Robotic-Assisted Left Ventricular Lead Placement

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KEYWORDS

• Robotic • Epicardial leads • Cardiac resynchronization therapy

KEY POINTS

- The current endovascular approach for cardiac resynchronization is limited by anatomic constraints precluding accurate targeting of the optimal pacing site.
- Convention surgical left ventricular (LV) lead placement has been used as rescue therapy but with significant morbidity and similar limited precision for targeting the optimal pacing site.
- Robot-assisted surgery for LV lead placement allows for superior precision to target the optimal pacing site in conjunction with preoperative and intraoperative mapping techniques.
- Robot-assisted surgery for LV lead placement has been associated with comparable therapeutic efficacy of cardiac resynchronization as with leads via the coronary sinus.

INTRODUCTION

Cardiac resynchronization therapy (CRT) has been demonstrated by several randomized controls trial to improve exercise capacity, quality of life, hospitalizations for heart failure (HF), cardiac structure, and mortality in patients with symptomatic HF, impaired left ventricular (LV) systolic function, and wide QRS complex.[1–6] Dyssynchronous ventricular activation is the putative pathophysiologic mechanism that leads to detrimental hemodynamics, and structural and molecular changes associated with worse clinical outcomes and is the therapeutic target for CRT. Despite the marked disease modifying effect of the therapy on specific targeted populations, there is significant heterogeneity in individual response, such that approximately one-third of patients do not experience a clinical response or benefit from reverse remodeling.[7–9] A great deal of effort has been focused on refining patient selection to improve clinical response by identifying predictors of nonresponse or superresponse to CRT. The presence of echocardiographic dyssynchrony, myocardial scar burden, and optimal programming have all been evaluated with variable results. The most important clinical factors associated with response remain QRS width and morphology, in particular, left bundle branch block morphology with QRS duration of greater than 150 milliseconds. These factors signify substantial septal to posterior wall electromechanical delay that may be mitigated by CRT. However, the most important technical factors to achieving CRT are related to identifying the optimal pacing site and precise delivery of a pacing lead to that target region.

IDENTIFYING THE OPTIMAL PACING SITE

The early studies on CRT did not systematically evaluate the site of LV simulation, region of maximal electromechanical delay, or account

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for variability in coronary sinus (CS) anatomy that could limit lead delivery. The traditional site of LV stimulation was subjectively determined fluoroscopically with greatest separation between the right and LV leads. Butter and colleagues[10] in 2001 demonstrated that contractile function significantly improved with LV free wall stimulation compared with anterior stimulation. The overall extent of the optimal stimulation site or "sweet spot" for CRT was determined in an animal model to be circumscribed by broad area centered in the mid to apical LV lateral wall; optimal CRT is better preserved with apical compared with basal pacing.[11] The core clinical trials of CRT demonstrated conflicting data in regards to lead placement. In the COMPANION, MADIT-CRT, and RAFT trials, anterior, posterior, or lateral LV stimulation sites had equivalent improvements in functional outcome and mortality[12–14]; however, apical lead position was associated with excess mortality.[13,14]

The clinical experience of implementing CRT lacks precision, but there is considerable research into quantitatively determining optimal pacing sites using echocardiography, cardiac MRI, and electrical mapping at the time of implant. The use of tissue Doppler imaging (TDI) to guide LV lead placement at the site of maximal delay is associated with the greatest improvement in cardiac structure and function.[15] Speckle-tracking 2-dimensional radial strain analysis to guide CRT has been shown to result in improvements in combined mortality or HF hospitalizations.[16,17] Cardiac MRI has similarly been used to assess strain and to guide lead placement away from regions of dense myocardial scar.[17–19] Maximal local electrical delay (QLV), a measure of dyssynchrony and assessed at the time of device implantation, is associated with acute hemodynamic response and reverse modeling and may serve as a simpler tool to map the optimal pacing site at implant.[20–22]

CONVENTIONAL APPROACH TO CARDIAC RESYNCHRONIZATION THERAPY

The standard technique for cannulating the CS includes using specialized lead delivery systems with different shapes to account for variations in right atrial anatomy and location of the CS ostium. The lead delivery system is used to guide either a J-tipped guidewire or diagnostic electrophysiologic catheter into the CS. Subselective sheaths and angioplasty wires may be used to facilitate access in difficult cases. The lead delivery sheath is then tracked over the wire or catheter into the CS. A balloon-occlusive venogram is performed to fully delineate CS anatomy and subjectively identify a suitable branch to target for lead delivery.

In general, a posterolateral or lateral branch is chosen without consideration of whether the branch subtends the site of maximal electromechanical delay or the presence of myocardial scar. If a posterior or lateral branch is not available or technically feasible, then a more anterior branch may be selected given the results of the major clinical trials. A lead is then guided into the target branch with the aide of a stylet or an over-the-wire technique, at which point the presumed success of CRT is ascertained by angiographic lead position and stability with suitable pacing thresholds and absence of diaphragmatic stimulation. Box 1 lists the several anatomic constraints that may limit successful cannulation of the CS, delivery of a pacing lead into the appropriate branch, or maintaining lead stability.[23]

Despite several different techniques and a multitude of specially designed tools for CS cannulation or lead delivery, up to 10% of attempts fail.[6] If these anatomic barriers are overcome, there remains the issue of suboptimal pacing thresholds, a high degree of latency limiting effective CRT in areas of myocardial scar, and phrenic nerve stimulation.

The technical challenge posed by these factors leads to prolonged procedure time, greater radiation exposure, greater exposure to iodinated

Box 1
Anatomic features limiting coronary sinus cannulation or lead delivery

Coronary sinus cannulation

Prominent sub-Eustachian pouch

Prominent Thebesian valve

Dilated right atrium distorting the coronary sinus os

Dilated left ventricle distorting the coronary sinus os

Lead delivery or stability within the coronary sinus

Coronary sinus stenosis

Coronary sinus spasm

Prominent valve of Vieussens

Tortuous coronary sinus body or branches

Persistent left superior vena cava

Small or absent posterolateral or lateral branches

Ectactic branches