Left bundle branch area pacing via persistent superior vena cava: A case report

Alan Bulava, MD, PhD,*† David Sitek, MSc,* Jan Tesařík, MSc*

*From the *Department of Cardiology, České Budějovice Hospital, České Budějovice, Czech Republic, and †Faculty of Health and Social Sciences, University of South Bohemia in České Budějovice, České Budějovice, Czech Republic.*

Introduction

Left bundle branch area (LBBA) pacing was proposed as an alternative to right ventricular pacing to preserve synchronous left ventricular activation and eliminate the risk of developing pacing-induced cardiomyopathy.[1] There is growing evidence of the superiority of LBBA pacing over conventional right ventricular pacing. In many centers, LBBA pacing has become a first-line therapy; however, in others, LBBA pacing has yet to become the preferred or default approach.[2,3] A complete conduction system pacing solution consisting of the world's first certified system has recently been released.[4] However, the delivery sheaths were designed for a left-sided approach via superior vena cava. We report a challenging case of successful LBBA lead implantation in a patient with an anatomical variant of persistent left superior vena cava without connection to the right brachiocephalic vein.

KEY TEACHING POINTS

- Left bundle branch area pacing (LBBAP) can be performed via the coronary sinus in patients with persistent left superior vena cava (PLSVC) and no bridging veins.
- Specific lead implantation technique is needed for stylet-driven leads in patients with PLSVC.
- LBBAP should be the preferred type of pacing in patients affected by previous arrythmia-induced cardiomyopathy and potentially high percentage of ventricular pacing.
- Further improvement of dedicated tools might facilitate wide adoption of LBBAP in different anatomies.

Case report

A 56-year-old woman was admitted to the hospital owing to poorly tolerated recurrent atrial fibrillation (AF) episodes. Pharmacological cardioversion using amiodarone was carried out. However, significant symptomatic sinus bradycardia appeared on the third day during the amiodarone loading phase (600 mg per day). Exploration of the past medical history also revealed bradycardia episodes on propafenone (300 mg twice a day [bid]). The patient already underwent 1 radiofrequency catheter ablation of a typical right atrial flutter and 1 pulsed-field catheter ablation (PFA) 3 years and 18 months before admission, respectively. The last PFA was rather time-consuming owing to difficult transseptal access and the need for general anesthesia owing to the extreme anxiety of the patient. Isolation of all 4 pulmonary veins and the left atrial posterior wall was uneventfully accomplished with still inducible AF at the end of the procedure performed in September 2022. With regards to these conditions and biatrial dilatation (left atrial volume index 45 mL/m^2, left atrial area 26 cm^2, right atrial area 20 cm^2), we considered the second PFA procedure futile after also considering the patient's preference. Antiarrhythmic drugs (AAD) had to be stopped due to persistent bradycardia, and the patient was referred for permanent pacemaker implantation. Since the patient has already experienced several heart failure episodes during AF with moderately reduced left ventricular ejection fraction, a decision was made to attempt LBBA pacing lead implantation to prevent future pacing-induced cardiomyopathy and also to leave an open space for indication of radiofrequency catheter modification of the atrioventricular (AV) node, should the AAD be ineffective or intolerant.

After the left subclavian vein puncture, a persistent left superior vein was readily suspected since the progression of the J-shape wire was anatomically abnormal. The diagnosis was confirmed by contrast venography (Figure 1A), which proved no anatomical connection to the right brachiocephalic vein. The patient was right-handed and preferred the left-sided implantation, so we continued and introduced the

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Address reprint requests and correspondence: Prof Alan Bulava, M.D., Ph.D., Department of Cardiology, České Budějovice Hospital, B. Němcové 54, 370 01 České Budějovice, Czech Republic. E-mail address: alanbulava@seznam.cz.

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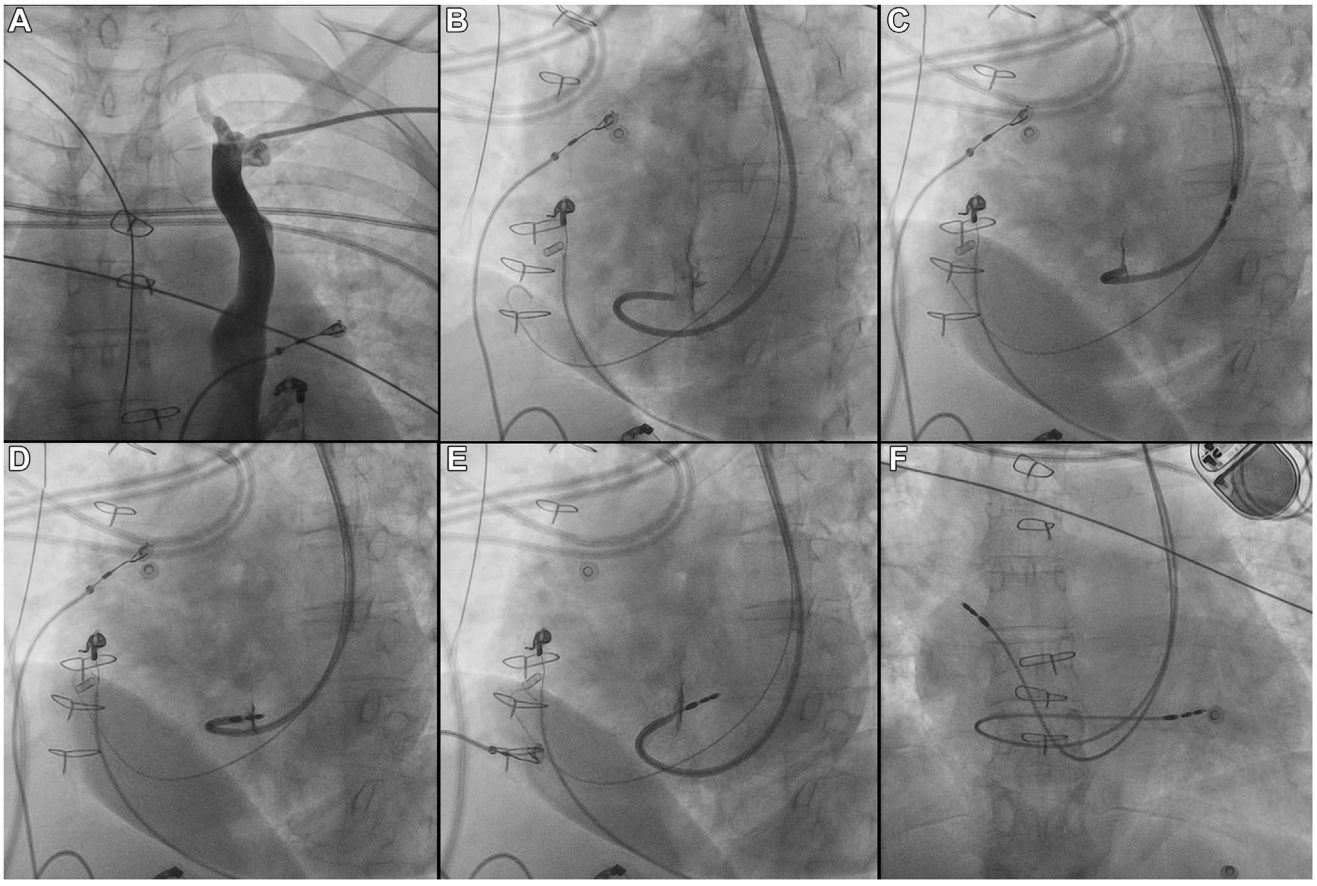

Figure 1 **A:** Contrast venogram of the persistent left superior vena cava in the anteroposterior view. **B:** A Selectra 3D 42 cm/55 mm sheath (Biotronik, Berlin, Germany) was introduced as a first choice, leaving a gap between the tip and the right aspect of the interventricular septum (40° left anterior oblique view). **C:** A shorter curve (40 mm) helped with the closer perpendicular alignment. **D:** The Solia S60 lead (Biotronik, Berlin, Germany) was screwed in the septum, initially without the support of the stylet, since any attempt to insert the lead with the stylet entirely caused dislocation of the sheath from the optimal position. **E:** To facilitate further lead implantation, the stylet was inserted fully inside the lead, and deep penetration toward the left side of the septum was achieved. **F:** The final position of the right atrial and ventricular pacing leads in an anteroposterior view.

Selectra 3D sheath 39 cm, 55 mm curve (Biotronik, Berlin, Germany). The sheath was first manipulated over the wire to the right atrium via the coronary sinus, then with a counterclockwise rotation directed to the right ventricle. Slight counterclockwise rotation brought the sheath straightforwardly against the interventricular septum. However, the distance between the tip of the sheath and the right ventricular septal wall remained too big for a successful lead deployment (Figure 1B). Any attempt at sheath pull-back led to losing the position suitable for LBBA lead implantation. Therefore, we changed the Selectra sheath to a shorter distal curve (39 cm length, 40 mm curve) to facilitate proper alignment to the interventricular septum (Figure 1C). Though the perpendicular alignment of the second sheath was almost perfect, introducing the Solia S60 lead (Biotronik, Berlin, Germany) with a stylet inside instantly caused sheath dislocation. To prevent this, we had to withdraw the stylet and screw the lead without the stylet first to approximately 5 mm depth into the septum (Figure 1D). To proceed deeper, we again had to introduce the stylet into the lead. We uneventfully proceeded with the standard stylet-driven lead implantation technique to the final position (Figure 1E) until we observed an impedance drop and fascicular signal on the electrophysiology recording system (Figure 2A). With the time interval from stimulus to the peak of R wave in lead V_6 of 70 ms, the V_6-V_1 interpeak interval of 58 ms (Figure 2B), and right axis deviation, left anterior fascicular pacing (LAFP) was confirmed. Finally, the right atrial lead was screwed to the high right atrium (Figure 1F).

Pacing parameters were excellent: R-wave sensing 8.7 mV, threshold 0.4 V at 0.4 ms, and unipolar pacing impedance 430 ohm. The lead was connected to a dual-chamber pacemaker device in the ventricular port, while the right atrial lead was inserted in the atrial port. Ultra-high-frequency electrocardiogram recording showed typically delayed right ventricle but preserved left ventricular activation during LAFP (Figure 3). The procedure time was 55 minutes, and the fluoroscopy time was 10.3 minutes with a dose of 6640 mGy·cm^2. Both the procedure and in-hospital stay were complication free. The patient was discharged the next day, and antiarrhythmic therapy was reinstituted, comprising 300 mg of propafenone bid with metoprolol 50 mg once a day.

At the 1-month follow-up, the pacing parameters remained stable (threshold 0.5 V at 0.4 ms, sensing 11 mV,

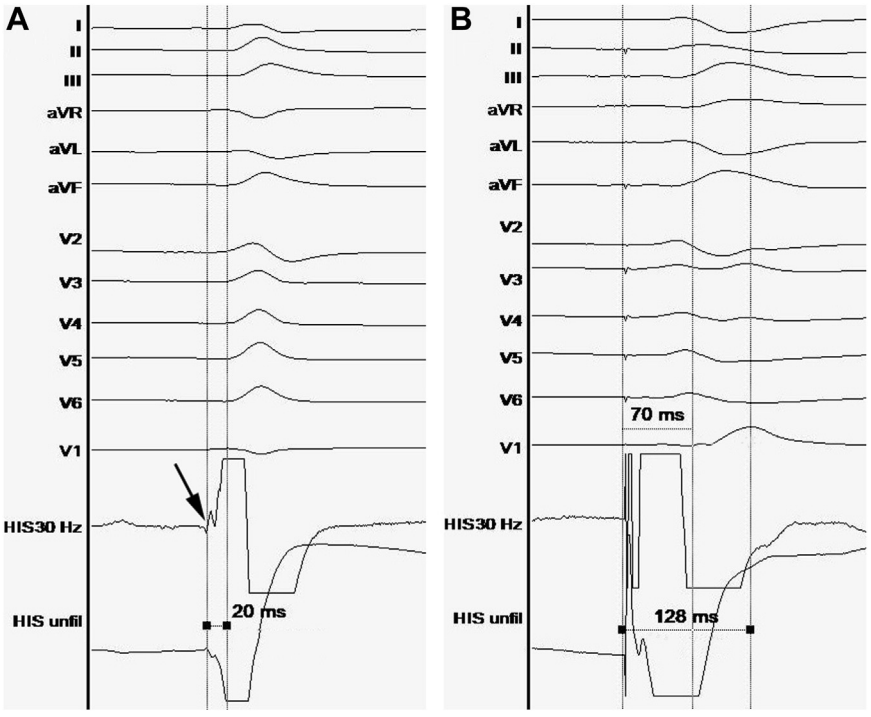

Figure 2 **A:** Fascicular signal preceding the onset of the QRS by 20 ms. **B:** Measurement of the left and right ventricular activation times showed 70 ms and 128 ms, respectively (from the onset of the QRS to the peak R wave in lead V_6 and R' in lead V_1, respectively).

impedance 450 ohm). Still, 1 week later, the patient was re-admitted to the hospital with recurrent AF despite medication with propafenone 300 mg bid. Radiofrequency modification of the AV node was performed, and the patient was dismissed the day after with 100% pacing (LAFP).

Discussion

Persistent left superior vena cava is a congenital anomaly in about 0.3%–0.5% of the general population and 12% of patients with other abnormalities.[5] The anomaly is usually symptom free and barely causes clinical problems under normal circumstances. However, it may become a significant problem in different anesthesiologic, oncologic, and cardiologic procedures. One of the typical scenarios is the necessity of a left-sided pacemaker or defibrillator lead implantation. While many case reports and small series have been published on conventional lead placement in the right atrium and right ventricle[6] through the persistent left superior vena cava with absent connections to the right brachiocephalic

Figure 3 Ultra-high-frequency electrocardiogram showed synchronous activation of the left ventricle and delayed activation of the right ventricle, which was compatible with the left anterior fascicular pacing.

vein, to the best knowledge of the authors, none of these so far reported successful implantation of the right ventricular pacing lead in the LBBA and only a single case report of a successful His bundle pacing was reported.[7]

With our technique of stylet-driven lead implantation in the LBBA in a patient with persistent left superior vena cava, we wanted to show that LBBA pacing could be performed using currently available guiding sheaths even from the coronary sinus in this challenging anatomy if persistent left superior vena cava presents with no anatomical connection with the right brachiocephalic vein. Moreover, biventricular pacing can be problematic in patients with persistent left superior vena cava, and this case report shows that LBBA pacing could be a viable alternative for this anatomy.

LBBA pacing techniques are available with either lumenless or stylet-driven lead implantation.[8] Some manufacturers offer 1 type of guiding sheath. In contrast, some provide a whole family of introducer sheaths with different lengths and distal curves, giving the operators more options for different patient anatomies. None of the sheaths, however, is designed explicitly for a right-sided approach. However, right-sided implantation was feasible if the operator modified the delivery catheter with the 90-degree curve at the right subclavian vein–superior vena cava junction.[9,10] Therefore, we decided to continue with the left-sided implantation to prove the feasibility of such an approach. With this case we learned that using our approach through the coronary sinus, the standard currently available Selectra 3D sheath looks relatively stable and supportive for appropriate lead placement provided that (1) a short curve (ie, 40 mm) is used and (2) the lead is engaged into the interventricular septum first without a stylet, and only after the lead is screwed several millimeters inside the septum is further progress toward the LBBA ascertained again with the conventional stylet fully inserted. Nonetheless, further development of dedicated tools is needed, as this might improve and facilitate wider clinical adoption of LBBA pacing in various pacing indications and challenging anatomical conditions.[10] We cannot exclude that a lumenless lead would perform similarly in such anatomical conditions; however, this system is commercially provided with only 1 type of guiding sheath, which may be considered a significant limitation.

The other option for our patient could be to find an anatomical connection between the persistent left superior vena cava and the right brachiocephalic vein. Such bridging veins may be found in approximately 30% of patients, enabling fairly standard "right-sided" lead implantation even in the LBBA, provided these veins could be selectively cannulated.[11] However, in our case such a bridging vein was absent.

Apart from anatomical abnormalities, our patient's clinical scenario could have been resolved by a redo ablation procedure, which, if successful, would prevent the necessity for AAD treatment with adverse bradycardia. Since our patient, who presented with dilated right and left atria, has already undergone a complex left atrial ablation procedure consisting of the pulmonary vein isolation and box lesion using PFA, we considered the probability of successful redo catheter ablation low.[12] In our experience, after more than 1000 PFA cases, the chances of finding the pulmonary vein reconnected during redo procedures are meager, and our patient demanded a definite solution. As a result, securing the patients with permanent pacemaker was opted for. The inefficacy of AADs in our case still left us the space for subsequent catheter modification of the AV node. In the sense of pace-and-ablate strategy, LBBA pacing seems to be the optimal approach for our patient, who has already experienced episodes of heart failure on account of recurrent arrhythmias. Although there is no clear evidence that arrhythmia-induced cardiomyopathy is correlated with pacing-induced cardiomyopathy, possible common pathophysiological pathways leading to left ventricular function deterioration might suggest the case.[13]

Conclusion

LBBA pacing can be performed in patients with persistent left superior vena cava and no bridging veins. Further improvement of dedicated tools might facilitate wider clinical adoption of conduction system pacing in challenging anatomical conditions. Additional studies or prospective registries are needed to evaluate the feasibility, efficacy, and safety of LBBA pacing lead implanted via the coronary sinus.

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