Use of an electroanatomic mapping system with high-density multipolar mapping catheters to guide transvenous atrial pacing lead implantation in a Fontan patient

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Introduction

The Fontan operation is the final stage of palliation for patients with single-ventricle heart disease, resulting in complete separation of the pulmonary and systemic circulations via total cavopulmonary connection. For patients with single-ventricle physiology who undergo Fontan palliation, atrial arrhythmias and sinus node dysfunction are frequent electrophysiologic sequelae.[1,2] Consequently, pacemaker implantation is the most common cardiac procedure in this population, with an atrial lead typically being the most significant.[3] Epicardial pacemaker implantation has been the traditional approach but has disadvantages, including the need for repeat sternotomy or thoracotomy, challenges related to exposing viable atrial tissue, and higher pacing thresholds.

Recently, transvenous atrial pacing has been increasingly reported in select Fontan patients owing to the benefits of avoiding a repeat sternotomy, achieving magnetic resonance imaging–compatible systems, and avoiding higher pacing and lower sensing thresholds associated with epicardial systems.[4] Patients with lateral tunnel or atriopulmonary variants of the Fontan operation have atrial tissue incorporated into the Fontan connection, and are candidates for a transvenous approach, though they must be carefully selected owing to potential increased risk of Fontan pathway thrombus.[5] Challenges with the transvenous approach include the use of ionizing radiation and difficulties related to identification of an adequate endocardial pacing site in the presence of significant scar within the Fontan pathway, both from surgery and from prior ablation attempts.[6,7] Electroanatomic mapping systems (EAM) are powerful tools that are widely available in electrophysiology laboratories. They can enable the identification of viable pacing sites and guide lead placement without fluoroscopy in patients with complex congenital heart disease.[8,9] Technological advancements of these systems, including the integration of high-density multipolar array mapping catheters, stand to further improve the utility of these systems in guiding lead implantation, particularly in patients without structurally normal hearts.

Here we report a case of single-chamber transvenous pacemaker placement in a Fontan patient with a largely electrically quiescent atrium, sinus node dysfunction, and atrial arrhythmias guided by an EAM and high-density multipolar mapping catheter.

KEY TEACHING POINTS

- Adults with palliated congenital heart disease are prone to arrhythmias and can benefit from permanent pacemaker placement; however, their cardiac anomalies and myocardial scarring present technical challenges.
- There is a growing interest in transvenous devices in select patients who have undergone single-ventricle palliation owing to their less invasive nature compared to the traditional epicardial approach in this population.
- The use of electroanatomic mapping systems in conjunction with newer multipolar mapping catheters at the time of pacemaker placement can rapidly identify viable pacing targets to improve the likelihood of procedural success in patients with extensive cardiac scarring.

Case report

A 41-year-old female single-ventricle patient born with double-inlet left ventricle, L-transposition of the great

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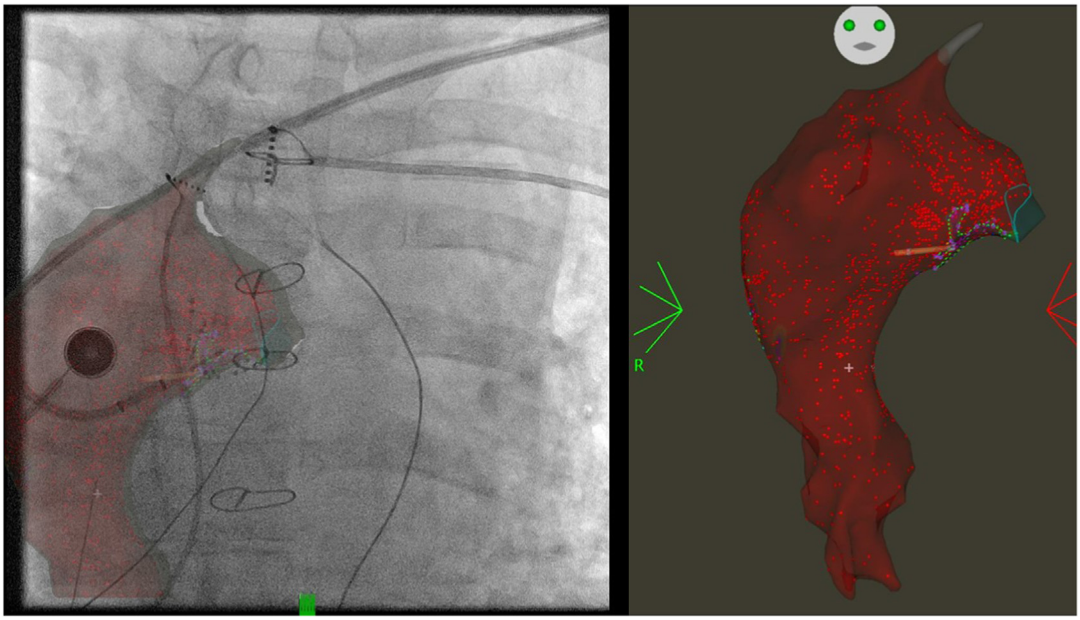

Figure 1 Left, anterior-posterior (AP) projection from intraprocedural fluoroscopy with an overlayed electroanatomic mapping system (EAM) image for reference. The PENTARAY multipolar mapping catheter (Biosense Webster) is within the Fontan circuit mapping the site of highest voltage, just inferior to the take-off of the left pulmonary artery. Right, AP view of the EAM voltage map with transparency reduced to highlight the position of the pacemaker lead at its final location, within the zone of highest voltage.

arteries, and pulmonary atresia was referred for transvenous single chamber pacemaker implantation for the combination of sinus node dysfunction and incessant atrial arrhythmias. She received initial surgical palliation as an infant with a systemic to pulmonary artery shunt and eventually underwent lateral tunnel Fontan palliation at 7 years of age. Overall, she had been doing well until 6 years prior to her referral. At that time, she developed sinus node dysfunction and recurrent intra-atrial reentrant tachycardia (IART).

She underwent electrophysiology study and ablation twice. Each procedure identified multiple atrial reentrant circuits, which were ablated in the systemic venous and pulmonary venous atria via transbaffle puncture. Her initial study was also significant for typical atrioventricular nodal reentrant tachycardia, which was ablated. Her ablation procedures were acutely successful. However, she had recurrence of IART within a month of each procedure. Despite therapy with dofetilide and nadolol, she continued to have IART recurrences with rapid conduction, leading to hospitalization and urgent conversion. Attempts at rate or rhythm control were ineffective owing to significant baseline bradycardia, which limited uptitration of her antiarrhythmics. Dofetilide and nadolol were discontinued, and amiodarone was initiated. An atrial pacemaker was recommended to support antiarrhythmic therapy titration and to provide atrial rate stabilization and automatic antitachycardia pacing. She had no significant baffle leak or direct right-to-left shunt based on echocardiography and prior angiography and was a candidate for indefinite anticoagulation. For these reasons, and to avoid a repeat sternotomy in this high-risk patient, a transvenous single-chamber device was determined to be the optimal choice.

The procedure was performed under general anesthesia and on uninterrupted anticoagulation with apixaban. The left axillary vein was accessed percutaneously under ultrasound guidance, a prepectoral pacemaker pocket was developed, and a 7F tear-away sheath was placed in the vein. A 7F PENTARAY™ multipolar mapping catheter (2-6-2 mm spacing; Biosense Webster, Irvine, CA) was advanced to the lateral tunnel Fontan. The CARTO® 3 system (Biosense Webster) was used to create an anatomic shell and bipolar voltage map of the Fontan pathway in sinus rhythm. The area of highest voltage was marked in the posteromedial portion of the pathway, just inferior to the take-off of the left pulmonary artery (Figure 1), and was targeted for lead placement. The area of this island of relatively electrically healthy tissue (bipolar voltage of at least 0.5 mV) was later estimated to be 2.5 square centimeters total (Figure 2). Areas with lower voltage were presumed unlikely to be acceptable for lead fixation and were not targeted in the next part of the procedure. Mapping took 12 minutes.

A Medtronic SelectSecure™ MRI SureScan™ 3830 lead (Medtronic Minneapolis, MN) was connected to the CARTO system using alligator clips in a bipolar configuration. With the known lead diameter and electrode spacing entered into CARTO, the lead was able to be accurately visualized on the electroanatomic map, which was used to guide the lead within the island of normal voltage, with minimal fluoroscopy use. Using a J-shaped C315 delivery sheath (Medtronic Minneapolis, MN), the lead was able to be fixated within the island of normal voltage within 10 minutes. The lead measurements demonstrated a p-wave amplitude of 1.5 mV and capture threshold of 0.5 V at 0.4 ms with pacing impedance of 589 ohms. The lead was connected to the atrial port of a

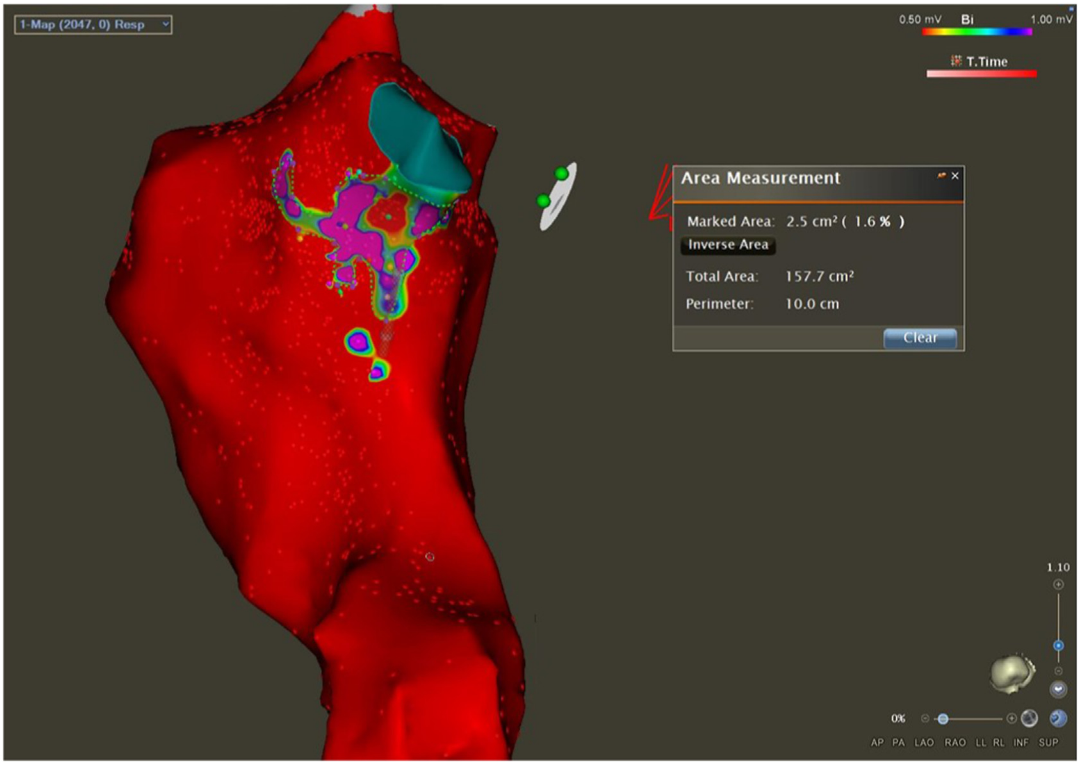

Figure 2 Left anterior oblique caudal view of the electroanatomic mapping system voltage map. The scale is calibrated to show voltage measured to be less than 0.5 mV as red and greater than 1.0 mV as purple to accentuate the area of the healthiest tissue, which was targeted, measuring 2.5 cm^2.

dual-chamber pacemaker, with a pin-plug in the ventricular port, in order to provide automatic atrial antitachycardia pacing without the presence of a ventricular lead, which is not available for transvenous placement in Fontan patients. The total fluoroscopy time was 2.8 minutes (234 $\mu Gy \cdot m^2$) and the procedure duration was 1 hour and 8 minutes. A chest radiograph the next day demonstrated stable lead position (Figure 3). At 2-month follow-up, the atrial lead sensing was 1.8 mV and the pacing threshold and impedance remained stable. She had not experienced further symptoms of chronotropic incompetence, nor did she have further arrhythmias to that point, while on amiodarone therapy.

Discussion

In patients with congenital heart disease and coexisting bradycardia and recalcitrant atrial arrhythmias, pacemakers are a powerful, guideline-based treatment with the potential to greatly improve patient well-being.[10,11] This can be achieved through supporting the initiation and titration of antiarrhythmic medications, smoothing atrial rate, or providing automatic antitachycardia pacing.[12] Patients with a Fontan repair commonly meet these indications. The Fontan procedure results in a high burden of surgical scar, which is compounded by the long-term effect of abnormal hemodynamic stresses in the Fontan atrium. Although ablation may improve arrhythmias, it is generally considered palliative, and it results in the creation of even more atrial scar. The resulting extensive scarring can produce large electrically quiescent portions of the atrium. As a result, atrial tachyarrhythmias and bradycardia owing to either direct damage to the sinoatrial node or sinus exit block are common,[13] and much of the atrium is unsuitable for pacing owing to poor sensing, high capture thresholds, or exit block.

The challenges of this procedure with the traditional approaches are familiar to many pediatric and adult congenital electrophysiologists and congenital heart surgeons. Challenges with finding an adequate pacing site can result in long procedure times, high radiation exposure, and an increased risk of leaving the lab with suboptimal lead placement or no lead placement at all.[7] Prior reports have demonstrated the utility of an EAM to identify areas of the highest voltage in patients with congenital heart disease.[8,9] Here, in conjunction with a multipolar mapping catheter, we were able to use an EAM to quickly and precisely target a small portion of the highly diseased atrium in which pacing was likely to be successful. This resulted in good sensing and threshold measurements, which have persisted into short-term follow-up.

There is emerging literature to suggest that the use of multipolar mapping catheters decreases mapping and procedure times during catheter ablation, and reports have detailed their use in patients with congenital heart disease.[14,15] There are hopes that as the experience with these tools grows, their use will increase the chances of success and decrease the risk of recurrence. Their use in aiding the implantation of a pacemaker lead in a patient with congenital heart disease has not been shown previously. To our knowledge this is the first

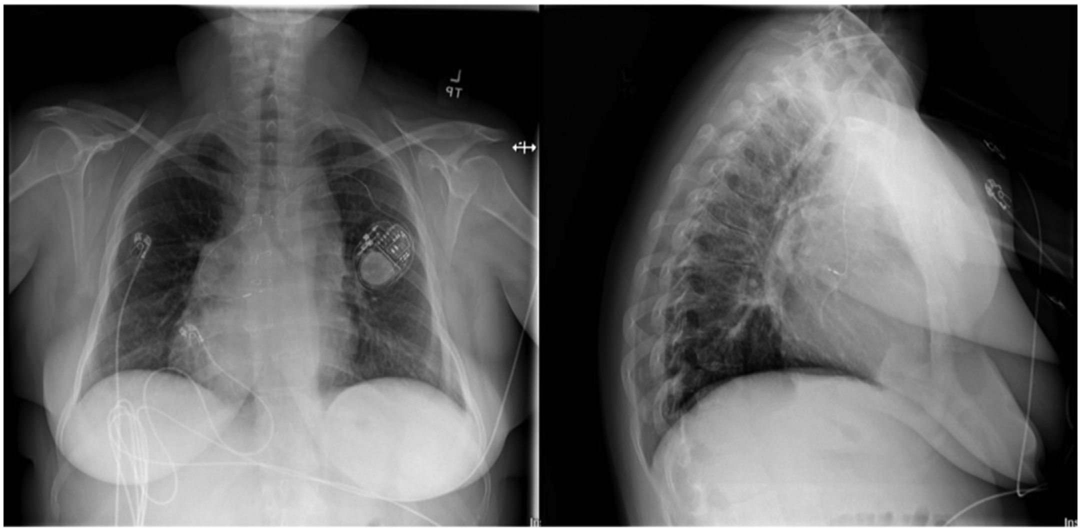

Figure 3 Chest radiography from the morning after the procedure showing final lead placement in the posterior-anterior and lateral projections.

reported use of an EAM in combination with a multipolar mapping catheter to rapidly collect Fontan circuit geometry, quantify the amount of viable tissue, and direct the pacing lead to an adequate pacing site. Using these tools, we were able to achieve a procedure time of a little over an hour and fluoroscopy use that was much lower than has previously been reported.

Conclusion

There is a growing interest in the use of transvenous devices for select single-ventricle patients owing to their less invasive nature compared to the traditional epicardial approach. The utilization of tools and techniques already available in the electrophysiology lab for use during ablation procedures can be employed to reduce procedure times, decrease radiation exposure, and increase the chances of successful lead placement. There is more work that needs to be done to identify the best techniques to make these systems possible in patients with challenging substrates.

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