The combination of coronary sinus ostial atresia/abnormalities and a small persistent left superior vena cava—Opportunity for left ventricular lead implantation and unrecognized source of thromboembolic stroke

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BACKGROUND Coronary sinus (CS) ostial atresia/abnormalities prevent access to the CS from the right atrium (RA) for left ventricular (LV) lead implantation. Some patients with CS ostial abnormalities also have a small persistent left superior vena cava (sPLSVC).

OBJECTIVE The purpose of this study was to describe CS ostial abnormalities and sPLSVC as an opportunity for LV lead implantation and unrecognized source of stroke.

METHODS Twenty patients with CS ostial abnormalities and sPLSVC were identified. Clinical information, imaging methods, LV lead implantation techniques, and complications were summarized.

RESULTS Forty percent had at least 1 previously unsuccessful LV lead placement. In 70%, sPLSVC was identified by catheter manipulation and contrast injection in the left brachiocephalic vein, and in 30% by levophase CS venography. In 30%, sPLSVC was associated with drainage from the CS into the left atrium (LA). When associated with CS ostial abnormalities, the sPLSVC diameter averaged 5.6 ± 3 mm. sPLSVC was used for successful LV lead implantation in 90% of cases. In 80%, the LV lead was implanted down sPLSVC, and in 20%, sPLSVC was used to access the CS from the RA. Presumably because of unrecognized drainage from the CS to the LA, 1 patient had a stroke during implantation via sPLSVC.

CONCLUSION When CS ostial abnormalities prevent access to the CS from the RA, sPLSVC can be used to successfully implant LV leads. In some, the CS partially drains into the LA and stroke can occur spontaneously or during lead intervention. It is important to distinguish sPLSVC associated with CS ostial abnormalities from isolated PLSVC.

KEYWORDS Small persistent left superior vena cava; Left ventricular lead; Unroofed coronary sinus; Coronary sinus ostial atresia; Thromboembolic stroke

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Introduction

Cardiac resynchronization therapy (CRT) is the criterion standard treatment of patients with heart failure and reduced ejection fraction.[1] In the MADIT-CRT, failure to implant the left ventricular (LV) lead resulted in 7.5% of patients unable to receive CRT.[2] Despite improvements in lead implantation techniques and new tools, many patients still cannot benefit from CRT owing to technical difficulties during LV lead implantation, especially those with coronary sinus (CS) ostial atresia/abnormalities (CSOAs) that prevent access to the CS from the right atrium (RA). In some patients, a small persistent left superior vena cava (sPLSVC) offers an alternative pathway to the CS from the left brachiocephalic vein

It is important to distinguish isolated PLSVC from CSOA + sPLSVC. In patients with PLSVC and normal CS opening, venous blood flows from the brachiocephalic vein through the CS into the RA (Figures 1A and 1B). In CSOA + sPLSVC, blood from the CS enters the left atrium (LA) if the CS is partially unroofed (Figure 1D) or terminates if the CS is completely occluded (Figure 1C). When there is CSOA, sPLSVC can facilitate LV lead implantation: either directly down sPLSVC from the left brachiocephalic vein or as a conduit to gain access to the CS from the RA. This report aims to call attention to the existence of CSOA + sPLSVC because of its potential to facilitate LV lead placement and its risk of stroke when associated with LA drainage. Once implanting physicians become aware that patients with CSOA may have sPLSVC, its prevalence will become apparent and its thromboembolic risk when associated with LA drainage during therapeutic catheter placement or lead insertion/extraction can be better characterized (Figure 2).

Methods

Study population

Between June 2014 and September 2019, patients from 11 institutions where CSOA + sPLSVC were identified were included in this study. Depending on the requirements of each institution, institutional review board approvals were obtained for the analyses of de-identified and secure patient

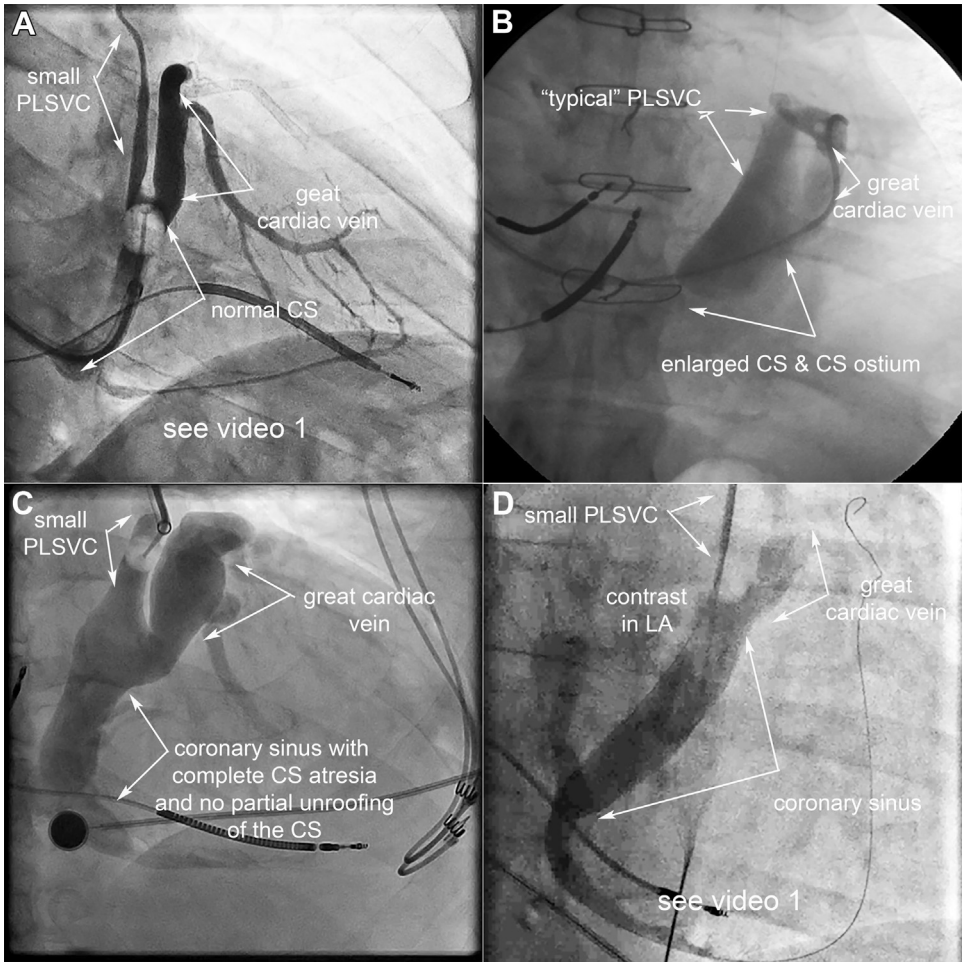


Figure 1 Clinical variations of PLSVC (Online Supplemental Video 1). **A:** sPLSVC visualized at the time of occlusive CS venography connecting to the left brachiocephalic. The size and ostium of the CS are normal. **B:** Typical PLSVC entered from the RA. A catheter is in the great cardiac vein superior to the entry of PLSVC. **C:** Occlusive venogram in a patient with CSOA + sPLSVC with no flow from the CS to the RA or LA. **D:** LAO occlusive venogram in a patient with CSOA + sPLSVC where contrast enters the LA but not the RA: partial unroofing of the CS. CS = coronary sinus; CSOA = coronary sinus ostial atresia/abnormalities; LA = left atrium; LAO = left anterior oblique; PLSVC = persistent left superior vena cava; RA = right atrium; sPLVC = small persistent left superior vena cava.

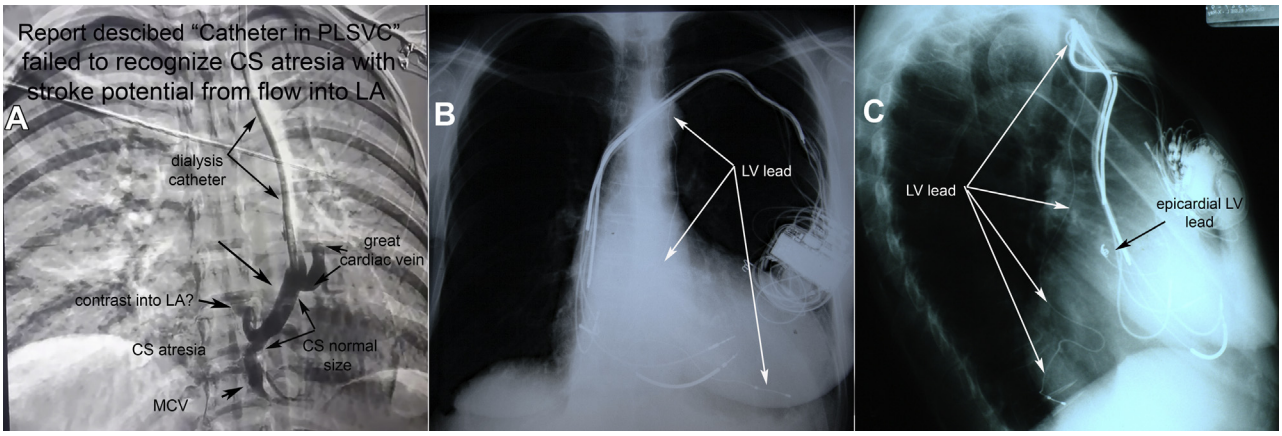


Figure 2 A patient with CSOA + sPLSVC. **A:** The reading of this chest radiograph described "a dialysis catheter in PLSVC" implying that blood from the catheter has free access to the RA. Because the combination of CSOA + sPLSVC is not well recognized, the presence of CSOA with the potential for stroke was not mentioned. Note the caliber of the CS below the entry of sPLSVC is normal and approximately equal to the diameter of the great cardiac vein. There is partial unroofing of the CS with drainage into the LA creating potential for thromboembolic events. **B:** Posterior-anterior chest radiograph of a patient with CSOA + sPLSVC who had the LV lead placed via sPLSVC on her third transvenous attempt. The epicardial lead was placed after 2 previous failed attempts to place the LV lead via the CS but developed exit block. **C:** Lateral chest radiograph of the patient in panel B. CS = coronary sinus; CSOA = coronary sinus ostial atresia/abnormalities; LA = left atrium; LV = left ventricular; PLSVC = persistent left superior vena cava; MCV = middle cardiac vein; RA = right atrium; sPLVC = small persistent left superior vena cava.

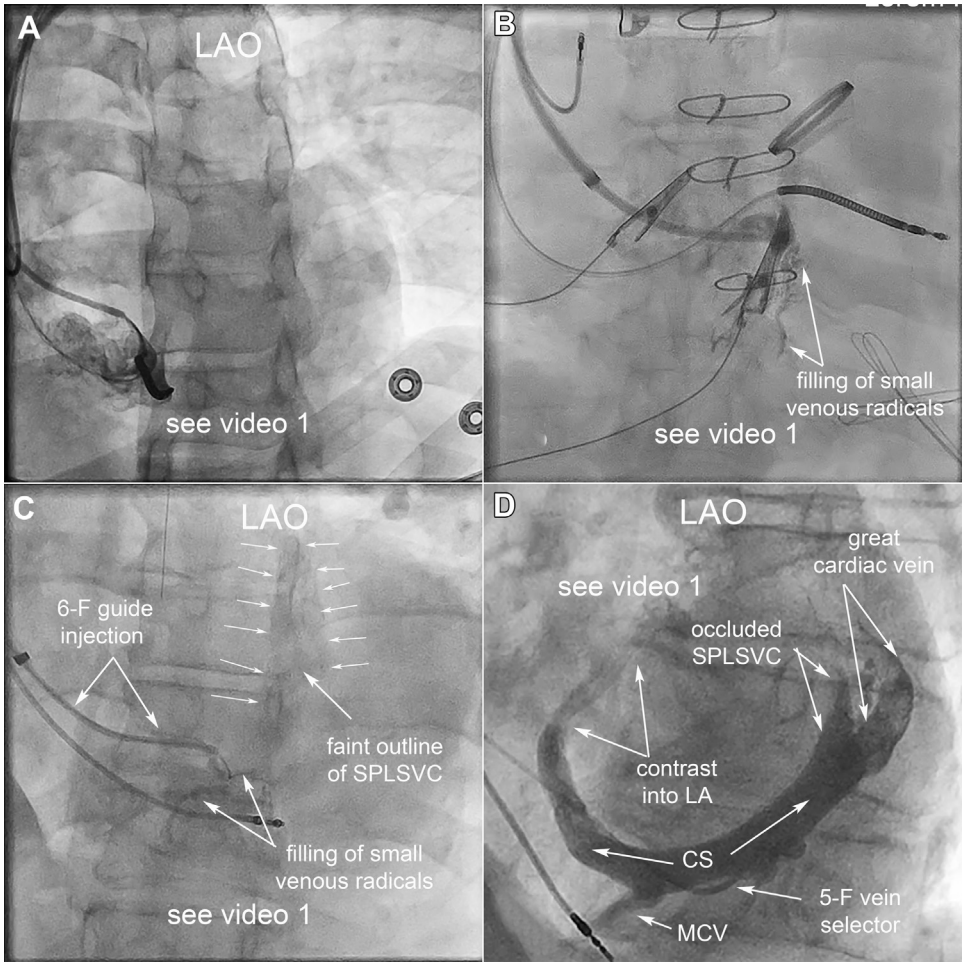


Figure 3 Contrast injection at the CS ostium in patients with CSOA + sPLSVC. **A:** Despite counterclockwise torque and contrast injection in multiple locations, the CS was not visualized. **B:** With contrast injection, only small venous radicals were identified. **C:** Sufficient contrast injected into venous radicals at the CS ostium faintly revealed sPLSVC. **D:** 5-F catheter advanced deep into a venous radical at the CS ostium. Sufficient contrast is injected to fill the CS. Flow is seen into the LA. sPLSVC is occluded at the brachiocephalic vein from previously implanted leads. Abbreviations as in figures 1 and 2.

data. The research reported in this article adhered to Helsinki Declaration guidelines.

Data collection and statistical analysis

From these cases, clinical information, radiographic images, and imaging techniques used to identify CSOA + sPLSVC were extracted. How sPLSVC facilitated LV lead implantation and complications during the procedure was summarized. Continuous variables are expressed as mean ± SD. Categorical variables are expressed as the number of patients with percentage.

Results

Clinical characteristics of patients with CSOA + sPLSVC

A total of 20 patients undergoing attempted LV implantation where access to the CS from the RA was prevented by CSOA (Figure 3; Online Supplemental Video 1) and PLSVC (Figures 4 and 5; Videos 2 and 3) were included. The clinical and imaging information of patients identified with CSOA + sPLSVC is summarized in Table 1. The mean age of patients was 58.5 ± 13 years, and 20% (n = 4) were female. Among them, 40% (n = 8) had at least 1 previously unsuccessful attempt at LV lead placement and 20% (n = 4) had dysfunctional epicardial LV leads. One had an attempt at conduction system pacing.

Identification of sPLSVC in patients with CSOA

sPLSVC was identified via vein selector manipulation and direct contrast injection into the left brachiocephalic vein near the sternoclavicular junction (Figure 4; Online Supplemental Video 2) in 70% (n = 14) or via levophase CS venography (Figure 5; Online Supplemental Video 3) in 30% (n = 6). In 2 patients with prior implant failure, sPLSVC was suspected yet dedicated cardiac computed tomography (CT) did not identify the structure. In 1 patient, CT angiography of the chest to rule out aortic dissection identified sPLSVC. Once the combination of CSOA + sPLSVC was identified, further imaging revealed that 30% (n = 6) were associated with an unroofed CS and venous drainage into the LA. The mean diameter of sPLSVC in the setting of CSOA measured 5.6 ± 3 mm.

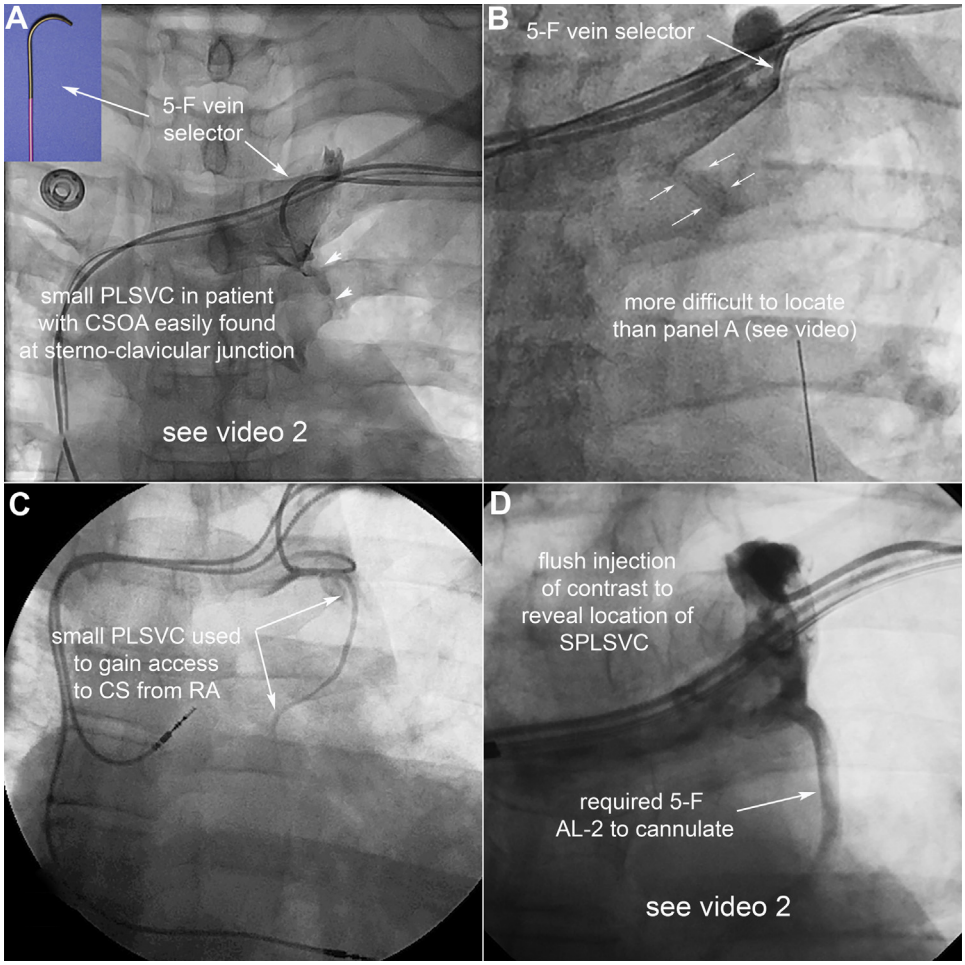


Figure 4 Direct contrast injection at the sternoclavicular junction to identify CSOA + sPLSVC. **A:** sPLSVC readily identified and, with a 5-F vein selector, attached to a contrast injection system. **B:** sPLSVC was more difficult to locate, but the wire was easily advanced. **C:** A small-caliber sPLSVC, which was used to gain CS access from the RA via snare technique. **D:** A case of sPLSVC difficult to cannulate. Abbreviations as in figures 1 and 2.

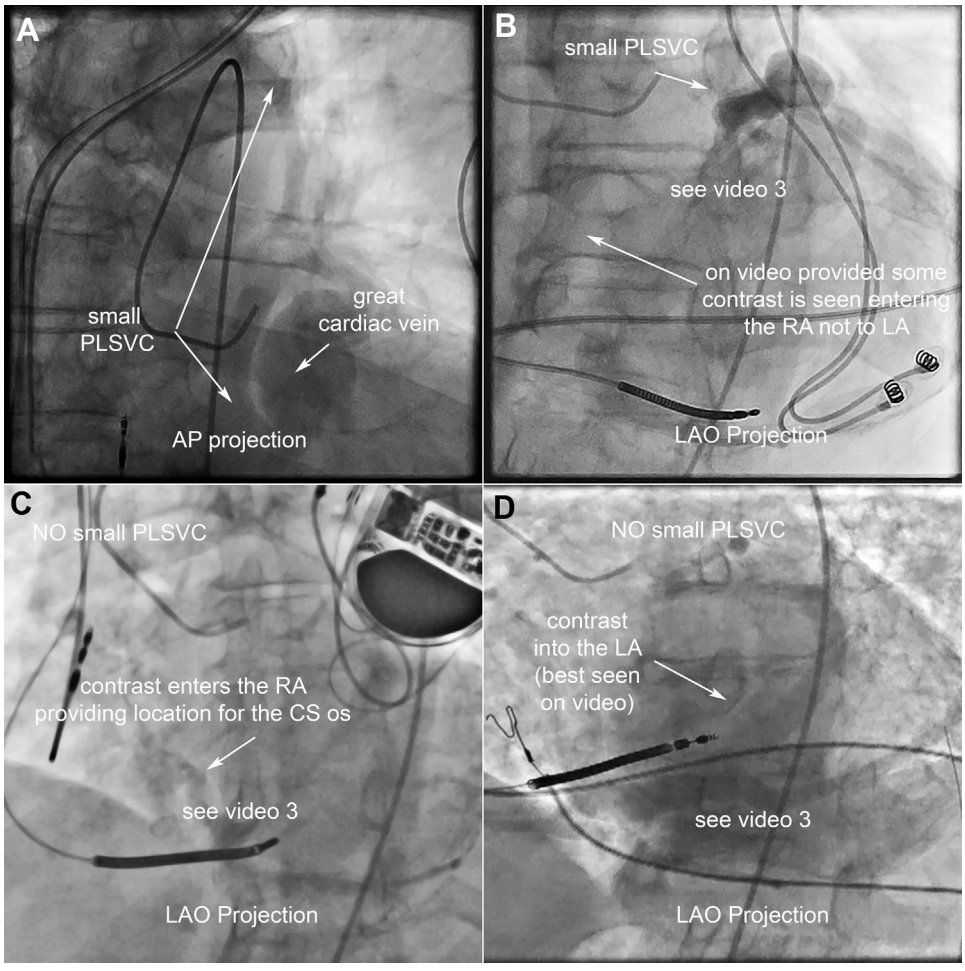


Figure 5 Levophase CS venography in patients where the CS was not previously identified. **A:** Posterior-anterior projection demonstrated sPLSVC draining into the left brachiocephalic vein. **B:** The same patient in the LAO projection to look for contrast entering the LA. **C:** Levophase venogram provided the location of the previously unlocated CS ostium. There was no sPLSVC. **D:** A patient with an unroofed CS without sPLSVC. There was no access to the CS from either the RA or the left brachiocephalic vein. Abbreviations as in figures 1 and 2.

LV lead implantation in patients with CSOA + sPLSVC

Implantation was successful in 90% of patients (n = 18), directly down sPLSVC (Figure 6; Online Supplemental Video 4) in 80% (n = 16). In 1 patient, subclavian fibroplasty was necessary to locate sPLSVC because of brachiocephalic vein occlusion from previously implanted leads. In 2 patients, sPLSVC was used to facilitate LV lead placement via the CS ostium (Figure 7; Online Supplemental Video 5). In both cases, a wire was advanced down sPLSVC, out of the CS, and into the RA/superior vena cava (SVC) where it was snared. In 1, venoplasty of the CS ostium was necessary to advance the sheath into the CS from the RA (Figure 7). One patient with CSOA + sPLSVC failed an attempt at conduction system pacing and suffered from a stroke during attempted implantation down sPLSVC. Despite the patient's history of atrial fibrillation and being off anticoagulants during the procedure, the stroke was attributed to partial drainage of the CS to the LA.

Discussion

This is the first report to describe a group of patients with the combination of CSOA + sPLSVC identified at the time of LV lead implantation. Previous reports described this anomaly as a "small PLSVC" without recognizing the clinical significance of its association with CSOA. Recognition of CSOA + sPLSVC has implications for both LV lead implantation and identifying a source of thromboembolic events spontaneously during lead implantation and extraction or therapeutic catheter placement (Figure 2). This study demonstrated that (1) CSOA + sPLSVC is an important anatomical variant of CS anatomy that can be used to facilitate LV lead implantation; (2) CSOA + sPLSVC must be distinguished from PLSVC with the normal to enlarged CS because there is potential for drainage into the LA and thromboembolic risk; (3) in patients with CSOA, levophase CS venography in the left anterior oblique (LAO) projection is the most reliable way to visualize sPLSVC and determine whether there is drainage into the LA; (4) cardiac CT may not reliably identify sPLSVC; and (5) when implanting LV leads down CSOA +

Table 1 Clinical and imaging characteristics in patients with CSOA + sPLSVC

Age (y)	Gender	How sPLSVC was located	Unroofed CS	Number of previous implants	Epicardial leads	sPLSVC diameter (mm)	Implant success	Implantation and complications
45	Male	Direct interrogation of the L brachiocephalic	No	1	No	3.0	Yes	Snare used to implant into the CS via the RA
37	Male	Direct interrogation of the L brachiocephalic	No	0	No	1.5	Yes	sPLSVC used to implant into the CS via the RA
63	Male	Direct interrogation of the L brachiocephalic	No	2	No	4.0	Yes	Implant down sPLSVC
67	Female	Direct interrogation of the L brachiocephalic	No	2	Yes	3.8	Yes	Implant down sPLSVC
47	Male	Direct interrogation of the L brachiocephalic	No	1	No	8.0	Yes	Implant down sPLSVC
58	Male	Direct interrogation of the L brachiocephalic	No	0	No	5.0	Yes	Implant down sPLSVC
64	Male	Levophase venography	No	≥1	Yes	4.5	Yes	Implant down sPLSVC
73	Male	Levophase venography	Yes	≥1	No	N/A	No	sPLSVC occluded, unable to implant
47	Male	Levophase venography	Yes	≥1	No	3.0	Yes	Implant down sPLSVC
55	Male	Levophase venography	Yes	2 (both failed)	No	2.5	Yes	Implant down sPLSVC
76	Male	90° catheter at the sternoclavicular junction	No	1 (failed)	No	10.0	Yes	Implant down sPLSVC
71	Female	Direct interrogation of the L brachiocephalic	Yes	2	Yes	3.0	Yes	Implant down sPLSVC
63	Male	Direct interrogation of the L brachiocephalic	No	2	Yes	N/A	Yes	Implant down sPLSVC
55	Male	Direct interrogation of the L brachiocephalic	Yes	1	No	3.2	Yes	Implant down sPLSVC
78	Female	Direct interrogation of the L brachiocephalic	No	0	No	8.0	Yes	Implant down sPLSVC
73	Male	Direct interrogation of the L brachiocephalic	No	0	No	10.0	Yes	Implant down sPLSVC
54	Male	Levophase venography	No	0	No	10.0	Yes	Implant down sPLSVC
66	Female	Direct interrogation of the L brachiocephalic	Yes	No	No	5.0	No	Stroke with the second attempt to implant the LV lead
30	Male	Direct interrogation of the L brachiocephalic	No	No	No	10.0	Yes	Implant down sPLSVC
48	M	CTA of the chest	No	No	No	N/A	Yes	Implant down sPLSVC

CS = coronary sinus; CSOA = coronary sinus ostial atresia/abnormalities; RA = right atrium; sPLVC = small persistent left superior vena cava.

sPLSVC with drainage to the LA, anticoagulation should be planned to mitigate the risk of thromboembolism.

Distinguishing CSOA + sPLSVC from PLSVC with a normal to enlarged CS

As described by John Marshall in 1850, the ligament/vein of Marshall (VOM) serves as an important anatomical landmark separating the beginning of the CS and the end of the great cardiac vein (GCV).[3,4] Besides draining venous blood from the atrial myocardium into the CS, the VOM can be arrhythmogenic, which is often ablated during atrial fibrillation ablation procedures.[4,5] Embryologically, the ligament of Marshall/VOM are remnants of the left SVC, which normally obliterates during cardiac development due to shifting blood flow to the right SVC. When complete regression fails, a connection persists between the left brachiocephalic and the CS, referred to as PLSVC.[4]

PLSVC without CSOA is one of the most commonly recognized variations in coronary venous anatomy, occurring in ~0.3% of the general population and significantly higher in patients with congenital heart disease.[6–8] With typical PLSVC, venous blood from the left brachiocephalic vein flows caudally toward the CS, resulting in a massively dilated CS below the insertion (Figure 1B). Blood flows uninhibited from the CS into the RA, and there is no connection to the LA. However, there are also rare reported cases of "small PLSVC," often associated with the atretic/stenotic CS instead of the dilated CS.[9–12] The authors believe that the nomenclature "small PLSVC" does not provide sufficient emphasis on its association with CSOA. We propose the term "CSOA + sPLSVC" because the presence of CSOA is the clinically relevant feature for LV lead implantation and its potential of CS drainage into the LA creating thromboembolic risk (Figure 1D).

Clinically, these distinct anatomical variances create different obstacles in lead implantation. In isolated PLSVC, the massively dilated CS prevents an adequate occlusive venogram from visualizing potential target branches unless the balloon is advanced into the brachiocephalic vein

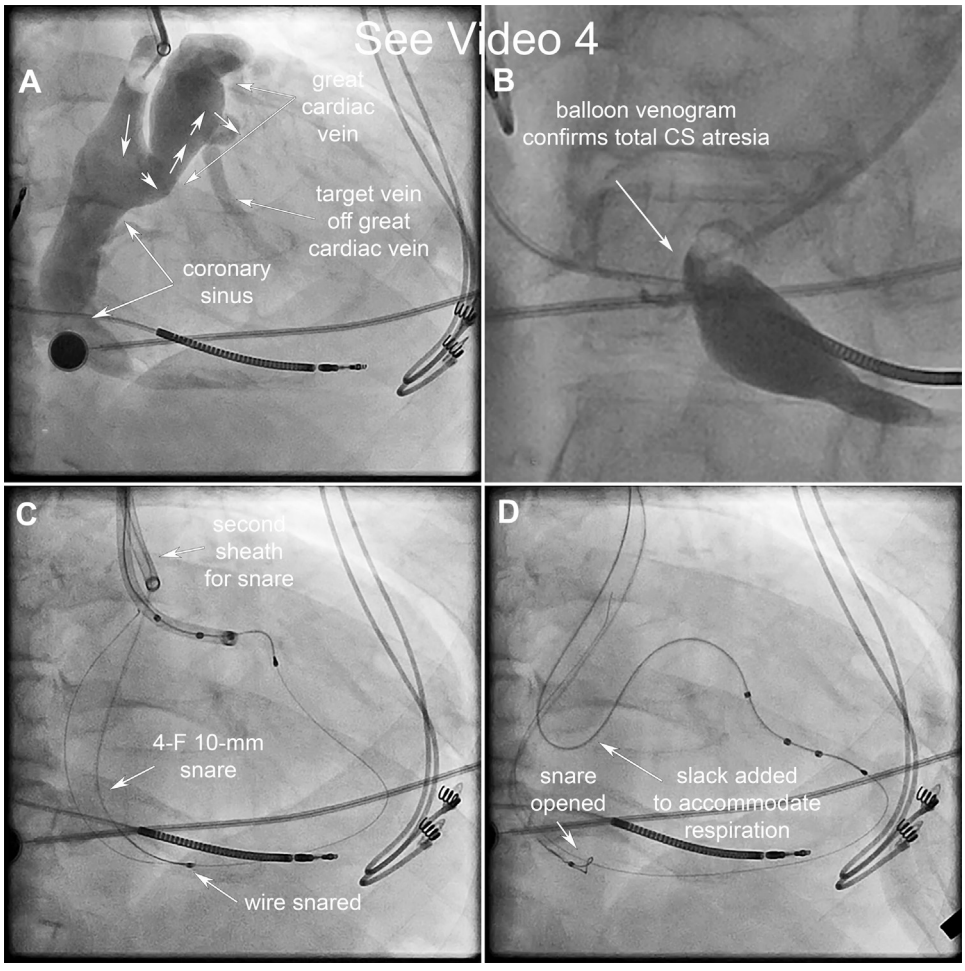


Figure 6 Direct LV lead implantation down CSOA + sPLSVC without flow into the LA or RA (Online Supplemental Video 4). **A:** Occlusive venogram of the CS from sPLSVC revealed the target vein off the great cardiac vein. The caliber of the CS and great cardiac vein was equal. **B:** Venogram near the CS ostium confirmed no flow into the LA. **C:** Despite the 180° turn to the target vein, a wire was advanced through the collaterals into the CS but the lead would not advance. A second sheath was added to attempt lead advancement using the snare technique. **D:** With the wire snared, the lead is advanced into the target vein. Abbreviations as in figures 1 and 2.

(Figure 1B).[13] Proximal to where the PLSVC enters the coronary sinus blood flow and thus coronary sinus size are normal. The portion of the coronary sinus proximal to entry of the PLSVC is technically the great cardiac vein but is usually described as the coronary sinus beyond the vein of Marshall. Therefore, when approached from the RA, the normal size brachiocephalic vein above the entry of PLSVC can be engaged and occlusive venography performed to identify potential branches for lead implantation. In CSOA + sPLSVC, the CS ostium is atretic or occluded and often cannot be found. Identification of sPLSVC provides an alternative route of implantation.

When to suspect and how to look for sPLSVC

Locating the CS is the first step to LV lead implantation. Adopting a systematic way of cannulating the CS will improve success and shorten the procedure time. As described previously, dropping the catheter tip down the tricuspid annulus from the RV with counterclockwise torque can help direct the tip into the CS across the Eustachian ridge and the Thebesian valve.[13] When the RA is dilated, operators can consider using a jumbo delivery sheath with bigger curvature to reach across the ridge and engage the CS. In cases of CSOA, contrast injection will not reveal the CS ostium (Figure 3A) and a small catheter may engage venous radicals that suggest CSOA (Figure 3B; Online Supplemental Video 1). Aggressive small catheter manipulation and contrast injection may provide a hint of sPLSVC (Figure 3C; Online Supplemental Video 1) and may even outline the entire CS (Figure 3D; Online Supplemental Video 1). Regardless of what is seen (or not) when looking from the RA, it is imperative to consider an atretic or stenotic CS and to look for sPLSVC (Figures 4 and 5; Videos 2 and 3).

Levophase CS venography

Levophase CS venography in the LAO projection is the most definitive method to evaluate CSOA (Figure 5; Video 3). It will identify patients with sPLSVC (Figure 5A) and help determine whether there is flow into the LA (Figure 5B; Online Supplemental Video 3). Levophase CS venography is

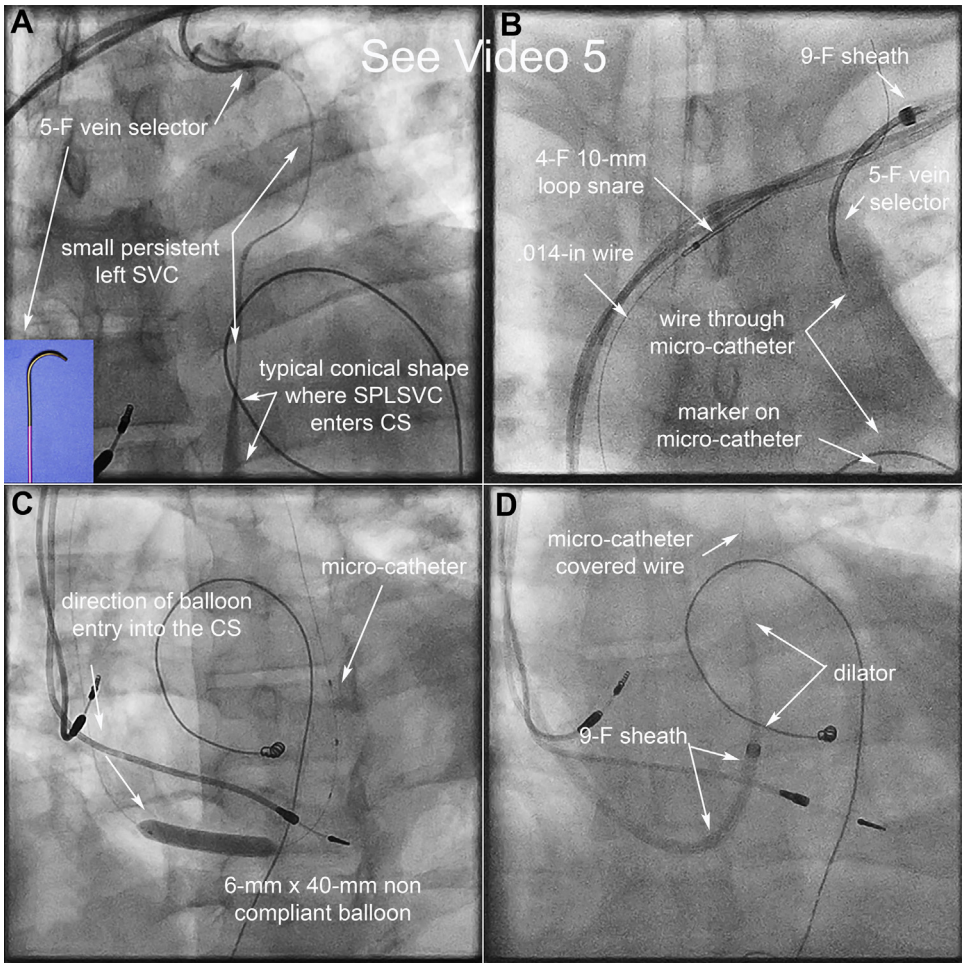


Figure 7 sPLSVC to facilitate entry into the atretic CS ostium from the RA via snare and venoplasty (Online Supplemental Video 5). **A:** The CS could not be entered from the RA, and sPLSVC was identified using a 5-F vein selector. **B:** Using the combination of a microcatheter and a vein selector, a polymer tip floppy wire was advanced down sPLSVC into the CS/RA/SVC/brachiocephalic vein and snared to create a rail to facilitate balloon advancement. **C:** After predilation with a 3-mm balloon advanced down sPLSVC (not shown), the CS ostium was dilated with the 6-mm balloon advanced from the RA. **D:** Standard 9-F sheath was advanced into the CS over the rail created by the microcatheter-covered wire. Abbreviations as in figures 1 and 2.

also useful in patients without sPLSVC to identify atypical ostial locations (Figure 5C; Online Supplemental Video 3) and in those with an unroofed CS where the venous return flows into the LA (Figure 5D; Online Supplemental Video 3). Levophase CS venography in patients with CSOA + sPLSVC has a classic triangular configuration where sPLSVC enters the CS body. When sPLSVC is identified by levophase venography, direct injection can better visualize its anatomical relations with the CS and other venous branches (Figure 6; Online Supplemental Video 4).

CT imaging in CSOA + sPLSVC

In this study, preoperative cardiac CT was not a reliable way to detect sPLSVC. The only sPLSVC detected was by CT angiography in a case of suspected dissection. Similar results were shown in other studies. One study looking at the effectiveness of visualizing the oblique VOM with CT revealed a poor detection rate of ~20%.[14] Another study was able to detect 40% of sPLSVC in patients with CS atresia by using multidetector CT.[15] However, two-thirds of patients underwent 128-section CT, which improved the chance of detecting smaller vessels but might not be available in all centers. Echocardiography was a reliable technique to search for PLSVC in neonates in a Japanese study that included >5000 patients.[8]

CSOA + sPLSVC—Looking for partial drainage into the LA

In the classic unroofed CS, all blood from the CS drains into the LA (Figure 5D; Online Supplemental Video 3) and there is no connection from the CS to the brachiocephalic vein. In CSOA + sPLSVC, most or all of the blood drains into the left brachiocephalic vein. In some cases, part of venous blood also flows into the LA (partial unroofing). When some blood from the CS drains into the LA, there is the potential for systemic embolization that can occur during or after LV lead implantation.

In our study, 1 patient suffered from an embolic stroke during the second attempt to implant the LV lead. These events can occur when CSOA + sPLSVC with LA drainage

is not recognized. One case report described a patient who suffered from a recurrent embolic stroke despite previously unrevealing comprehensive workup and ultimately revealed sPLSVC with drainage to the LA as the etiology.[16] How frequent a therapeutic catheter is placed in what appears to be sPLSVC but actually CSOA + sPLSVC with LA drainage is unknown (Figure 2). Recognizing CSOA + sPLSVC with LA drainage significantly contributes to better understanding of stroke risk with cardiovascular implantable electronic device (CIED). In 1 study looking at stroke risk in all patients undergoing lead extraction for CIED infection for 17 years identified stroke risk at 1.9% (15 of 774 patients). Of the 8 patients who suffered from a stroke postprocedure, 3 did not have obvious etiologies.[17] The lack of a clear cause of postprocedure stroke makes the authors wonder if CSOA + sPLSVC with LA drainage might be possible culprits in these cases.

Based on this study, contrast drainage to the right of the spine during levophase CS venography in the LAO projection is strongly suggestive of LA drainage and unroofed CS (Figures 1D, 2, and 3D). When choosing to implant/extract leads in CSOA + sPLSVC with LA drainage, anticoagulation should be performed in the same way as LA catheter ablation: uninterrupted oral anticoagulation, heparin during the procedure to goal activated clotting time >300 seconds, and continued oral anticoagulation indefinitely. The risk of implanting down sPLSVC with CSOA and LA drainage should be considered and tailored to each patient. For example, a patient with a mechanical valve or other reasons for chronic anticoagulation might be candidates despite partial drainage to the LA.

Implanting LV leads down CSOA + sPLSVC

In our study, an LV lead was successfully placed in 90% of patients (n = 18) with CSOA + sPLSVC. Among them, direct implantation of LV leads down sPLSVC was achieved in 16. In the other 2 patients, sPLSVC served as a conduit to assist cannulation of the CS from the RA and LV leads were placed using traditional approaches from the RA to the CS (Figure 7; Online Supplemental Video 5). Implanting LV leads down sPLSVC can be challenging because many of the target veins are 180° back into the GCV. The anatomy demands a series of tortuous turns down sPLSVC, into the CS body, 180° back into the GCV, and down a posterolateral branch (Figure 6; Online Supplemental Video 4). Difficulty of implantation often depends on vessel size, which is directly correlated to the amount of venous blood return to the brachiocephalic vein. With complete RA/LA CS atresia, sPLSVC compensates for the entire coronary venous blood return and is often larger. When there is only partial atresia to the RA or drainage into the LA, a smaller portion of venous blood flows through sPLSVC and the sPLSVC diameter is smaller. Figure 6 (Online Supplemental Video 4) showed an example of direct LV lead implantation down sPLSVC.

sPLSVC can also be used to engage the CS from the RA. A wire can be advanced down sPLSVC to the RA/SVC where it is snared to create a rail to facilitate entry of balloons, catheters, and sheaths into the CS. Figure 7 (Online Supplemental Video 5) provides an example. In this case, the CS was initially cannulated from the RA using a light support polymer tip angioplasty wire. However, attempts to advance anything including a 3-mm balloon or microcatheters were unsuccessful. After identifying sPLSVC by direct contrast injection in the left brachiocephalic vein at the sternoclavicular junction, a guidewire and a microcatheter were advanced down sPLSVC, out of the CS, into the RA, and eventually back up the SVC where it was snared. The rail created by the snared wire made it possible to advance a standard 9-F sheath into the CS after balloon venoplasty.

Whether to implant down sPLSVC or pursue physiological pacing in cases of CSOA + sPLSVC should depend on the experience of each operator. However, the search for sPLSVC should be performed to understand the true prevalence of this anatomical variance. Two lessons worth emphasizing are as follows: (1) When looking for sPLSVC with catheters in the brachiocephalic vein at the sternoclavicular junction, the pericardiophrenic vein may be identified, which does not reach the CS. (2) Once the lead is in place, it is essential to leave enough LV lead slack within sPLSVC to accommodate chest expansion during deep inhalation. A posterior-anterior and a lateral chest radiograph of the final lead position was shown in Figures 2B and 2C.

Limitations

This is a retrospective observational series of patients with reported CSOA + sPLSVC across multiple centers. Because of the lack of systemic understanding of this anatomical variation by most implanting physicians, it is difficult to report the prevalence of CSOA + sPLSVC even within the centers that participated in this study. Larger prospective studies are needed to elucidate the true prevalence of CSOA + sPLSVC and its thromboembolic risk when associated with LA drainage.

Conclusion

Inability to locate the CS owing to CS ostial abnormalities is a common cause of LV lead implant failure. The combination of CS ostial abnormalities and sPLSVC is currently not well recognized, and its true prevalence is unknown. When there is difficulty locating the CS, implanters should consider sPLSVC as a potential option for LV lead implantation. CS ostial abnormalities and sPLSVC can be associated with partial unroofing of the CS and drainage into the LA, and anticoagulation is advisable during implantation/extraction as if the patient were undergoing pulmonary vein isolation to mitigate thromboembolic risk. Systematic recognition of CS ostial abnormalities and sPLSVC with or without LA drainage is essential in CIED implantation and extraction. In cases of unexplained thromboembolic events and recent CIED intervention, CS ostial abnormalities and sPLSVC with LA drainage should be considered.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrthm.2021.05.004.

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