



## Impact of Persistent Left Superior Vena Cava on Procedural Complexity and Long-Term Follow-up after Pacemaker Implantation: A Retrospective Comparative Study

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### Abstract

**Background:** Persistent left superior vena cava (PLSVC) is the most common thoracic venous anomaly and poses technical challenges during permanent heart rhythm device (PHRD) implantation. Evidence on its procedural and long-term implications remains limited.

**Aim:** This study aims to compare procedural characteristics, complications, and long-term pacing performance of patients undergoing single chamber pacemaker implantation with and without PLSVC.

**Methods:** In this retrospective single-centre study, 250 patients undergoing single-chamber permanent pacemaker implantation via the left axillary/subclavian vein were evaluated. Of these, 52 had PLSVC and 198 did not. Baseline characteristics, procedural details, complications, and follow-up outcomes were compared. Propensity score matching (PSM) was performed to adjust for baseline differences.

**Results:** Patients with PLSVC were younger ( $62.0 \pm 11.3$  vs.  $65.4 \pm 10.8$  years,  $p=0.047$ ), with comparable comorbidities and diagnoses. Compared with non-PLSVC, patients with PLSVC had longer procedure time ( $41.3 \pm 9.6$  vs.  $31.7 \pm 7.3$  min,  $p<0.001$ ), fluoroscopy time ( $502.5 \pm 154.8$  vs.  $343.7 \pm 91.0$  sec,  $p<0.001$ ), and higher contrast use ( $16.4 \pm 5.4$  vs.  $9.4 \pm 3.4$  mL,  $p<0.001$ ). Complication rates were similar (9.6% vs. 8.6%,  $p>0.999$ ). After PSM, differences in procedure time, fluoroscopy exposure, and contrast use remained significant. Median follow-up was similar in both groups (4.1 [3.9–6.3] vs. 4.0 [3.8–6.9]) years,  $p<0.001$ , respectively, PLSVC vs Non PLSVC groups.

**Conclusion:** PLSVC significantly increases procedural complexity during single chamber pacemaker implantation, requiring stylet shaping, but does not adversely affect long-term outcomes.

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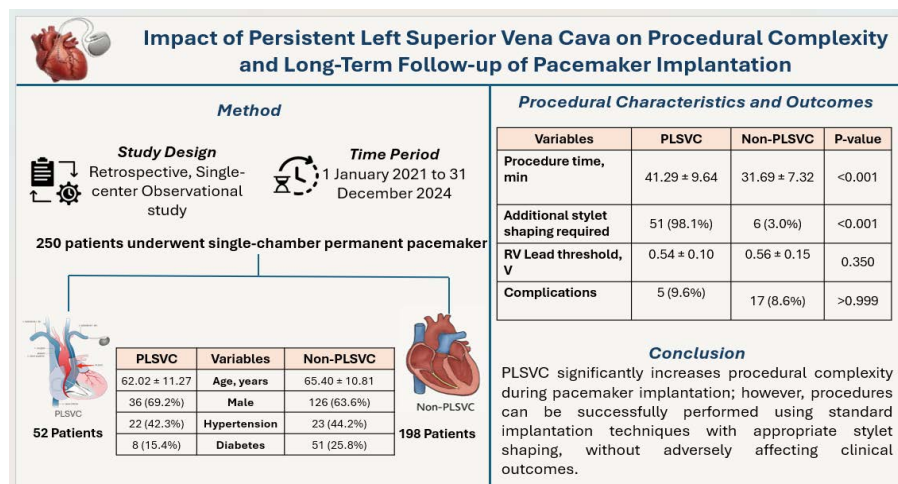
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## Introduction

Persistent left superior vena cava (PLSVC) is the most common congenital thoracic venous anomaly, occurring in approximately 0.3–0.5% of the general population and up to 10% of patients with congenital heart disease [1,2]. Although often asymptomatic and detected incidentally, its presence is clinically important during invasive cardiovascular procedures. Permanent heart rhythm device (PHRD) implantation can be technically challenging when PLSVC is present, as the venous return typically drains via the coronary sinus, creating an atypical and tortuous pathway for stable lead placement [3,4]. Published experience on device implantation in PLSVC is limited to case reports, case series and small studies. These studies demonstrate that successful implantation is feasible using standard techniques, such as pre-shaped or steerable stylets, alpha-loop formation, and alternative lead-delivery strategies, with acceptable short-term outcomes [2,3]. However, existing evidence is largely limited to isolated case reports and small series, and robust comparative data on procedural characteristics and clinical outcomes in patients with versus without PLSVC remain scarce. This paucity of evidence hampers the ability to generalize findings and formulate standardized management strategies. To address this limitation, we conducted a study by comparing procedural characteristics, complications, and long-term pacing performance of patients undergoing single chamber pacemaker implantation with and without PLSVC.

## Materials and Methods

### Study design and patient population

This retrospective, single-center observational study was conducted from 1 January 2021 to 31 December 2024 at a high-volume tertiary care academic institution in North India. The study aimed to evaluate procedural characteristics, complication rates, and overall safety outcomes in patients with persistent left superior vena cava (PLSVC) undergoing permanent single chamber pacemaker implantation, compared with those having normal venous anatomy. During the study period, a total of 4,024 patients underwent PHRD implantation at our center. These included 3,409 single-chamber pacemakers (84.7%), 398 dual-chamber pacemakers (9.9%), 129 implantable cardioverter-defibrillators (ICDs; 3.2%), and 88 cardiac resynchronization therapy (CRT) devices (2.2%). Among these, 61 patients (1.5%) were incidentally identified to have PLSVC during the implantation procedure. All such patients underwent device implantation through the left axillary or subclavian venous approach. Of this subgroup, 52 patients received single-chamber permanent pacemakers, 5 underwent dual-chamber pacemaker implantation, 3 received single-chamber ICDs,

and 1 underwent CRT device implantation. For comparative analysis, all 52 PLSVC patients who received single-chamber permanent pacemakers were retrospectively included. A control cohort comprising 198 age- and sex-matched patients with normal systemic venous anatomy who underwent single-chamber pacemaker implantation during the same period was selected in a 1:4 ratio (Figure 1).

## Data Collection and Definitions

Clinical, demographic, and procedural data were extracted from institutional medical records, device implantation logs, and procedure reports. Baseline parameters included age, sex, comorbidities, and left ventricular ejection fraction. Procedural details such as venous access route, fluoroscopy time, total procedural duration, and lead characteristics were systematically recorded. Procedural success was defined as successful implantation of the intended device with stable lead position and satisfactory pacing parameters at the time of discharge. Procedural complications were classified as intra-procedural (e.g., cardiac perforation, tamponade, lead dislodgement, vascular injury, or arrhythmia requiring intervention) or post-procedural (e.g., pocket hematoma, infection, or pneumothorax). Safety outcomes were assessed during in-hospital stay and follow-up visits. Written informed consent was obtained from all patients and their families before device implantation. All procedures were performed in accordance with Institutional Ethical Standards.

## Implantation Procedure

All patients were prepared under strict aseptic precautions, including local site preparation with alcohol and betadine. Intravenous antibiotic prophylaxis was administered 4 hours prior to the procedure. In both groups, vascular access was obtained via the left axillary vein through an extra-thoracic puncture under fluoroscopic and contrast venography guidance. After successful venous puncture, a 0.035-inch guidewire was advanced through the left superior vena cava (PLSVC group) or right superior vena cava (non-PLSVC group), and an 8F peel-away introducer sheath was inserted. In the non-PLSVC group, the pacing lead was advanced into the right ventricular (RV) cavity using a straight stylet, with a curved stylet employed when necessary to facilitate accurate positioning at the RV apex or right ventricular outflow tract (RVOT). In the PLSVC group, the pacing lead was advanced using standard straight or curved stylets. Stylet shaping and lead manipulation were performed as required to facilitate tricuspid valve crossing and optimal RV positioning. Active fixation (screw-in) pacing leads were used in all patients.

## Post-procedure Care

Following implantation, patients were monitored in the hospital for 24–36 hours. Intravenous antibiotics were continued for 48 hours, followed by oral antibiotics for 5

days. Patients were reviewed 5 days after discharge for suture removal and medication assessment.

## Statistical Analysis

Continuous variables were expressed as mean  $\pm$  standard deviation (SD) and compared using the independent t-test or Mann–Whitney U test, as appropriate. Categorical variables were summarized as frequencies and percentages and compared between groups using the Chi-square test or Fisher’s exact test, as applicable. Propensity score matching was performed using logistic regression, including age, sex, hemoglobin, diabetes, hypertension, smoking status, diagnosis, and presenting symptoms as covariates. Patients with PLSVC were matched 1:1 to non-PLSVC using nearest-

neighbor matching on the logit of the propensity score. Covariate balance was assessed using standardized mean differences, with a threshold of  $<0.1$  considered acceptable. All statistical analyses were performed for the PLSVC group. A two-sided p-value  $<0.05$  was considered statistically significant. Analyses were conducted using R software, version 4.3.3.

## Results

In total, 250 patients were enrolled for analysis, of whom 52 (20.8%) had persistent left superior vena cava (PLSVC), while the remaining 198 (79.2%) constituted the non-PLSVC (control) group. Baseline demographic, clinical, and laboratory characteristics are summarized in Table 1.

**Table 1:** Baseline demographic, clinical, and laboratory characteristics of patients with and without PLSVC.

| Variables                                          | Total<br>N=250 patients | PLSVC<br>n=52 patients | Non-PLSVC<br>n=198 patients | p-value |
|----------------------------------------------------|-------------------------|------------------------|-----------------------------|---------|
| Age, years                                         | 64.70 $\pm$ 10.97       | 62.02 $\pm$ 11.27      | 65.40 $\pm$ 10.81           | 0.047   |
| Sex                                                |                         |                        |                             |         |
| Male                                               | 162 (64.8)              | 36 (69.2%)             | 126 (63.6%)                 | 0.452   |
| Female                                             | 88 (35.2)               | 16 (30.8%)             | 72 (36.4%)                  |         |
| Diagnosis                                          |                         |                        |                             |         |
| Complete Heart Block                               | 203 (81.2)              | 40 (76.9%)             | 163 (82.3%)                 | 0.954   |
| Advance AV Block                                   | 27 (10.8)               | 7 (13.5%)              | 20 (10.1%)                  |         |
| Sick Sinus Syndrome                                | 9 (3.6)                 | 2 (3.8%)               | 7 (3.5%)                    |         |
| Bifascicular block with or without PR prolongation | 8 (3.2)                 | 2 (3.8%)               | 6 (2.0%)                    |         |
| AF with Slow VR                                    | 3 (1.2)                 | 1 (1.9%)               | 2 (3.0%)                    |         |
| Symptoms                                           |                         |                        |                             |         |
| Syncope                                            | 155 (62.0)              | 31 (59.6%)             | 124 (62.6%)                 | 0.014   |
| Dizziness                                          | 67 (26.8)               | 9 (17.3%)              | 58 (29.3%)                  |         |
| Dyspnea                                            | 13 (5.2)                | 6 (11.5%)              | 7 (3.5%)                    |         |
| Other                                              | 15 (6.0)                | 6 (11.5%)              | 9 (4.5%)                    |         |
| Comorbidities                                      |                         |                        |                             |         |
| Hypertension                                       | 111 (44.4)              | 22 (42.3%)             | 89 (44.9%)                  | 0.733   |
| Smoking                                            | 98 (39.2)               | 26 (50.0%)             | 72 (36.4%)                  | 0.073   |
| Diabetes                                           | 59 (23.6)               | 8 (15.4%)              | 51 (25.8%)                  | 0.117   |
| Laboratory Parameters                              |                         |                        |                             |         |
| Hemoglobin, g/dl                                   | 12.05 $\pm$ 1.78        | 11.47 $\pm$ 1.64       | 12.20 $\pm$ 1.79            | 0.008   |
| TLC, /mm <sup>3</sup>                              | 10904.16 $\pm$ 4036.14  | 11415.04 $\pm$ 4032.2  | 10769.99 $\pm$ 4036.63      | 0.306   |
| Urea, mg/dl                                        | 46.58 $\pm$ 22.65       | 45.92 $\pm$ 19.99      | 46.75 $\pm$ 23.35           | 0.815   |
| Creatinine, mg/dl                                  | 1.28 $\pm$ 0.44         | 1.30 $\pm$ 0.43        | 1.28 $\pm$ 0.45             | 0.698   |
| Sodium, mEq/L                                      | 139.6 $\pm$ 63.32       | 135.71 $\pm$ 5         | 140.63 $\pm$ 71.11          | 0.619   |
| Potassium, mEq/L                                   | 4.42 $\pm$ 0.7          | 4.45 $\pm$ 0.7         | 4.41 $\pm$ 0.7              | 0.731   |
| Ejection Fraction, %                               | 57.46 $\pm$ 7.97        | 57.00 $\pm$ 7.42       | 57.58 $\pm$ 8.12            | 0.644   |
| Associated Lesions                                 | 8 (3.2)                 | 2 (3.8%)               | 6 (3.0%)                    | >0.999  |
| Atrial Septal Defect                               | 3 (1.2)                 | 1 (1.9%)               | 2 (1.0%)                    | >0.999  |
| Bicuspid Aortic Valve                              | 5 (2.0)                 | 1 (1.9%)               | 4 (2.0%)                    |         |
| None                                               | 242 (96.8)              | 50 (96.2%)             | 192 (97.0%)                 |         |

**Note:** Data are presented as mean  $\pm$  standard deviation or n (%). A p value  $<0.05$  was considered statistically significant. AF: Atrial fibrillation; AV: Atrioventricular; LSVC: Left superior vena cava; PLSVC: Persistent left superior vena cava TLC: Total leukocyte count; VR: Ventricular response

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Patients with PLSVC were younger compared with the non-PLSVC group ( $62.0 \pm 11.3$  vs.  $65.4 \pm 10.8$  years,  $p=0.047$ ).

The distribution of sex, diagnosis, and comorbidities was comparable between the two groups. Procedural details are detailed in Table 2.

**Table 2:** Procedural details and in-hospital complications in patients with and without PLSVC.

| Variables                                                | Total<br>(N=250 patients) | PLSVC<br>(n=52 patients) | Non-PLSVC (n=198<br>patients) | p-value |
|----------------------------------------------------------|---------------------------|--------------------------|-------------------------------|---------|
| RV site of pacing                                        |                           |                          |                               |         |
| Apex                                                     | 228 (91.2)                | 46 (88.5)                | 182 (91.9)                    | 0.052   |
| RVOT                                                     | 20 (8.0)                  | 4 (7.7)                  | 16 (8.1)                      |         |
| Septal                                                   | 2 (0.8)                   | 2 (3.8)                  | 0 (0.0)                       |         |
| Additional stylet shaping/lead manipulation not required | 193 (77.2)                | 1 (1.9)                  | 192 (97.0)                    | <0.001  |
| Additional stylet shaping/lead manipulation required     | 57 (22.8)                 | 51 (98.1)                | 6 (3.0)                       |         |
| Procedure Parameters                                     |                           |                          |                               |         |
| Procedure time, min                                      | 33.69 ± 8.76              | 41.29 ± 9.64             | 31.69 ± 7.32                  | <0.001  |
| Fluoroscopic time, sec                                   | 376.74 ± 125.02           | 502.46 ± 154.83          | 343.73 ± 91.0                 | <0.001  |
| Contrast, ml                                             | 10.89±4.83                | 16.44±5.36               | 9.43±3.43                     | <0.001  |
| RV Lead threshold, V                                     | 0.55 ± 0.14               | 0.54 ± 0.10              | 0.56 ± 0.15                   | 0.350   |
| Impedance                                                | 658.1 ± 114.9             | 652.75 ± 105.68          | 659.51 ± 117.41               | 0.707   |
| Complications                                            | 22 (8.8)                  | 5 (9.6)                  | 17 (8.6)                      | >0.999  |
| Perforation                                              | 7/22 (31.8)               | 1/5 (20.0)               | 6/17 (35.3)                   | 0.872   |
| In hospital death                                        | 4/22 (18.2)               | 1/5 (20.0)               | 3/17 (17.6)                   |         |
| Pacemaker site infection                                 | 4/22 (18.2)               | 2/5 (40.0)               | 2/17 (11.8)                   |         |
| Lead dislodgement                                        | 3/22 (13.6)               | 1/5 (20.0)               | 2/17 (11.8)                   |         |
| DVT                                                      | 2/22 (9.1)                | 0 (0.0)                  | 2/17 (11.8)                   |         |
| Local site hematoma                                      | 1/22 (4.5)                | 0 (0.0)                  | 1/17 (5.9)                    |         |
| Pneumothorax                                             | 1/22 (4.5)                | 0 (0.0)                  | 1/17 (5.9)                    |         |

**Note:** Data are presented as mean  $\pm$  standard deviation or n (%). A p value <0.05 was considered statistically significant. DVT: Deep vein thrombosis; PLSVC: Persistent left superior vena cava; RV: Right ventricle; RVOT: Right ventricular outflow tract

The RV apex was the predominant pacing site in both groups. Notably, additional lead manipulation and stylet shaping were more frequently required in PLSVC patients (98.1% vs. 3.0%,  $p<0.001$ ). PLSVC patients also had significantly longer mean procedure times ( $41.3 \pm 9.6$  vs.  $31.7 \pm 7.3$  min,  $p<0.001$ ), fluoroscopy times ( $502.5 \pm 154.8$  vs.  $343.7 \pm 91.0$  sec,  $p<0.001$ ), and higher contrast usage ( $16.4 \pm 5.4$  vs.  $9.4 \pm 3.4$  mL,  $p<0.001$ ). The overall complication rate did not differ significantly between PLSVC and non-PLSVC groups (9.6% vs. 8.6%,  $p>0.999$ ). After propensity score matching, baseline variables were well balanced between the groups (Tables 3 and 4).

Differences in hemoglobin levels, age, and presenting

symptoms observed before matching were no longer significant. However, procedure time, fluoroscopy time, and contrast usage remained significantly higher in the PLSVC group after matching (all  $p<0.001$ ). Complication rates were similar between the groups before and after matching. Long-term follow-up findings are presented in Table 5. All procedures were performed through the left axillary approach. Screw-in leads were most frequently used (98.8%) without a significant intergroup difference. The alpha-loop technique was almost universally required in PLSVC patients (98.1% vs. none in non-PLSVC,  $p<0.001$ ). Median follow-up was similar in both groups (4.1 [3.9–6.3] vs 4.0 [3.8–6.9]) years,  $p<0.001$ , respectively, PLSVC vs Non PLSVC groups.

**Table 3:** Baseline characteristics before and after propensity score matching.

| Variables                                          | Before propensity score matching |                          |         | After propensity score matching |                         |         |
|----------------------------------------------------|----------------------------------|--------------------------|---------|---------------------------------|-------------------------|---------|
|                                                    | PLSVC n=52 patients              | Non-PLSVC n=198 patients | p-value | PLSVC n=52 patients             | Non-PLSVC n=52 patients | p-value |
| Age, years                                         | 62.02 ± 11.27                    | 65.40 ± 10.81            | 0.047   | 62.02 ± 11.27                   | 62.13±11.87             | 0.960   |
| Sex                                                |                                  |                          |         |                                 |                         |         |
| Male                                               | 36 (69.2)                        | 126 (63.6)               | 0.452   | 36 (69.2)                       | 35 (67.3)               | 0.833   |
| Female                                             | 16 (30.8)                        | 72 (36.4)                |         | 16 (30.8)                       | 17 (32.7)               |         |
| Diagnosis                                          |                                  |                          |         |                                 |                         |         |
| Complete Heart Block                               | 40 (76.9)                        | 163 (82.3)               | 0.954   | 40 (76.9)                       | 39 (75.0)               | >0.999  |
| Advance AV Block                                   | 7 (13.5)                         | 20 (10.1)                |         | 7 (13.5)                        | 7 (13.5)                |         |
| Sick Sinus Syndrome                                | 2 (3.8)                          | 7 (3.5)                  |         | 2 (3.8)                         | 2 (3.8)                 |         |
| Bifascicular block with or without PR prolongation | 2 (3.8)                          | 6 (2.0)                  |         | 2 (3.8)                         | 2 (3.8)                 |         |
| AF with Slow VR                                    | 1 (1.9)                          | 2 (3.0)                  |         | 1 (1.9)                         | 2 (3.8)                 |         |
| Symptoms                                           |                                  |                          |         |                                 |                         |         |
| Syncope                                            | 31 (59.6)                        | 124 (62.6)               | 0.014   | 31 (59.6)                       | 32 (61.5)               | 0.995   |
| Dizziness                                          | 9 (17.3)                         | 58 (29.3)                |         | 9 (17.3)                        | 8 (15.4)                |         |
| Dyspnea                                            | 6 (11.5)                         | 7 (3.5)                  |         | 6 (11.5)                        | 6 (11.5)                |         |
| Other                                              | 6 (11.5)                         | 9 (4.5)                  |         | 6 (11.5)                        | 6 (11.5)                |         |
| Comorbidities                                      |                                  |                          |         |                                 |                         |         |
| Hypertension                                       | 22 (42.3%)                       | 89 (44.9%)               | 0.733   | 22 (42.3%)                      | 23 (44.2%)              | 0.843   |
| Smoking                                            | 26 (50.0%)                       | 72 (36.4%)               | 0.073   | 26 (50.0%)                      | 25 (48.1%)              | 0.844   |
| Diabetes                                           | 8 (15.4%)                        | 51 (25.8%)               | 0.117   | 8 (15.4%)                       | 10 (19.2%)              | 0.604   |
| Laboratory Parameters                              |                                  |                          |         |                                 |                         |         |
| Hemoglobin, g/dl                                   | 11.47 ± 1.64                     | 12.20 ± 1.79             | 0.008   | 11.47 ± 1.64                    | 11.49 ± 1.85            | 0.971   |
| TLC, /mm³                                          | 11415.04 ± 4032.2                | 10769.99 ± 4036.63       | 0.306   | 11415.04 ± 4032.2               | 10873.79 ± 4519.90      | 0.521   |
| Urea, mg/dl                                        | 45.92 ± 19.99                    | 46.75 ± 23.35            | 0.815   | 45.92 ± 19.99                   | 45.17 ± 20.11           | 0.848   |
| Creatinine, mg/dl                                  | 1.30 ± 0.43                      | 1.28 ± 0.45              | 0.698   | 1.30 ± 0.43                     | 1.28 ± 0.39             | 0.787   |
| Sodium, mEq/L                                      | 135.71 ± 5                       | 140.63 ± 71.11           | 0.619   | 135.71 ± 5.0                    | 135.44 ± 6.11           | 0.806   |
| Potassium, mEq/L                                   | 4.45 ± 0.7                       | 4.41 ± 0.7               | 0.731   | 4.45 ± 0.70                     | 4.30 ± 0.78             | 0.329   |
| Ejection Fraction, %                               | 57.00 ± 7.42                     | 57.58 ± 8.12             | 0.644   | 57.00 ± 7.42                    | 55.73 ± 10.40           | 0.475   |
| Associated Lesions                                 | 2 (3.8%)                         | 6 (3.0%)                 | >0.999  | 2 (3.8%)                        | 2 (3.8%)                | >0.999  |
| Atrial Septal Defect                               | 1 (1.9%)                         | 2 (1.0%)                 | >0.999  | 1 (1.9%)                        | 0 (0.0%)                | >0.999  |
| Bicuspid Aortic Valve                              | 1 (1.9%)                         | 4 (2.0%)                 |         | 1 (1.9%)                        | 2 (3.8%)                |         |
| None                                               | 50 (96.2%)                       | 192 (97.0%)              |         | 50 (96.2%)                      | 50 (96.2%)              |         |

**Note:** Data are presented as mean ± standard deviation or n (%). A p value <0.05 was considered statistically significant. AF: Atrial Fibrillation; AV: Atrioventricular; IQR: Interquartile range; PLSVC: Persistent left superior vena cava; PSM: Propensity score matching; TLC: Total leukocyte count; VR: Ventricular response.

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**Table 4:** Procedural details and complications before and after propensity score matching.

| Variables                                                   | Before propensity score matching |                             |         | After propensity score matching |                            |         |
|-------------------------------------------------------------|----------------------------------|-----------------------------|---------|---------------------------------|----------------------------|---------|
|                                                             | PLSVC<br>n=52 patients           | Non-PLSVC<br>n=198 patients | p-value | PLSVC n=52<br>patients          | Non-PLSVC<br>n=52 patients | p-value |
| RV site of pacing                                           |                                  |                             |         |                                 |                            |         |
| Apex                                                        | 46 (88.5)                        | 182 (91.9)                  | 0.052   | 46 (88.5)                       | 47 (90.4)                  | 0.576   |
| RVOT                                                        | 4 (7.7)                          | 16 (8.1)                    |         | 4 (7.7)                         | 5 (9.6)                    |         |
| Septal                                                      | 2 (3.8)                          | 0 (0.0)                     |         | 2 (3.8)                         | 0 (0.0)                    |         |
| Additional stylet shaping/lead<br>manipulation not required | 1 (1.9)                          | 192 (97.0)                  | <0.001  | 1 (1.9)                         | 50 (96.2)                  | <0.001  |
| Additional stylet shaping/lead<br>manipulation required     | 51 (98.1)                        | 6 (3.0)                     |         | 51 (98.1)                       | 2 (3.8)                    |         |
| Procedure Parameters                                        |                                  |                             |         |                                 |                            |         |
| Procedure time, min                                         | 41.29 ± 9.64                     | 31.69 ± 7.32                | <0.001  | 41.29 ± 9.64                    | 33.10 ± 8.32               | <0.001  |
| Fluoroscopic time, sec                                      | 502.46 ± 154.83                  | 343.73 ± 91.0               | <0.001  | 502.46 ± 154.83                 | 346.53 ± 99.23             | <0.001  |
| Contrast, ml                                                | 16.44 ± 5.36                     | 9.43 ± 3.43                 | <0.001  | 16.44 ± 5.36                    | 9.23 ± 3.19                | <0.001  |
| RV Lead threshold, V                                        | 0.54 ± 0.10                      | 0.56 ± 0.15                 | 0.350   | 0.54 ± 0.10                     | 0.54 ± 0.10                | 0.924   |
| Impedance                                                   | 652.75 ± 105.68                  | 659.51 ± 117.41             | 0.707   | 652.75 ± 105.68                 | 649.44 ± 118.15            | 0.881   |
| Complications                                               | 5 (9.6)                          | 17 (8.6)                    | >0.999  | 5 (9.6)                         | 5 (9.6)                    | –       |
| Perforation                                                 | 1/5 (20.0)                       | 6/17 (35.3)                 | 0.872   | 1/5 (20.0)                      | 2/5 (40.0)                 | >0.999  |
| In hospital death                                           | 1/5 (20.0)                       | 3/17 (17.6)                 |         | 1/5 (20.0)                      | 1/5 (20.0)                 |         |
| Pacemaker site infection                                    | 2/5 (40.0)                       | 2/17 (11.8)                 |         | 2/5 (40.0)                      | 1/5 (20.0)                 |         |
| Lead dislodgement                                           | 1/5 (20.0)                       | 2/17 (11.8)                 |         | 1/5 (20.0)                      | 0 (0.0)                    |         |
| DVT                                                         | 0 (0.0)                          | 2/17 (11.8)                 |         | 0 (0.0)                         | 1/5 (20.0)                 |         |
| Local site hematoma                                         | 0 (0.0)                          | 1/17 (5.9)                  |         | 0 (0.0)                         | 0 (0.0)                    |         |
| Pneumothorax                                                | 0 (0.0)                          | 1/17 (5.9)                  |         | 0 (0.0)                         | 0 (0.0)                    |         |

**Note:** Data are presented as mean ± standard deviation or n (%). A p value <0.05 was considered statistically significant. DVT: Deep vein thrombosis; IQR: Interquartile range; LSVC: Left superior vena cava; PSM: Propensity score matching; PLSVC: Persistent left superior vena cava; RV: Right ventricle; RVOT: Right ventricular outflow tract

**Table 5:** Access in study population.

| Variables         | Total<br>N=250 patients | PLSVC<br>n=52 patients | Non-PLSVC<br>n=198 patients | p-value |
|-------------------|-------------------------|------------------------|-----------------------------|---------|
| Access for pacing |                         |                        |                             |         |
| Left Axillary     | 250 (100.0)             | 52 (100.0)             | 198 (100.0)                 | -       |
| Type of lead      |                         |                        |                             |         |
| Screw             | 247 (98.8)              | 50 (96.2)              | 197 (99.5)                  | 0.111   |
| Tinned            | 3 (1.2)                 | 2 (3.8)                | 1 (0.5)                     |         |
| Alpha loop        | 51 (20.4)               | 51 (98.1)              | 0 (0.0)                     | <0.001  |

**Note:** Data are presented as mean ± standard deviation or n(%). A p value <0.05 was considered statistically significant. IQR: Interquartile range; PLSVC: Persistent left superior vena cava; LSVC: Left superior vena cava.

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## Discussion

In this study of 250 patients undergoing single-chamber pacemaker implantation, including 52 with PLSVC, we found that PLSVC was associated with increased procedural complexity but did not affect long-term pacing performance. The present study is the largest retrospective study to date evaluating patients with PLSVC undergoing permanent pacemaker implantation. In patients with non-PLSVC, pacemaker or defibrillator leads are typically advanced through the right-sided venous system into the right atrium and ventricle in a straightforward manner. Whereas, in PLSVC, the venous anatomy is altered, directing the leads through the left-sided abnormal vein and the coronary sinus before reaching the right atrium [5,6]. Contrary to a previous prospective study from the same geographic area, our research demonstrated that this unusual venous course, often encountered unexpectedly during the procedure, makes the technique more challenging (8). This complexity frequently leads to longer procedure times, increased fluoroscopy exposure, and greater contrast use, as evidenced by our findings. In many cases, additional lead manipulation and careful stylet shaping may be required to achieve stable lead placement. Prior case reports have documented the frequent need for hardware, such as C-shaped stylets, steerable catheters, or active fixation leads, in patients with PLSVC. Equipment choice is crucial for safe and effective RV lead placement in PLSVC [2,7,8]. A stiff stylet carries risks of venous perforation or tricuspid injury, while a soft stylet lacks the necessary support and control for precise lead delivery. Therefore, an intermediate-stiffness stylet is generally preferred, as it provides the right balance of flexibility and push ability to achieve stable positioning without compromising safety [9,10]. In a case series, dual active-fixation leads positioned with a C-shaped stylet achieved successful implantation but required longer procedural duration and venography [7]. In our study, nearly all patients with PLSVC (98.1%) required lead manipulation using stylets to successfully navigate and position the pacing leads at the desired location. Most of our patients had screwing lead, but even those who had tined lead had similar stability over the follow-up period. Interestingly, almost all patients with PLSVC required an alpha loop configuration to achieve stable lead positioning, a technique frequently described in earlier studies as a practical solution to the tortuous venous anatomy [8]. Despite the technical challenges, the presence of a PLSVC does not necessarily preclude successful pacemaker implantation, even when identified as an on-table surprise [11]. Lead dislodgement had been reported more frequently in PLSVC patients, likely due to the tortuous coronary sinus course and difficulty securing stable RV positioning. Similarly, in our study, lead dislodgement occurred more often in the PLSVC group; however, in a study by Sinha S.

et al. [8], the incidence was low and comparable between groups (3.2% in PLSVC vs 4.8% in non-PLSVC). These observations emphasize the importance of stylet shaping and lead handling technique to minimize instability. Various strategies can be employed to place the RV endocardial lead in patients with PLSVC [8]. The most common approach was to reshape the stylet after the lead reached the right atrium via the coronary sinus, facilitating negotiation across the tricuspid valve. Abutting the lead against the free wall of the right atrium also provided better support for crossing into the right ventricle [12]. In prior report, the use of long 40-cm Worley sheaths has been described to enhance support during RV lead placement [13]. Additional maneuvers include leaving the venous sheath in place during manipulation, using a straight stylet initially to ease passage, and later employing Mond's modification if septal pacing is intended. Once acceptable pacing parameters are achieved, the venous sheath can be gradually peeled while maintaining stylet stability to secure final lead positioning [8,13,14]. Importantly, in our study, the RV lead threshold was identical in both groups which is influenced by procedural factors such as lead position, fixation stability, and myocardial substrate because threshold values have been observed to change acutely depending on implant technique, suggesting that despite the anatomical challenges of PLSVC, standard implantation techniques, resulted in long-term pacing performance [1,15,16].

## Limitations

Several limitations of this study should be acknowledged. First, this was a retrospective, single-center analysis with a relatively modest number of patients with persistent left superior vena cava (PLSVC), which may limit the generalizability of the findings to broader populations. Second, only patients who underwent single-chamber permanent pacemaker implantation were included; therefore, the results cannot be extrapolated to patients receiving other types of permanent heart rhythm devices (PHRDs), such as dual-chamber pacemakers, implantable cardioverter-defibrillators (ICDs), or cardiac resynchronization therapy (CRT) devices. Despite propensity score matching, residual confounding cannot be excluded.

## Conclusion

The presence of PLSVC may increase procedural difficulty and fluoroscopy exposure during single-chamber pacemaker implantation. However, successful lead placement can be achieved using standard implantation techniques with appropriate stylet shaping, similar to patients without PLSVC. However, long-term pacing performance and complication rates are comparable to those in patients without PLSVC, underscoring the feasibility and safety of device implantation in this challenging anatomy.

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