

# Beyond the Right Superior Vena Cava: CT Depiction of Persistent Left Superior Vena Cava Variants

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**Abstract:** ***Background:** Persistent left superior vena cava (PLSVC) is rare congenital thoracic venous anomaly, resulting from failure of involution of the inferior segment of left anterior cardinal vein during embryogenesis. Although frequently asymptomatic, PLSVC may have important clinical implications during central venous catheterization, cardiac device implantation, and cardiothoracic surgery. **Cases:** We present here four cases of PLSVC who presented with transfusion-associated circulatory overload (TACO), central venous catheter extending through anomalous vessel along the left heart border and isolated PLSVC with absent right superior vena cava. **Conclusion:** PLSVC encompasses a broad spectrum of anatomical variants with variable clinical significance. Recognition of these anomalies on CT is essential for accurate interpretation of thoracic imaging, safe central venous access, and pre-procedural planning.*

**Keywords:** Persistent left superior vena cava, Thoracic venous anomaly, Computed tomography, Coronary sinus dilatation, Central venous catheterization

## 1. Introduction

Persistent left superior vena cava (PLSVC) is the rare congenital anomaly of the systemic thoracic veins, arising from failure of involution of the inferior segment of the left anterior cardinal vein during the fifth to eighth week of embryogenesis.<sup>6</sup> In the normal developmental sequence, the inferior segment of the left anterior cardinal vein regresses to form the ligament of Marshall; failure of this regression results in persistence of the left-sided superior caval system.<sup>16</sup>

The reported prevalence of PLSVC ranges from 0.3% to 0.5% in the general population, rising to 1.3–4.3% in patients with congenital heart disease.<sup>21</sup> In the majority of cases PLSVC drains into the right atrium via a dilated coronary sinus, the so-called classical variant.<sup>34</sup> Less commonly, drainage occurs directly into the left atrium, the pulmonary venous system, or the pulmonary arterial circulation - arrangements carrying significant haemodynamic and procedural consequences.<sup>7</sup>

Although usually asymptomatic, PLSVC assumes clinical importance in several procedural settings: central venous catheterisation via the left subclavian or internal jugular vein, cardiac rhythm device implantation, transcatheter interventions, and open cardiothoracic surgery.<sup>34,5</sup> Failure to recognise the anomaly may lead to catheter malposition, device dislodgement, or intraoperative haemodynamic compromise.<sup>5,7,8</sup>

Multi-detector computed tomography (CT) with intravenous contrast enhancement provides excellent spatial resolution and multiplanar reconstruction capability, permitting comprehensive mapping of variant venous anatomy in a single acquisition.<sup>4</sup> The present series illustrates the spectrum of PLSVC variants encountered during routine and emergency CT practice, with particular attention to catheter-related findings and their procedural implications.<sup>8</sup>

## 2. Methods

This case series includes four patients with persistent left superior vena cava (PLSVC) encountered over a two-year period. Cases were identified either incidentally during routine interpretation of contrast-enhanced CT examinations or following further CT evaluation prompted by an abnormal left-sided course of a central venous catheter on chest radiography. Imaging findings were reviewed with emphasis on the venous anatomy, drainage pattern, associated cardiovascular anomalies, and their relevance to clinical management.

All CT studies were performed on multi-detector scanners (128 slice) few with intravenous administration of iodinated contrast medium in the venous or equilibrium phase and few with administration of iodinated contrast medium through the central venous catheter. Axial source images were reviewed alongside coronal, sagittal, and oblique maximum-intensity-projection (MIP) and volume-rendered (VR) reconstructions. Imaging findings were evaluated for: (i) the course and

calibre of the PLSVC; (ii) its drainage destination; (iii) associated venous anomalies, including coronary sinus dilatation, absence of the right superior vena cava, and brachiocephalic vein hypoplasia; and (iv) the position and trajectory of indwelling central venous catheters.<sup>124</sup>

### 3. Results

#### Case 1 - PLSVC with Pulmonary Arterial Drainage and TACO

A patient with transfusion-associated circulatory overload (TACO) demonstrated a rare PLSVC draining into the pulmonary arterial circulation, in whom a left internal jugular venous catheter was noted to course through the anomalous vessel<sup>78</sup> - representing the rare variant of PLSVC with pulmonary arterial drainage. (Figure 1)

#### Cases 2 - Classical PLSVC Draining into Dilated Coronary Sinus

Showed the classical variant of PLSVC draining into a markedly dilated coronary sinus, with central venous catheter inserted via the left internal jugular vein extending through the anomalous vessel<sup>38</sup> - a recognized pattern of apparent catheter malposition in unrecognized PLSVC. (Figure 2)

#### Case 3 - Classical PLSVC with Hypoplastic Left Brachiocephalic Vein

Showed the classical variant of PLSVC draining into a markedly dilated coronary sinus, with central venous catheters inserted via the left internal jugular vein extending through the anomalous vessel<sup>38</sup> - a recognized embryological correlate of PLSVC in which reduced flow through the hypoplastic left brachiocephalic vein reflects preferential drainage via the persistent cardinal system.<sup>6</sup> (Figure 3)

#### Case 4 - Isolated PLSVC with Absent Right Superior Vena Cava

CT angiogram performed for peripheral artery disease revealed isolated PLSVC as the sole superior caval drainage route, with complete absence of the right superior vena cava - the rarest anatomical arrangement, occurring in approximately 0.09–0.13% of the population.<sup>14</sup> In this the right brachiocephalic vein crossed the midline to drain into the left-sided superior vena cava before emptying into a dilated coronary sinus.<sup>14</sup> (Figure 4)

### 4. Discussion

The four cases presented illustrate the breadth of anatomical variants subsumed under the designation of PLSVC, ranging from the common classical pattern of coronary sinus drainage to the rare configuration of pulmonary arterial communication. This spectrum mirrors the range documented in landmark reviews of the condition.<sup>216</sup>

The embryological basis for the variable drainage destination of the PLSVC lies in the timing and completeness of involution of adjacent cardiac structures. When the sinus venosus develops normally, the PLSVC drains into the coronary sinus, as seen in Cases 2 and 3. Anomalous connections to the left atrium or pulmonary vasculature arise

when developmental errors occur at earlier stages, producing the haemodynamically significant variants typified by Case 1.<sup>617</sup>

The clinical significance of PLSVC is most acutely manifest in the context of central venous catheterisation. Catheters inserted via the left subclavian or left internal jugular vein will naturally follow the PLSVC into the coronary sinus if the anomaly is unrecognised, producing an aberrant trajectory on chest radiography that may be mistaken for malposition or looping in a conventional vessel.<sup>38</sup> Schummer et al. specifically described this four-case pattern in 2003, noting that pressure waveforms and catheter function may remain misleadingly normal even when the tip lies within the coronary sinus.<sup>8</sup>

The presence of a hypoplastic left brachiocephalic vein (Case 3) is an important ancillary CT finding that should prompt active search for PLSVC, as it reflects the redistributed venous flow that maintains the persistent cardinal vessel. Uemura et al. documented this association comprehensively in a surgical series, emphasising its implications for operative planning.<sup>6</sup>

The absent right superior vena cava demonstrated in Case 4 represents the extreme end of the spectrum and carries the greatest procedural hazard. In this configuration, all superior body venous drainage is channelled through the PLSVC and thence the coronary sinus; inadvertent coronary sinus catheterisation or ablation carries risk of right heart outflow tract obstruction and haemodynamic compromise.<sup>14</sup> Irwin et al. have outlined the diagnostic and therapeutic implications of this variant in detail.<sup>4</sup>

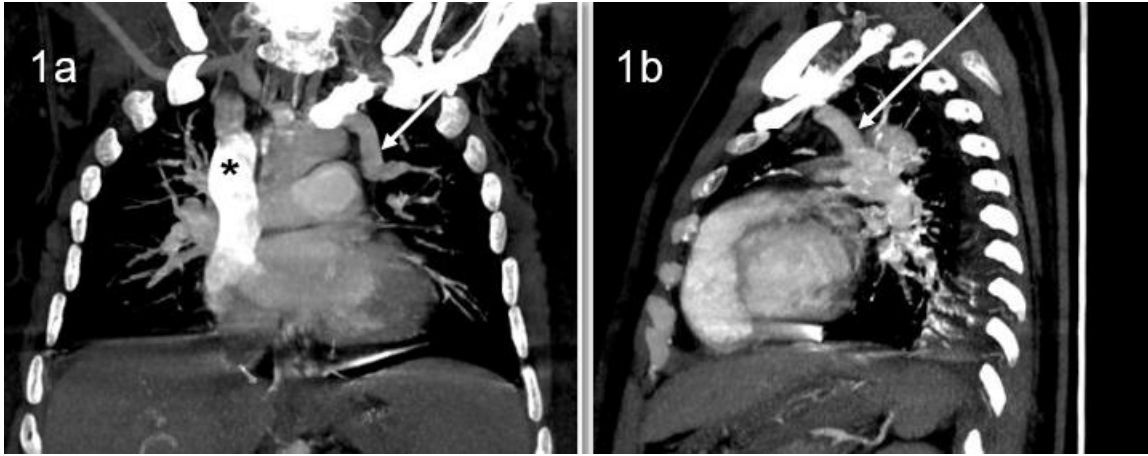
Multi-detector CT, with its capacity for isotropic volume acquisition, is uniquely suited to delineate these anomalies. MIP images align naturally with the oblique course of the PLSVC; VR displays provide intuitive spatial orientation for surgical and interventional planning.<sup>4</sup>

In a subset of patients with PLSVC, the site of venous drainage was accurately delineated by administering contrast through the pre-existing CVC line and CT acquisition was meticulously timed to coincide with optimal opacification of the anomalous venous pathway, allowing clear visualization of the PLSVC and coronary sinus.

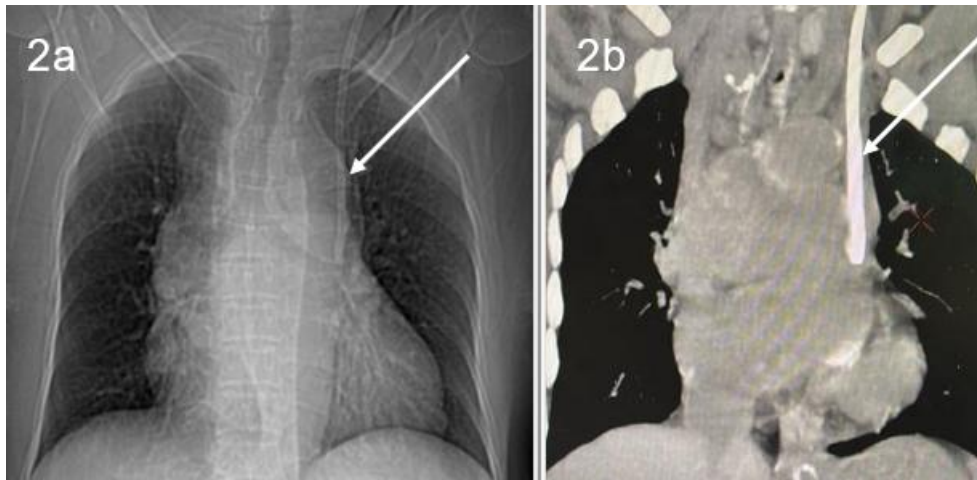
### 5. Conclusion

PLSVC encompasses a broad spectrum of anatomical variants with variable hemodynamic and procedural significance.<sup>617</sup> Recognition of these anomalies on CT is essential for accurate interpretation of thoracic imaging, safe central venous access, and pre-procedural planning in cardiac and thoracic interventions.<sup>125</sup> This series illustrates both the common classical variant and uncommon configurations, including pulmonary arterial drainage and isolated PLSVC with absent right superior vena cava, and highlights the pivotal role of multi-detector CT in comprehensive venous mapping.<sup>418</sup>

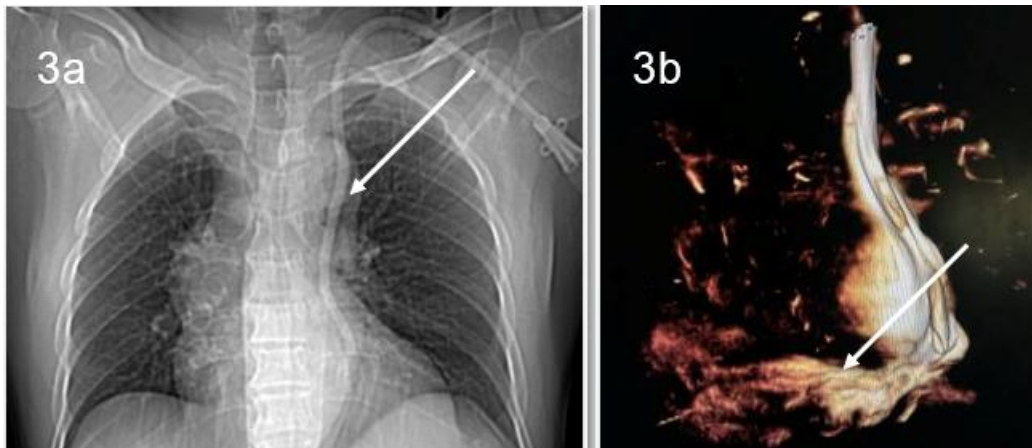
### Image Gallery

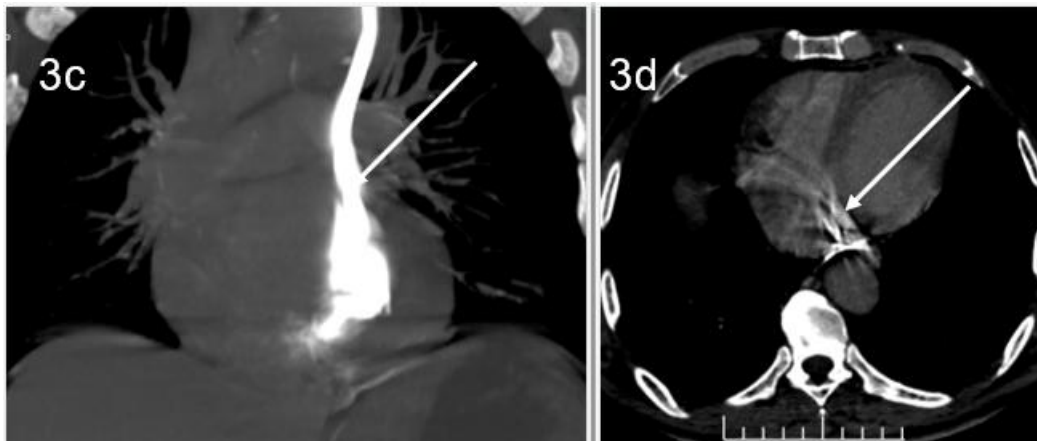


**Figure 1:** Coronal (1a) and Sagittal (1b) contrast enhanced CT thorax images showing normal RSVC (\*) anomalous vein draining into the pulmonary arterial circulation (arrow) - PLSVC with Pulmonary Arterial Drainage

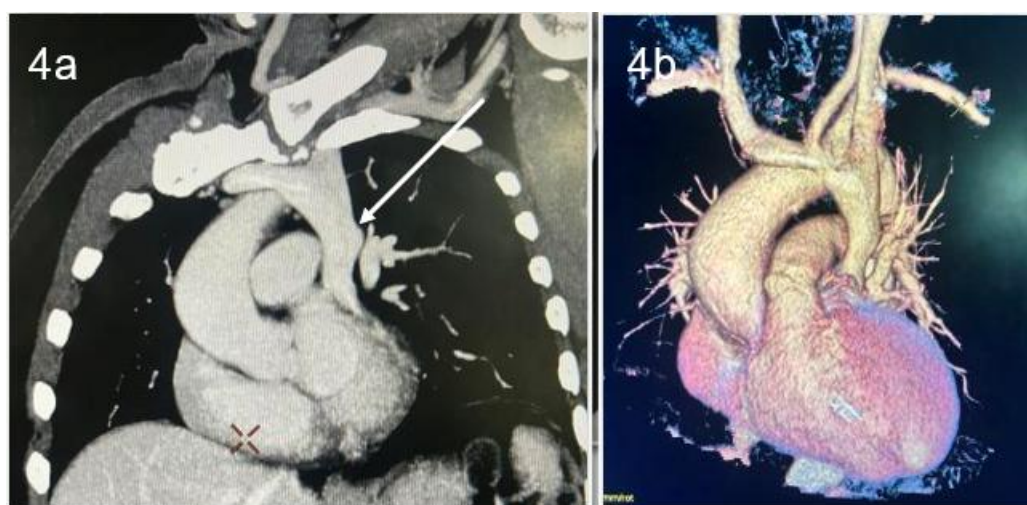


**Figure 2:** CT scanogram (2a) showing venous catheter coursing along the left heart border. CT coronal image (2b) demonstrating central venous catheter inserted via the left internal jugular vein extending through the anomalous vessel





**Figure 3:** CT scanogram (3a) showing venous catheter coursing along the left heart border. CT VR image (3b) showing contrast injected into catheter opacifying PLSVC draining into coronary sinus. CT thorax coronal MIP image (3c) demonstrating contrast opacified central venous catheter inserted via the left internal jugular vein extending through the anomalous vessel draining into dilated coronary sinus. Axial image (3d) showing opacification of coronary sinus - Classical PLSVC Draining into Dilated Coronary Sinus



**Figure 4:** CT chest angio coronal (4a) and VR (4b) images showing isolated PLSVC as the sole superior caval drainage route, with complete absence of the right superior vena cava - Isolated PLSVC with Absent Right Superior Vena Cava

**Conflicts of Interest** - None declared.

**Funding** - None.

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