First-in-human wireless left ventricular endocardial pacing in a patient with obliterated venous system and complete heart block

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Introduction

Left ventricular (LV) endocardial pacing using the WiSE-CRT (Wireless Stimulation Endocardially for Cardiac Resynchronization) system (EBR Systems, Sunnyvale, CA) is a novel technology that uses ultrasound energy to deliver wireless signals to pace the LV. This system was originally designed to offer a solution for patients with indicated cardiac resynchronization therapy (CRT) but in whom LV epicardial access was unobtainable.[1] In this case, we present a first-in-human use of the WiSE-CRT system to pace the LV in a patient with an obliterated venous system that made it impossible to use any traditional pacing techniques.

Case report

This case involves a 36-year-old man with a past medical history significant for hypertension, systemic lupus erythematosus complicated by systemic vasculitis, coronary artery disease for which he underwent 3-vessel coronary artery bypass graft 3 years prior, seizure disorder, superior vena cava syndrome, and end-stage renal disease on hemodialysis, with multiple dialysis catheter placements in the past. Most recently, he was being dialyzed via a transhepatic central catheter, which had already been infected multiple times. Subsequently, the patient had multiple intensive care unit admissions for sepsis complicated by disseminated intravascular coagulation and bacteremia with vancomycin-resistant *Enterococcus* and extended-spectrum beta-lactamase–producing *Klebsiella* requiring multiple antibiotics, including cefepime and linezolid.

The patient presented to our center after a syncopal episode. He was found to be in complete heart block with junctional escape rhythm at 35 beats per minute (Figure 1A). Transesophageal echocardiogram showed mildly sclerosed mitral and aortic valves with mild-to-moderate mitral and tricuspid regurgitation. LV function was normal with no regional wall motion abnormalities. He was initially taken to the electrophysiology laboratory in an attempt to implant a Micra™ leadless pacemaker (Medtronic, Minneapolis, MN) in the right ventricle (RV), given his extensive history of infection. However, vascular access was unfeasible, as both common iliac veins were completely occluded, likely owing to multiple dialysis catheter placements (Figure 1B). An attempt at accessing the right internal jugular vein to access the heart was also unsuccessful because the superior vena cava was chronically

KEY TEACHING POINTS

- This is the first use of the WiSE-CRT (Wireless Stimulation Endocardially for Cardiac Resynchronization) (EBR Systems, Sunnyvale, CA) device as a single-chamber pacemaker by pacing the left ventricle endocardially in a patient with poor right ventricle access.
- Leadless pacing is an appropriate alternative to conventional pacing in patients with high risk for intravascular infections.
- Wireless pacemaker technology facilitates the communication between the epicardium and endocardium, making innovative pacing strategies possible.

KEYWORDS Wireless; Pacing; Complete heart block; WiSE-CRT; Cardiac resynchronization therapy; Epicardial; Left ventricular pacing; Novel
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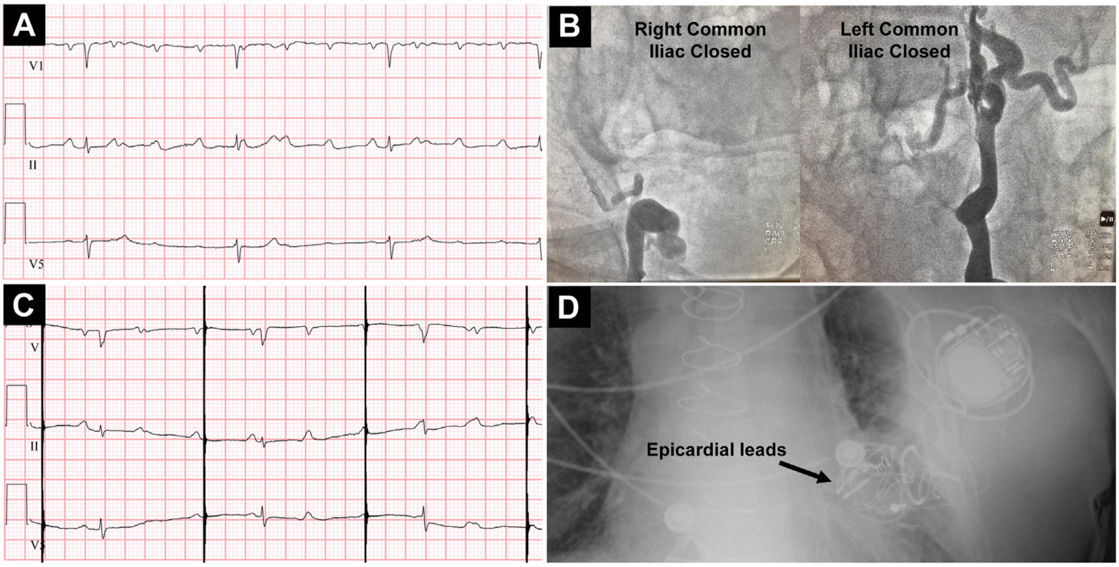

Figure 1 Before WiSE-CRT (EBR Systems, Sunnyvale, CA) implantation. **A:** Electrocardiogram (ECG) at baseline showing complete heart block. **B:** Occluded right and left common iliac veins making vascular access unsuccessful. **C:** ECG with failure to capture by the epicardial leads (visible in panel D) the day after the procedure.

occluded, as confirmed later by computed tomography scan. At this point, the patient had 2 options. The first was to have a transhepatic approach and place a single bipolar active fixation lead through that access; however, given his infection history with methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant enterococcus, and multiple transhepatic catheter infection, it would have been inevitable for him to develop endocarditis. The second option was to have epicardially placed pacing leads. The decision was then made to pursue surgical epicardial pacing and the patient was taken to the operating room. Under general anesthesia, a left anterolateral minithoracotomy was performed in the fifth intercostal space and a portion of the sixth rib was resected for exposure. Two initial screw-in unipolar (Medtronic 5071) epicardial leads were placed; however, there was no capture, and because of frailty of the myocardium they were left in place. A third suture-on (Medtronic 4968) bipolar lead was placed more anteriorly, which was capturing in the operating room with acceptable thresholds ∼2 mV. However, the next day even that epicardial lead was not capturing appropriately (Figure 1C and 1D) and the patient remained in complete heart block with junctional escape rhythm.

The decision was then made to pursue a novel strategy to pace the LV, given severely prohibitive and restricted access to the RV. An expedited plea to the U.S. Food and Drug Administration (FDA) was sent for a 1-time compassionate use of the WiSE-CRT system (EBR Systems, Sunnyvale, CA), using the noncapturing epicardial pacing lead as the trigger for endocardial LV pacing. An expedited institutional review board approval for compassionate use was also obtained. EBR Systems provided the WiSE-CRT device free of charge for compassionate use. In the meantime, the patient had a temporary transvenous pacing wire placed transhepatically to the RV.

Transmitter and battery implantations (phase 1)

After informed written consent was obtained, the patient was brought to the electrophysiology lab. General anesthesia was administered under cardiac anesthesia supervision. The patient was draped and prepped in the usual sterile fashion with the mid chest and axilla covered.

After local anesthetizing of the site, a vertical incision was made using a #15 blade at the fourth intercostal space. Dissection was performed and the ribs and intercostal muscles were exposed. Bleeding was checked and the appropriate areas were cauterized. A midaxillary incision was made along the same intercostal space with dissection to the prepectoral fascia and a pocket was made to accommodate the battery. Using long forceps, a subcutaneous tunnel was carefully made connecting the anterior and midaxillary pockets. A Penrose drain was pulled through the tunnel and a WiSE-CRT transmitter model 4100 cable was pulled through the tunnel using the Penrose drain. The transmitter was then sutured to the fourth and fifth ribs' costal cartilage. The transmitter was attached to a WiSE-CRT system battery model 3100. The pocket was irrigated with sterile bacitracin/kanamycin solution. A dry field was observed. Arista™ AH (BD, Warwick, RI) hemostatic powder was used to insure complete hemostasis. The battery was then placed in the pocket and sutured to the prepectoral fascia. The deep and superficial subcutaneous layers were closed with running stitches of 3-0 Vicryl (Ethicon, Inc., Raritan, NJ). The subcuticular layer was closed with running stitches of 4-0 Vicryl (Ethicon, Inc., Raritan, NJ) and sealed with Dermabond (Ethicon, Inc., Raritan, NJ).

Electrode insertion (phase 2)

Using modified Seldinger technique, an introducer was placed in the right femoral artery. A 12F sheath was advanced

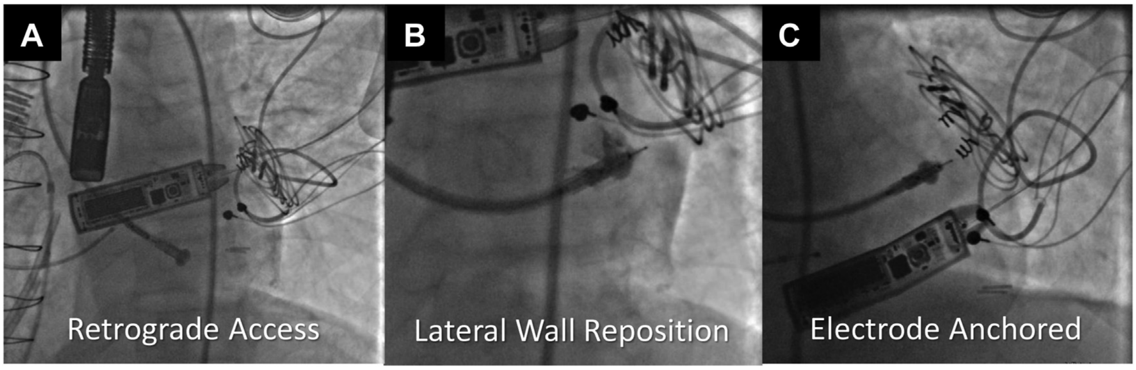

Figure 2 During WiSE-CRT (EBR Systems, Sunnyvale, CA) implantation. **A:** Retrograde access through the aortic valve into the left ventricle (LV). **B:** Lateral wall repositioning. Contrast injection is used to delineate the LV endocardial borders. **C:** Electrode anchoring into the lateral LV wall.

over the guidewire to introduce the electrode delivery system into the right femoral artery then retrogradely to the LV. Transesophageal echocardiogram guidance was used to visualize the lateral wall of the LV.

Using pressure monitoring and fluoroscopy guidance, retrograde access across the aortic valve was done (Figure 2A). The patient was then heparinized, and follow-up activated coagulation times along with heparin boluses were used to maintain an activated coagulation time above 250 seconds. Under ultrasound and fluoroscopy guidance the 12F deflectable sheath with an inflatable atraumatic balloon at the distal tip was inserted retrogradely into the LV over a pigtail catheter. The sheath was then deflected and opposed against the lateral wall, which was the safest and fastest placement given the retrograde aortic access. An 8F electrode catheter was inserted into the delivery sheath and advanced until only a few millimeters from the distal end of the sheath. Different sites on the LV endocardium were mapped for range and angle from the transmitter and pacing thresholds. At the best site, the receiver electrode was then gently pushed out so that the barb was fully deployed into the endocardium, which was confirmed with contrast injections (Figure 2B and 2C). The receiver electrode was then released, and the sheath was withdrawn. Figure 3A shows the entire WiSE-CRT system implanted. The device transmitter was programmed to sense the pacing pulse (spikes) from the currently placed noncapturing epicardial lead and send ultrasound energy signals to the endocardiac receiver electrode, which in turn paced the ventricle. At the end of the procedure, heparin was reversed by protamine and the arterial access then closed using 2 Perclose ProGlide (Abbott, Plymouth, MN) suture-mediated closure systems. The patient tolerated the procedure with no complications. The patient was then being paced from the LV with appropriate capture (Figure 3B).

Discussion

The WiSE-CRT system is a novel technology that offers an alternative solution for patients with heart failure who meet standard indications for CRT but have an unsuccessful LV epicardial pacing owing to either difficult coronary sinus access or unacceptably high pacing thresholds. This system depends on an already implanted RV lead to sense electrical impulses. A subcutaneous transmitter powered by a battery converts this electrical energy into ultrasonic, then transmits this energy wirelessly to an endocardial receiver electrode in the lateral wall of the LV. This electrode then paces the LV

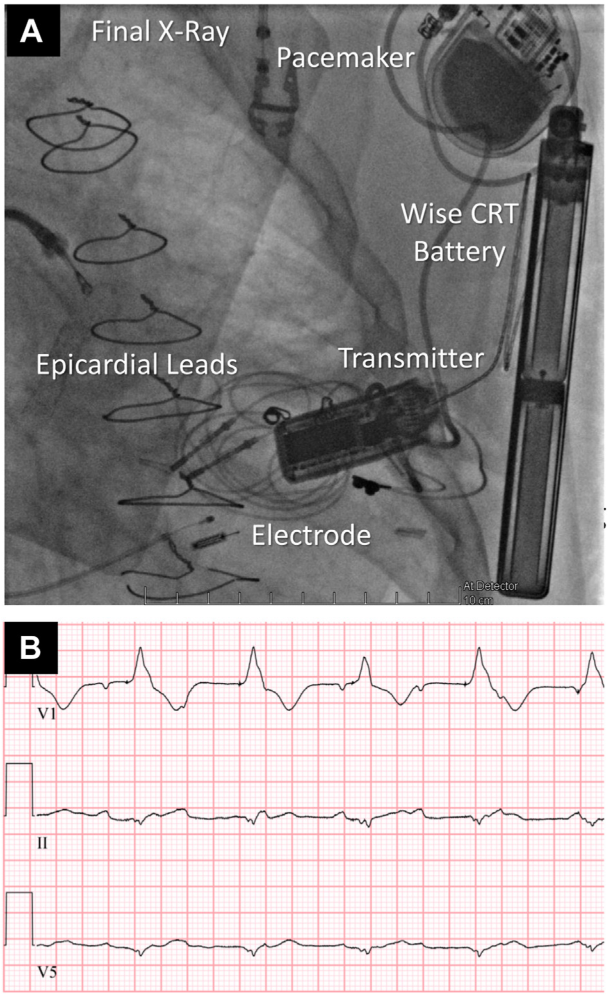

Figure 3 After WiSE-CRT (EBR Systems, Sunnyvale, CA) implantation. **A:** Final radiograph showing the WiSE-CRT system and the epicardial leads. **B:** Final electrocardiogram showing left ventricular pacing.

endocardially in a synchronized fashion with the RV lead. This technology was demonstrated to be feasible and safe in the SELECT-LV trial[2] and subsequent multicenter studies,[3] despite no prior experience.[4]

In this case, we present a new and innovative use of the WiSE-CRT system in a patient with unfortunate complete heart block, likely a rare finding in systemic lupus erythematosus with positive anti-ribonucleoprotein antibodies.[5] The patient had multiple complex comorbidities, including end-stage renal disease necessitating hemodialysis. The patient had multiple transvenous ports over the years in the common iliac and subclavian veins bilaterally. Near-total occlusion and severe stenosis in those veins made it impossible to have vascular access for venous intracardiac access. The patient was being dialyzed using a transhepatic port, which was a last resort and rather an unusual site for vascular access. This complex vascular anatomy made an attempted RV endocardial pacemaker implantation unfeasible. A multidisciplinary approach with cardiothoracic surgery was sought to place epicardial leads with a minithoracotomy approach. Despite good capture initially during the procedure with acceptable thresholds, none of the epicardial leads was able to capture appropriately the following day. The patient then remained in complete heart block with junctional escape rhythm. A temporary transvenous pacing wire was placed in the RV under fluoroscopy guidance in a combined effort between interventional radiology and electrophysiology using the transhepatic port the patient uses for hemodialysis. The patient was then being monitored in the cardiac critical care unit.

Given our initial successful experience with the WiSE-CRT system in heart failure patients, we sought to apply this technology to this patient. An expedited plea to the FDA for compassionate use as well as an institutional review board approval was obtained. Given the fact that the epicardial leads were functional electrically, they were ideal to be used as an energy source that can be detected by the WiSE-CRT transmitter. This energy would then be sent to the LV wirelessly and, once received by the LV electrode, would trigger an impulse in the LV lateral wall and function essentially as a single-chamber pacemaker.

This innovative technology offers a new method of wireless communication between the heart chambers that can be used in creative approaches. The use of the WiSE-CRT "off-label" has been described in scattered reports to create a completely wireless biventricular CRT system by transmitting wireless signals from the Micra device in the RV.[6,7] The novelty in our approach, however, lies in using a noncapturing epicardial lead to pace the LV endocardially when RV access was not feasible, thus offering a practical solution for such patients.

Despite initial successful outcomes from a cardiac standpoint, the patient died 2 weeks later from sepsis secondary to intra-abdominal infection. Further long-term outcomes like the percentage of LV pacing were unfortunately not available.

Conclusion

This is the first-in-human case of successful implantation of the WiSE-CRT wireless LV endocardial pacing system without the presence of RV leads. We demonstrate in this case the success and safety of a novel and creative pacing strategy in a patient with a complete heart block, obliterated venous system hindering RV access, and a failed epicardial pacing attempt.

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