short LVAT suggest
recruitment of the conduction system. An LVAT less than 85 ms \(^{11}\) in the setting of LBBB as well as relative shortening of LVAT by 10 ms have recently been correlated with left conduction system capture with validation by left septal recordings. Both of these criteria were met in this case. Underlying intra-myocardial delay (intraventricular conduction delay) may also preclude a short LVAT and/or R’ in V1 despite conduction system capture. In addition, anodal capture of the RV septum can abrogate the R’ but may not change the LVAT. It is important to note that in spite of an “imperfect” final paced QRS morphology, this patient with profound cardiomyopathy and underlying LBBB nonetheless had acute evidence of echocardiographic resynchronization and sustained echocardiographic and clinical improvement. This finding may speak to a relatively wide tolerance for lead position when adopting a LBBAP strategy.

This report of a patient having normalization of LVEF after LBBAP using a stylet-driven lead invites the question of when to use the traditional lumen-less 3830 lead and when to opt for one of the newer systems that use a stylet-driven lead. The 3830 lead is narrower with a 4.1 French diameter while the Boston Scientific Ingevity lead is wider with a 6 French diameter. In addition, the isodiametric shape between the lead helix and the lead body of the 3830 is thought to facilitate advancement of the lead into the septum (due to a larger bore being made by the helix). On the other hand, stylet driven leads have a smaller helix relative to the lead body. With that noted, multiple operators have noted the stylet provides additional and stiffer support to allow for penetration into the septum \(^{10}\) and avoid the risk of RV septal entanglement as has been noted in prior cadaveric study of the 3830. \(^{12}\) An additional advantage of the stylet-driven leads are the opportunity to assess real-time changes in QRS morphology and impedance during
lead advancement (by attaching sensing cables to the exposed stylet in a unipolar fashion).

Theoretically, the wider diameter of the styled-driven lead may be associated with greater damage to the septum if there are multiple redeployments. The larger tunnel could also theoretically dispose towards higher risk of lead dislodgement. Relevant to longer term follow-up, the presence of a lumen may facilitate future extraction if needed. More experience and direct comparisons as well as future investigations on long-term thresholds, safety, and clinical outcomes are needed.

MEDIA LEGEND

FIGURES

Figure 1: Panel A—The Boston Scientific Site Selective Pacing C3 fixed curve sheath. The sheath can be re-shaped as necessary. Panel B—The stylet-driven lead has followed the sheath to the interventricular septum and the helix is deployed with the stylet at the lead tip. Panel C—The entire lead is turned clockwise with slight forward pressure and the stylet in place at the lead tip for support. The lead is advanced until a suitable position is found as described in the text.

Figure 2: Panel A—Contrast injection through sheath (i.e., right ventricular “septography”) in left anterior oblique (LAO) projection demonstrating lead embedded
within septum with tip reaching LV surface. Tip-to-ring distance is 12.5 mm. Panel B—Posteroanterior (PA) chest radiograph. The RV lead was implanted in the low septal RVOT due to a stable position with suitable parameters being found at this location. Panel C—Lateral chest radiograph.

**Figure 3:** Panel A—Baseline electrocardiogram (ECG) with left bundle branch block (LBBB) and QRS duration 182 ms. Panel B—Postoperative ECG demonstrating left conduction system (LCS) pacing for cardiac resynchronization therapy (LCS-CRT). Paced QRS duration shortened to 156 ms when measured from the stimulation artifact to QRS-end (QRS_{st}) and 122 ms when measured from onset of the intrinsicoid deflecton in V2 to QRS-end (QRS_{id}). Left ventricular activation time (LVAT) was 84 ms.
References:


LVAT = 84 ms

Baseline QRS duration = 182 ms

Paced QRS$_{st}$ duration = 156 ms
Paced QRS$_{id}$ duration = 122 ms

LVAT = 84 ms
Key Teaching Points

- Left bundle branch area pacing (LBBAP) has been recently described as a form of physiological or conduction system pacing (CSP) with lower and more stable thresholds as compared to His bundle pacing (HBP). Both LBBAP and HBP have been described as alternatives to biventricular pacing (BVP) in the approach to cardiac resynchronization therapy (CRT) in heart failure with a wide QRS duration.

- Previous experience of LBBAP in CRT (LBBAP-CRT) has been generally described with the Medtronic system (Medtronic, Minneapolis, MN), composed of a 3830 lead with fixed helix lumen-less design and a fixed-curve sheath (C315 SelectSite). Multiple vendors have introduced specialized delivery sheaths that allow for CSP utilizing standard stylet-driven leads. We review the technical aspects of LBBAP using the new sheath delivery systems.

- We report the first case of a super-response and complete normalization of LVEF utilizing the Boston Scientific Invegy+ 7842 standard lead with a novel Boston Scientific Site Selective Pacing C3 sheath (Boston Scientific, Marlborough, MA). Our preliminary observation of successful LBBAP-CRT using a standard stylet-driven lead requires further study and reproduction.