Cardiac resynchronization therapy in coronary sinus atresia delivered using leadless endocardial pacing

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Introduction

Cardiac resynchronization therapy (CRT) has revolutionized the treatment of advanced heart failure. However, effective placement of a left ventricular (LV) pacing lead via the coronary venous system is subject to anatomical constraints.

We present the case of a 78-year-old man with a history of dilated cardiomyopathy and severe LV impairment. It was not possible to implant a lead in the coronary sinus (CS) to deliver biventricular pacing owing to atresia of the CS ostium, so we implanted our patient with the ultrasound-based WiCS-LV system and successfully delivered CRT.

Case report

A 78-year-old man with a history of dilated cardiomyopathy and chronic atrial fibrillation was scheduled for implantation of a biventricular pacemaker/implantable cardioverter-defibrillator (CRT-D). Despite multiple attempts, it proved impossible to catheterize the CS ostium, and so implantation of an LV lead was abandoned. A 52-cm Tendril lead (St Jude Medical) was implanted in the right atrial appendage, and a 58-cm Durata (St. Jude Medical, St. Paul, MN) single-coil defibrillation lead was fixed in the apical interventricular septum. These leads were connected to a Unify Assura CRT-D device, implanted in a left prepectoral pocket with the LV port capped.

Following this procedure, the patient underwent imaging with contrast-enhanced computed tomography, with image acquisition optimized for cardiac venous mapping. Complete atresia of the CS ostium and persistence of a small-caliber left-sided superior vena cava (SVC) was confirmed. Multiple enlarged Thebesian vessels were also noted draining anteriorly into the left atrium (LA). Importantly, the volume-rendered images also confirmed an absence of any posterolateral target veins for delivery of a CS lead (Figure 1).

We therefore elected to deliver CRT therapy to our patient endocardially by implanting the WiCS-LV system (EBR Systems Inc, Sunnyvale, CA); ours was one of the first patients to be implanted following its commercial release.

WiCS-LV is the only leadless endocardial pacing system for CRT. It uses ultrasound-based technology to transfer energy acoustically from an ultrasound transmitter implanted on an intercostal muscle to a small 12.7-mm ultrasound receiver-electrode implanted on the LV endocardial wall. The electrode transduces the acoustic energy to electrical energy, which then stimulates the LV. The WiCS-LV system is co-implanted with a right ventricular (RV) pacing system, and the cycle for biventricular pacing commences with the WiCS-LV system sensing the RV pacing pulse. Confirmation of the electrode in the LV is followed by LV stimulation within 3 ms of the sensed RV pulse, and synchronous biventricular pacing.

Preoperatively, the patient was assessed for suitability of the WiCS-LV system. Transthoracic echocardiography was performed to assess which, if any, intercostal spaces between the 4th and 7th provided a minimum 1 × 3.5 cm acoustic window to the LV without rib or lung encroachment. Implantation of the system was performed in 2 stages. The transmitter was surgically anchored in the previously identified intercostal space and the battery placed in the left mid-axillary line. The following day the patient was implanted with the passive endocardial electrode via the right femoral artery and a retrograde aortic approach, as previously described[1] (Figure 2). We successfully targeted our endocardial electrode placement to the site of latest mechanical activation defined by speckle-tracking 2D radial strain echo analysis, following the protocol for optimal CS LV lead placement in the TARGET[2] and STARTER[3] trials. QLV at this site measured 104 ms.

At 1-month follow-up 94% biventricular pacing had been achieved. QRS duration had reduced by 23%, from 150 ms

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KEY TEACHING POINTS

- WiCS-LV is the world's first leadless endocardial pacing system for cardiac resynchronization therapy (CRT).
- The WiCS-LV system uses the conversion of acoustic energy to electrical energy to pace the left ventricle, timed off a right ventricular pacing pulse.
- This technology has the potential to overcome some of the anatomical limitations of conventional CRT and permit targeted site selection for left ventricular pacing.

during intrinsic conduction at baseline to 118 ms when biventricular-paced with the WiCS-LV system; dyssynchrony parameters had normalized (Figure 3); and there was evidence of LV reverse remodeling with a 10% reduction in end-systolic volume and an 8% increase in ejection fraction observed. In addition, the patient experienced a significant subjective improvement in his heart failure symptoms compatible with a 1-class reduction in New York Heart Association at 1 month; and commensurate with this improvement, he demonstrated a 14% increase in 6-minute walk test distance and 36% reduction in his Minnesota Living with Heart Failure Questionnaire score.

Discussion

The coronary venous system can pose a variety of obstacles to the successful delivery of a CS pacing lead. The Thebesian and Vieussens valves can obstruct catheter engagement and lead passage, and heterogeneity in the caliber and distribution of the posterior and marginal cardiac veins can preclude adequate lead placement. However, in this instance, we encountered a much less common obstacle involving complete atresia of the right atrial ostium of the CS. The route for coronary venous return was provided by the persistent left SVC (PLSVC) draining retrogradely into the innominate vein, right SVC, and right atrium,[4] and by Thebesian vessels draining into the LA. Other reports of CS ostium atresia have documented direct communication between the CS and LA,[5,6] although this was not present in our patient.

Successful delivery of an LV pacing lead via a PLSVC has been previously reported in 2 patients with CS atresia.[7,8] However, in these cases the caliber of the PLSVC was adequate to successfully cannulate, and the first-order coronary venous tributaries provided acceptable targets. In our patient, there were no posterior venous targets; and even if there had been, the small caliber of the PLSVC, possibly due to the coexistence of well-developed Thebesian veins, would have made delivery of a pacing lead extremely challenging.

Whatever the anatomical limitations, failure to deliver and secure a pacing lead in an appropriate target vein remains an important limitation of conventional CRT implantation. Failure to implant an LV lead occurred in 12% of patients at their first implant in the CARE-HF study, with over 50% of failures being due to an inaccessible CS or target vein;[9] and although implant techniques and technology have evolved since the early days of CRT, implant failure remains an important issue in a minority of patients. Furthermore, it is also now appreciated that even if a CS lead can be delivered, failure to achieve a position that is concordant with a late-activated, viable region of myocardium is associated with lack of benefit from biventricular pacing.[10] When prospectively evaluated, it has been shown that lead placement targeted to these regions provides the optimal response.[2,3] However, the confines of cardiac venous anatomy do not always permit the selection of these sites for pacing.

Surgical epicardial lead implantation and transseptal procedures have been performed in patients who could not be paced transvenously; however, lead implantation in this way appears to be associated with an increased morbidity and mortality compared with conventional implant procedures.[11] Transseptal techniques have been limited by concerns

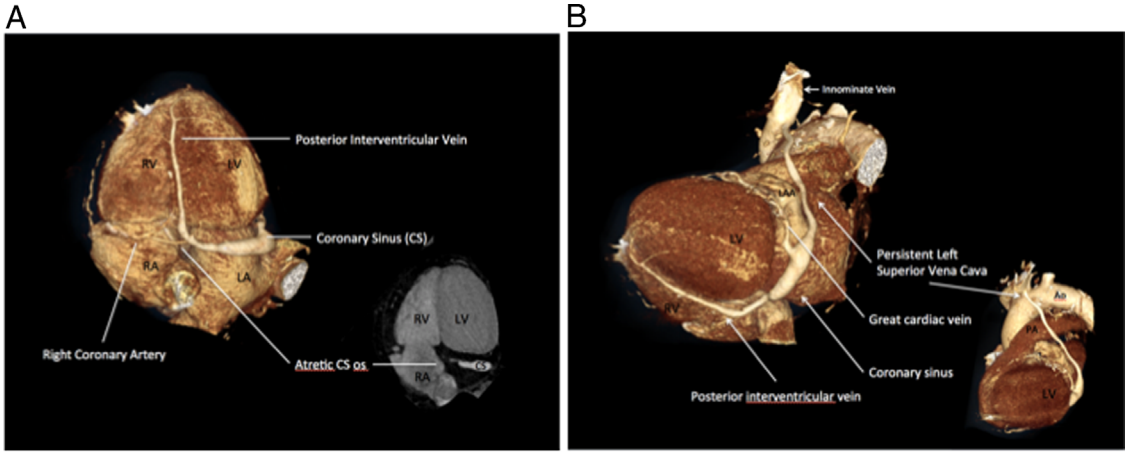

Figure 1 **(A)** Computed tomography and volume-rendered image of the inferior surface of the heart documenting complete absence of the right atrial ostium of the coronary sinus (CS). LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle. **(B)** Volume-rendered images from left lateral and oblique projections demonstrating a persistent left superior vena cava communicating with the innominate vein, and an absence of any first-order posterolateral veins.

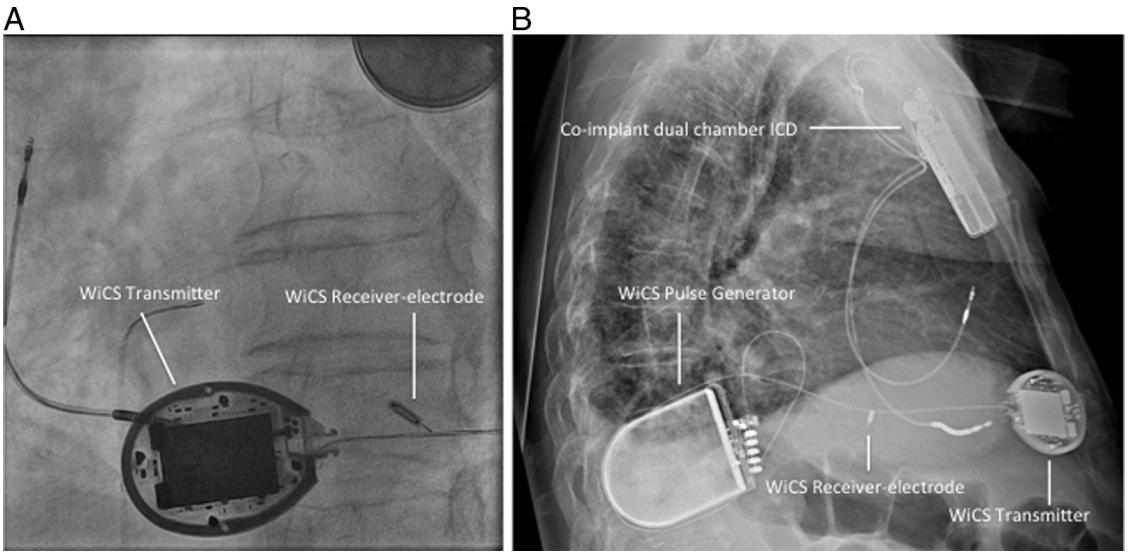

Figure 2 Anterior **(A)** and lateral **(B)** fluoroscopic projections demonstrating the components of the WiCS-LV system in situ.

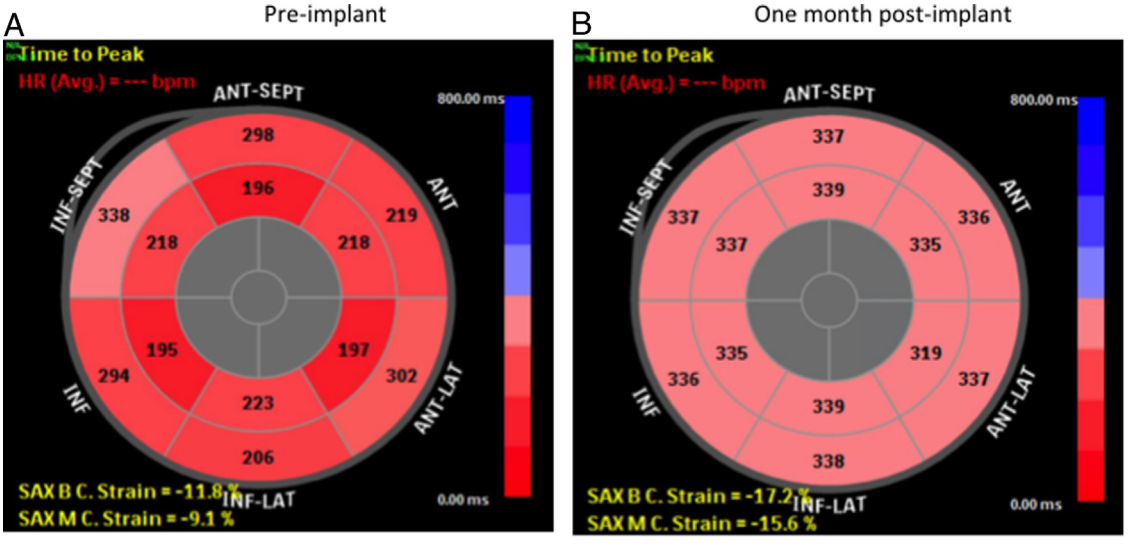

Figure 3 Time to peak systolic strain for basal and mid–left ventricular segments depicted before **(A)** and after implantation of the WiCS-LV system **(B)**. Note the uniformity in segmental timing of peak strain following resynchronization, and the increase in overall circumferential strain values. SAX = short axis; B = basal; M = mid; C.strain = circumferential strain.

regarding thromboembolic complications, the need for lifelong anticoagulation, interaction with the mitral valve, and lack of dedicated lead extraction equipment. Nevertheless, despite these limitations, this technique highlighted potential physiological advantages of endocardial compared with epicardial pacing, which included preservation of the transmural activation sequence and faster impulse propagation.[12] These benefits appear to result in superior hemodynamic performance.[13] The WiCS-LV system, which delivers endocardial LV pacing, allows access to all regions of the left ventricle and is free from the well-known transseptal lead complications; therefore, it has great potential value.

Conclusions

The feasibility and potential clinical efficacy of the WiCS-LV system have been demonstrated by the WISE CRT study[14] and the preliminary results of the SELECT-LV study,[15] and further evaluation of this new technology is ongoing within a European registry. We have demonstrated that it can be used with good effect to overcome anatomical constraints that would have previously proven a major obstacle to successful CRT, and by allowing targeted electrode placement it has the potential to maximize hemodynamic benefits and improve response.

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