Cardiac resynchronization therapy through left bundle branch pacing in a patient with persistent left superior vena cava

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Introduction

Cardiac resynchronization therapy (CRT) is a mainstay in the treatment of heart failure with severe left ventricular dysfunction, especially in presence of left bundle branch block (LBBB). Biventricular pacing demonstrated notable results in improving prognosis and quality of life in these patients,[1,2] but its implantation is strictly dependent on a favorable cardiac venous anatomy to allow the delivery of a left ventricular lead into the coronary sinus (CS). Persistent left superior vena cava (LSVC) is the most common congenital thoracic venous anomaly, with prevalence from 0.2% to 3% in the general healthy population.[3] With several variants described, this anomaly is mostly an asymptomatic finding with minimal hemodynamic effect. Its presence, however, may lead to CS enlargement, increased vessel tortuosity, and, more rarely, even CS ostium atresia, affecting cardiovascular interventions such as CRT implantation.

KEY TEACHING POINTS

- Persistent left superior vena cava is the most common congenital thoracic venous anomaly, with a prevalence of 0.2%–3% in the general population.
- Diagnosis is usually made accidentally and patients are generally asymptomatic. Coronary sinus dilation is a typical clue and can be detected during transthoracic echocardiography.
- Anomalies in the thoracic venous return may complicate transvenous lead implantation. Determining the presence of a bridging vein (30% of cases) or the absence of the right superior vena cava (10% of cases) will aid operatory planning.
- Implantation of left ventricular leads can be challenging and even unfeasible in case of extreme coronary sinus dilation. Left bundle branch pacing represents a useful tool to achieve cardiac resynchronization therapy in this case.

Case report

A 69-year-old male patient was referred to our center for a CRT-defibrillator (CRT-D) implantation in primary prevention. He was known for diabetes, dyslipidemia, hypothyroidism, and class III renal impairment. He was hospitalized for acute myocardial infarction complicated by heart failure with left ventricular ejection fraction (LVEF) of 21% at echocardiography. The basal electrocardiogram showed LBBB with a QRS length of 156 ms. Coronary angiography demonstrated triple vessel disease, for which he underwent surgical coronary revascularization. Postoperative period was uneventful, except for an episode of atrial fibrillation, for which anticoagulation was started. Pharmacological therapy for heart failure was initiated during the hospitalization, with introduction of angiotensin receptor/neprilysin inhibitor, beta-blocker, and sodium-glucose cotransporter 2 inhibitor, which were titrated to the maximum tolerated dose during the clinical follow-up. Despite optimal medical therapy and revascularization, at 6 months postsurgery, the patient was in NYHA class II, had identical LBBB, and an echocardiography showed just a marginal improvement in LVEF, to 30%. CRT-D implantation was therefore indicated.

KEYWORDS Conduction system pacing; Left bundle branch pacing; Persistent left superior vena cava; Cardiac resynchronization therapy; Cardiac implantable electronic device; Left ventricular dysfunction; Congenital thoracic venous anomaly; Heart failure
(Heart Rhythm Case Reports 2024;10:402–405)

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CRT-D implantation

Figure 1 shows the different steps during implantation of the CRT-D. Owing to the persistence of an LSVC noted in the surgical report, a preprocedure left superior limb venogram was performed, showing an exclusive drainage into the CS (Figure 1a). Thus, CRT-D was implanted from the right subclavian vein. Venogram of the right superior limb showed

https://doi.org/10.1016/j.hrcr.2024.03.006

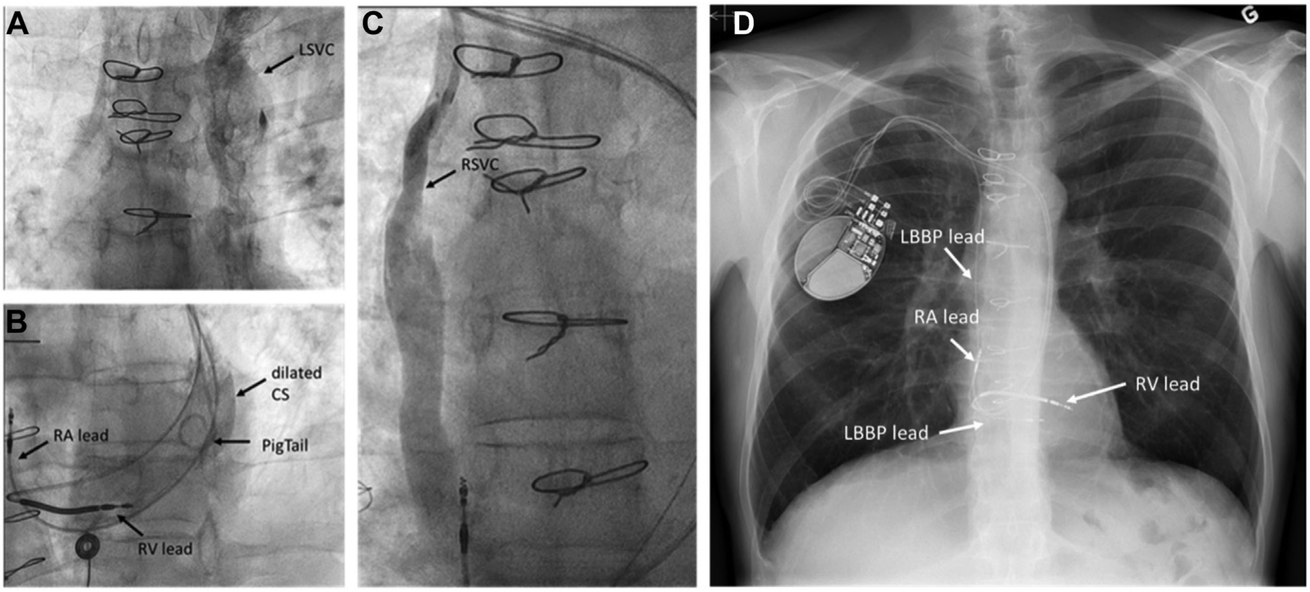

Figure 1 Periprocedural fluoroscopy during different moments of the implant. **a:** Left superior limb venogram showing persistent left superior vena cava (LSVC). **b:** Coronary sinus (CS) venogram by means of a pigtail catheter, showing extreme dilation, not allowing tributary vein visualization. **c:** Right superior vena cava (RSVC) cannulation with a 5.5F vein subselector. **d:** Final result, showing right atrial (RA), right ventricular (RV), and left bundle branch pacing (LBBP) leads.

a large connecting branch between the right superior vena cava (RSVC) and the LSVC. This branch was responsible of most of the right superior district drainage, while the actual RSVC was just a small vessel directly connected to the right atrium. As a result, the CS received venous return from almost all the craniobrachial district and, therefore, presented extreme dilation.

After multiple initial attempts of cannulating the atretic RSVC, difficult to access owing to its significant angulation and size, right atrial and ventricular leads were implanted through the bigger bridging vein, connected to the right atrium by the CS. Stylets were used to direct each lead to its anatomical location, with a single curve for the right atrial lead and a double curve for the right ventricular one. Optimal lead parameters for both right leads were obtained.

The CS dilation represented a main challenge for left ventricular lead implantation, as it precluded any acceptable venogram for identification of tributary veins, even after multiple efforts by means of either Swan-Ganz catheter and 6F Pigtail catheter (Figure 1b). A new effort to access the right atrium from the RSVC was made, to allow contrast injection closer to the CS ostium so as to provide a better visualization of eventual target branches. Cannulation of the RSVC was finally achieved with a 5.5F hockey stick vein subselector (Worley Hockey Stick vein selector; Merit Medical, South Jordan, UT), as shown in Figure 1c. A 0.035 J wire was advanced down to the right ventricle and, after removal of the subselector, the CS catheter was used to obtain another venogram, which, unfortunately, failed to show any possible target vessel.

As left ventricular lead delivery was not feasible, resynchronization by means of left bundle branch pacing (LBBP) was then attempted from the RSVC. The subselector was then removed to advance the sheath over the wire (Preshaped SelectSecure™ C315; Medtronic, Minneapolis, MN), allowing to implant the lead (SelectSecure 3830; Medtronic) in the left bundle branch (LBB) area, until capture of the LBB was confirmed showing a left posterior fascicular pacing pattern (r′ in V_1 and left axis), with a left ventricular activation time of 78 ms and a V_6–V_1 activation time of 60 ms (Figure 1d). Final LBBP lead presented good final parameters, with a sensing of 5 mV, an impedance of 389 ohms, and a threshold of 0.3 V @ 0.4 ms. The LBBP lead was connected to the IS-1 connector of the generator (Momentum™ CRTD G124; Boston Scientific, Marlborough, MA), that allowed programming of ventricular pacing in unipolar configuration. Owing to the long procedural time in a patient with a PADIT score[4] of 5, the TYRX™ Absorbable Antibacterial Envelope (Medtronic, Minneapolis, MN) was also used. Schematic representation of the patient's anatomy and final lead configuration is shown in Figure 2. After achievement of LBB capture, a shortening of the QRS from 179 ms to 131 ms was observed (Figure 3a and 3b). Even if direct access to the right atrium was obtained, previously implanted right leads were not repositioned, as it would have lengthened even more the procedural time (2 hours and 29 minutes). Moreover, to accommodate the 3 leads, eventual venoplasty of the RSVC could have been necessary, raising the risk of possible complications, such as infection and acute kidney injury owing to multiple dye injections. No acute complication occurred.

Follow-up

Device follow-up was conducted in person at 1 month and then every 3 months by means of remote monitoring, while clinical follow-up was performed at the referral center.

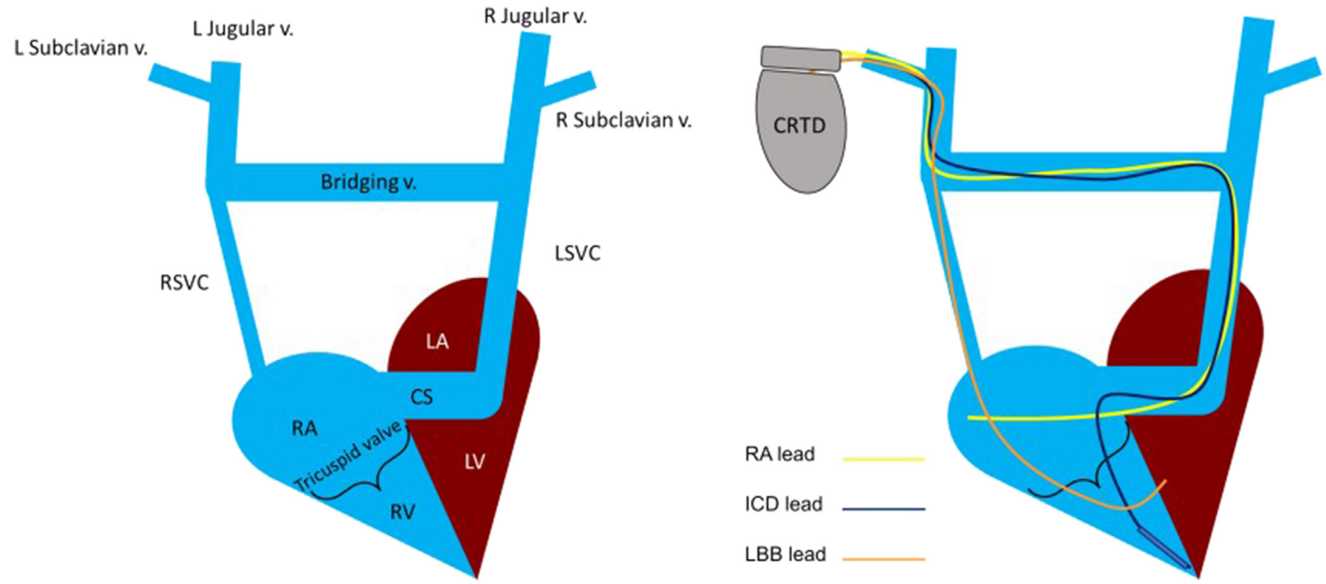

Figure 2 Schematic representation of patient venous anatomy and lead implantation. Left panel: patient anatomy. Right panel: final position of the 3 leads. CRT-D = cardiac resynchronization therapy-defibrillator; CS = coronary sinus; ICD lead = defibrillator lead; L = left; LA = left atrium; LV = left ventricle; LSVC = left superior vena cava; R = right; RA = right atrium; RV = right ventricle; RSVC = right superior vena cava; v. = vein.

Four weeks after the implant, venous thrombosis of the right superior limb occurred; since the patient was already on anticoagulation, successful transcatheter venoplasty was performed. No further complication occurred. At 13 months after the implant, an echocardiography performed in our center showed an improvement in LVEF up to 42% and the patient was in NYHA functional class I.

Discussion

Persistent LSVC is the most common congenital thoracic venous anomaly, with a prevalence of 0.2%–3% in the general population and up to 10% in patients with congenital heart disease.[3] During fetal life, the right superior cardinal vein forms the RSVC, while the caudal portion of the left superior cardinal vein forms the CS and then regresses into the ligament of Marshall. The lack of regression leads to persistence of the LSVC, draining in the right atrium through the CS. A dilated CS, resulting from increased venous return to this structure, can be detected through a regular transthoracic echocardiography using parasternal long-axis or apical 3-chamber views and should raise suspicion of persistent LSVC. Injection of agitated saline (bubble test) from the left arm can help confirm the diagnosis. In 90% of patients the 2 venae cavae coexist, and in 30% of cases a bridging vein connects the 2 vessels. In 10% of cases, RSVC is absent, so LSVC is responsible for the venous return for the entire upper half of the body; 10%–20% of those patients may have the LSVC draining into the left atrium through an unroofed CS or the left superior pulmonary vein, causing significant right-to-left shunt with possible neonatal cyanosis.[5]

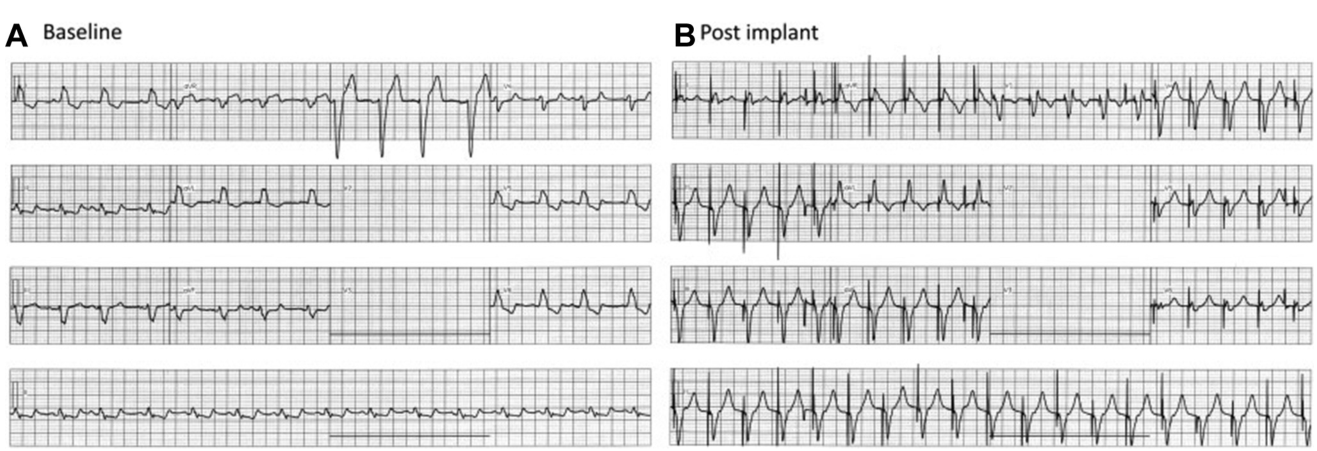

Figure 3 Electrocardiogram (ECG) morphology at baseline and postimplant. **a:** ECG at baseline. **b:** Postimplant ECG during pacing, showing a terminal r′ morphology in V_1 owing to left bundle branch capture. V_2 and V_3 leads are missing owing to noise issues.

When not associated with other congenital heart diseases, persistent LSVC is generally an accidental finding and the majority of patients are asymptomatic; however, the complex thoracic anatomy can impact transvenous lead implant owing to lack of conventional access to the right atrium and CS dilation. Provided that RSVC is present, a right-sided approach can facilitate right lead implantation. When the RSVC is absent, the CS is the only access to the right atrium; however, despite being challenging, the implant of right leads is still possible, as shown here in our case.

LSVC and a CS altered anatomy can represent other relevant obstacles to biventricular lead positioning. Conduction system pacing (CSP) or physiologic pacing, by either LBBP or His bundle pacing, can achieve synchronous myocardial activation without needing a favorable CS anatomy. His bundle pacing has already been reported as a possible solution in these patients,[6] but it has to be noted that His bundle leads are at higher risk for revision, according to literature.[7] Several observational studies on LBBP showed promising results in both heart failure prevention[8] and treatment,[9,10] with no raised concern on lead stability at follow-up.[11]

Benefit of physiologic pacing over biventricular pacing in CRT settings has been hypothesized, but large randomized trials are still lacking. In a retrospective observational study on 477 patients with class I or II CRT indication, Vijayaraman and colleagues[12] documented a significant reduction in the primary composite endpoint of all-cause mortality or heart failure hospitalization in physiologic CRT (either LBBP or His bundle pacing) compared to biventricular pacing during a mean follow-up of 27 ± 12 months (28.3% vs 38.4%; $P < .013$).

A meta-analysis on 262 patients from 4 nonrandomized studies showed shorter QRS length (mean difference of 27.91 ms), improved NYHA functional class, and better echocardiographic response (mean difference of 6.77% in LVEF) at 6–12 months in patients receiving CRT by means of LBBP compared to conventional CRT.[13]

A preliminary randomized trial[10] comparing LBBP to conventional CRT in 40 patients with nonischemic cardiomyopathy and LBBB showed greater improvements in LVEF (mean difference of 5.6%), left ventricular end-diastolic diameter (mean difference of -24.97 mL), and N-terminal pro-B-type natriuretic peptide (mean difference of -1071.80 pg/mL) at 6 months in the LBBP group. Similar changes were noted in NYHA functional class, 6-minute walk distance, QRS duration, and rates of CRT response (90% vs 89.5% for LBBP and biventricular pacing, respectively) in the 2 groups. In the 3 cited studies, a greater response in patients with LBBB morphology was noted.

Thus, CSP seems to have at least comparable performance in selected populations requiring CRT, with possible improved echocardiographic parameters if compared to biventricular pacing. For these reasons, the 2023 HRS/APHRS/LAHRS Guideline on Cardiac Physiologic Pacing[14] consider CSP as a second-line option if biventricular pacing fails to achieve CRT in patients with LVEF ≤35% and LBBB. However, randomized trials on larger populations and longer follow-up are needed to confirm this finding and eventually determine if LBBP may be offered at first instance for CRT. This is particularly important when complex CS anatomy is expected, to avoid long procedural time and possible complications. Moreover, right-sided implant of LBBP is feasible,[15] allowing its application in patients with persistence of the LSVC.

Conclusion

In this case, altered CS anatomy owing to persistence of LSVC presented a major challenge to left ventricular lead delivery. CRT by means of LBBP can be a valuable tool in heart failure treatment, especially in complex anatomies, as it can be performed from the right side, and it does not depend on CS morphology.

Funding Sources: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Disclosures: None.

References

1. Heidenreich PA, Bozkurt B, Aguilar D, et al. 2022 AHA/ACC/HFSA guideline for the management of heart failure: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation 2022;145:E895–E1032.
2. McDonagh TA, Metra M, Adamo M, et al. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. Eur Heart J 2021;42:3599–3726. https://doi.org/10.1093/eurheartj/ehab368.
3. Azizova A, Onder O, Arslan S, Ardali S, Hazirolan T. Persistent left superior vena cava: clinical importance and differential diagnoses. Insights Imaging 2020; 11:110.
4. Birnie DH, Wang J, Alings M, et al. Risk factors for infections involving cardiac implanted electronic devices. J Am Coll Cardiol 2019;74:2845–2854.
5. Kochav J; Persistent left superior vena cava. In: DeFaria Yeh D, Bhatt A, eds. Adult Congenital Heart Disease in Clinical Practice. Springer; 2018. p. 143–150.
6. Ng KS, Foo D, Lim J. His-bundle pacing in a patient with persistent left superior vena cava. Pacing Clin Electrophysiol 2005;28:588–590.
7. Vijayaraman P, Naperkowski A, Subzposh FA, et al. Permanent His-bundle pacing: long-term lead performance and clinical outcomes. Heart Rhythm 2018; 15:696–702.
8. Sharma PS, Patel NR, Ravi V, et al. Clinical outcomes of left bundle branch area pacing compared to right ventricular pacing: results from the Geisinger-Rush Conduction System Pacing Registry. Heart Rhythm 2022;19:3–11.
9. Zhang W, Huang J, Qi Y, et al. Cardiac resynchronization therapy by left bundle branch area pacing in patients with heart failure and left bundle branch block. Heart Rhythm 2019;16:1783–1790.
10. Wang Y, Zhu H, Hou X, et al. Randomized trial of left bundle branch vs biventricular pacing for cardiac resynchronization therapy. J Am Coll Cardiol 2022; 80:1205–1216.
11. Ezzeddine FM, Pistiolis SM, Pujol-Lopez M, et al. Outcomes of conduction system pacing for cardiac resynchronization therapy in patients with heart failure: a multicenter experience. Heart Rhythm 2023;20:863–871.
12. Vijayaraman P, Zalavadia D, Haseeb A, et al. Clinical outcomes of conduction system pacing compared to biventricular pacing in patients requiring cardiac resynchronization therapy. Heart Rhythm 2022;19:1263–1271.
13. Tan JL, Lee JZ, Terrigno V, et al. Outcomes of left bundle branch area pacing for cardiac resynchronization therapy: an updated systematic review and meta-analysis. CJC Open 2021;3:1282–1293.
14. Chung MK, Patton KK, Lau CP, et al. 2023 HRS/APHRS/LAHRS guideline on cardiac physiologic pacing for the avoidance and mitigation of heart failure. Heart Rhythm 2023;20:e17–e91.
15. Ponnusamy SS, Ganesan V, Ramalingam V, Kumar M, Rupert LJ, Vijayaraman P. Right sided approach for left bundle branch pacing using lumen-less lead: technical considerations and follow-up outcome. J Cardiovasc Electrophysiol 2023;34:2613–2616.