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CASE REPORT

Superior Vena Cava Obstruction After Pediatric Cardiac Surgery: A Case Series

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Abstract

Background: Superior vena cava (SVC) obstruction is a rare but potentially life–threatening complication following pediatric cardiac surgery, particularly in patients with congenital heart disease. Mechanical factors related to central venous catheterization and underlying venous anomalies may increase the risk of this condition.

Case: We reported a case series of three pediatric patients who developed postoperative SVC obstruction following corrective cardiac surgery and were managed in the intensive care unit (ICU). All patients underwent insertion of a central venous catheter (CVC) via the internal jugular vein for perioperative hemodynamic support. Postoperatively, all patients developed clinical manifestations consistent with SVC obstruction, including facial and upper extremity edema, venous congestion, hemodynamic instability, and reduced urine output. Vascular ultrasonography confirmed partial to severe SVC obstruction in all cases. Two patients had associated anatomical variations, including a persistent left SCV, which may have contributed to altered venous drainage. Management strategies included CVC repositioning or removal, anticoagulation therapy, and surgical release of the obstruction when indicated. These interventions resulted in clinical and hemodynamic improvement in all affected patients.

Discussion: This case series highlights the importance of recognizing mechanical and anatomical risk factors for SVC obstruction in pediatric cardiac surgery, including catheter size, tip position, and congenital venous anomalies.

Conclusion: careful selection of CVC size, optimal tip placement, and ultrasound guidance for catheter positioning and postoperative assessment may help prevent this serious complication. Early diagnosis and timely intervention are essential to reduce morbidity and improve outcomes in this vulnerable population.

Keywords: Cardiac surgery; case series; central venous catheters; pediatric; superior vena cava syndrome

Introduction

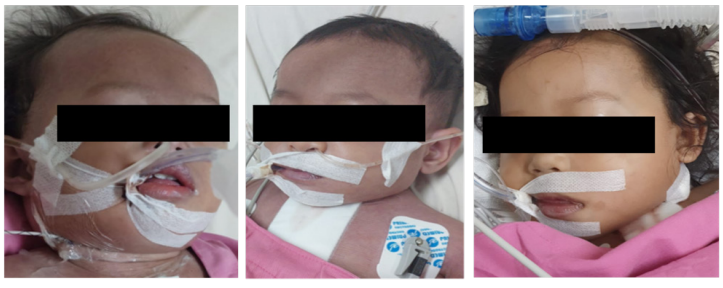
SCV obstruction in pediatric patients is rare. One of the recognized causes of this complication is the use of CVC, which has been associated with vascular stenosis and occlusion, particularly with prolonged catheterization. Anatomical variations of the pediatric SVC are frequently associated with other congenital cardiac anomalies. In addition, thrombophilia, tumors, and intrinsic vascular stenosis are known contributors to the development of SVC thrombosis.[1]. The incidence of SVC obstruction post–cardiac

surgery is not uniformly reported across studies. For instance, in pediatric orthotopic heart transplantation (OHT), the incidence was found to be 3.1%[2]. In another study involving repair of anomalous right upper pulmonary veins in children, 7% of patients required intra–operative revision due to obstruction and 5% required reintervention post–discharge[3]. This case series aims to describe the clinical presentation, underlying risk factors, diagnostic findings, and management strategies of postoperative SVC obstruction in pediatric patients with congenital heart disease, highlighting the roles of central venous catheterization and anatomical venous variations in its development.

Case Description

The following report describes 3 pediatric patients who developed postoperative SVC obstruction after congenital cardiac surgery and were managed in the ICU. At the beginning of surgery, a 5–Fr internal jugular CVC was inserted in all three pediatric patients to facilitate the administration of inotropes, vasopressors, and intravenous fluids. All patients subsequently developed postoperative symptoms of SVC obstruction, including swelling and erythema of the head, neck, and upper extremities, with symptom severity varying according to the degree of SVC narrowing.

Patient A was a 1–year–3–month–old child who underwent surgical closure of a large malalignment ventricular septal defect (VSD) with pulmonary malposition, underweight with growth stunting, and severe malnutrition. At the time of surgery, the patient weighed 6.8 kg and was 71.5 cm tall (BMI 11.11 kg/m^2; BSA 0.47 m^2). The corrective cardiac surgery was performed on June 6, 2024. In this patient, head swelling was noted on postoperative day 2, accompanied by signs of low cardiac output, with a urine output (UOP) of 0.2 mL/kg/h (compared with 2.1 mL/kg/h on the previous day). Postoperative transthoracic echocardiography (TTE), conducted postoperatively on the same day, demonstrated preserved left ventricular systolic function (LVEF of 52%) and tricuspid annular plane systolic excursion (TAPSE) of 7 mm. Trivial tricuspid regurgitation (TR) with a pressure gradient of 19 mmHg and mild aortic regurgitation (AR) with a pressure half–time of 505 ms were noted. No residual VSD, mitral regurgitation (MR), pulmonary regurgitation (PR), or pericardial effusion (PE) was observed. Postoperatively, vascular ultrasonography was performed 2 days after surgery (June 8, 2024), which revealed dilatation of the SVC to 11.6 mm in diameter and partial obstruction below the innominate vein at the SVC junction. A residual luminal opening of approximately 2.5 mm was identified, with minimal flow toward the right atrium and a stenotic flow velocity of 123 cm/s. A persistent left superior vena cava (PLSVC) was present, demonstrating patent flow partially draining into the intracardiac circulation and partially into a small innominate vein, with a diameter of 6 mm. Due to hemodynamic instability, surgical exploration



(a) (b) (c)

Figure 1 Clinical Presentation of Pediatric Patients with Postoperative SVC Obstruction (a) Patient A, (b) Patient M, and (c) Patient K

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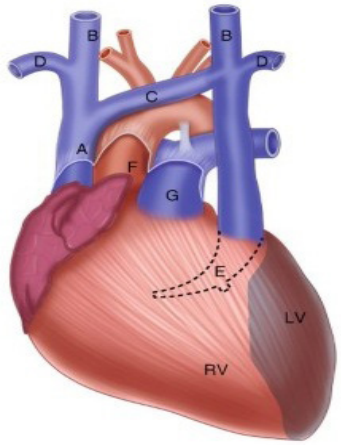

Figure 2 Persistent Left Superior Vena Cava (PLSVC)[9]

was immediately undertaken on the same day following vascular ultrasonography. Intraoperative surgical exploration findings confirmed PLSVC involving the hemiazygos vein. A CVC narrowed the SVC lumen. Following withdrawal of the catheter from the innominate vein, the SVC lumen expanded, although a soft thrombus was already present. The CVC was withdrawn without relocation, resolving the obstruction (Figure 1a).

Patient M was a 1–year–1–month–old child who had undergone VSD closure for a large VSD with a double–committed subarterial (DCSA) left–to–right shunt. The child was severely underweight with normal height and exhibited marasmic–type malnutrition. Anthropometric measurements included a weight of 7.65 kg, height of 72.3 cm, BMI of 14.62 kg/m^2, and BSA of 0.39 m^2. The corrective cardiac surgery was performed on 20 June 2024. In this patient, head swelling was observed on postoperative day 1, along with signs of low cardiac output and a UOP of 0.5 mL/kg/h. Postoperative TTE performed on the same day demonstrated an EF of 56%, TAPSE of 6 mm, mild TR with a peak gradient of 18 mmHg, and mild mitral regurgitation with a central jet measuring 12 mm. No. AR or residual VSD was observed. Postoperative vascular ultrasonography was performed on the following day (June 21, 2024), which confirmed SVC obstruction. A heparinization regimen was initiated, beginning with a bolus followed by continuous infusion. Following vascular ultrasonography, intraoperative reassessment was immediately performed and revealed no thrombus. The stenosis was caused by a pledget used during intraoperative SVC cannulation. The pledget was removed, followed by SVC repair. The CVC was subsequently withdrawn without relocation, resolving the obstruction (Figure 1b).

Patient K was a 2–year–4–month–old child who had undergone total correction of Tetralogy of Fallot (TOF). The child weighed 10.6 kg and measured 84.5 cm, with a BMI of 14.84 kg/m^2 and a BSA of 0.49 m^2. Surgery was conducted on 5 July 2024. Postoperative TTE was performed on the same day, which demonstrated an EF of 63% and a TAPSE of 6 mm. Residual VSD was not observed. There

Table 1 Zones of CVC Tip Placement[10]

Catheter Tip Location	Zona	Advantages	Disadvantages
Left brachiocephalic vein	C	Outside the pericardium. Left-sided catheters can be withdrawn to this position.	Smaller vein diameter. Close to the venous junction. Not suitable for long-term use, sclerosant drugs, or high-volume infusion.
Upper SVC	B	Ideal position for right-sided catheters. Outside the pericardium.	Left-sided catheter tips may abut the SVC wall.
At the right atrium (RA)	A	Tip position suitable for all access routes. Larger vessel diameter and optimal flow.	Intrapericardial location. Risk of arrhythmia. Catheter migration may result in cardiac tamponade.

was a trivial TR with a peak gradient of 16 mmHg, residual atrial septal defect (ASD) flow, and mild–to–moderate residual pulmonary stenosis (PS) with a peak gradient of 40 mmHg. Postoperative vascular ultrasonography was performed the following day (July 6, 2024), which showed SVC obstruction with a high flow velocity of 226 cm/s. No surgical intervention was required. The CVC was relocated from the internal jugular vein to the femoral vein, with complete removal of the internal jugular catheter, which resulted in resolution of the obstruction (Figure 1c).

All three patients demonstrated postoperative hemodynamic instability with increasing vasopressor requirements. In Patients A and M, hemodynamic status improved following surgical intervention to relieve the obstruction.

Discussion

SVC obstruction is a rare complication following cardiac surgery and occurs more frequently in pediatric patients. Importantly, international data suggest that postoperative SVC stenosis is multifactorial and not exclusively related to CVC placement. Postoperative SVC stenosis is multifactorial, with causes ranging from mechanical factors, surgical procedures and CVC to thrombosis, fibrosis, and iatrogenic factors. Obstruction may result from external compression or internal occlusion, leading to impaired venous drainage to the heart and potentially life–threatening hemodynamic instability. Mechanical factors, including improper venous cannula placement, retractor–induced compression, or thrombus formation on intravascular catheters, may contribute to the development of SVC obstruction[4]. Surgical procedure–related complications may also lead to SVC obstruction, particularly following corrective procedures such as repair of total or partial anomalous pulmonary venous drainage (TAPVD/PAPVD), the Mustard or Senning procedure, cardiac transplantation, and arterial switch operations[5]. In patients undergoing complex cardiac surgeries, SVC stenosis may occur as a result of intraoperative manipulation, leading to subsequent scarring or luminal narrowing of the vessel. Additionally, external compression of the SVC, such as from surgical closure or surrounding structures, may further compromise venous return and predispose to obstruction. This mechanical mechanism is particularly relevant in the immediate postoperative period. Importantly, while catheter–related obstruction was identified in our cases, routine early removal of CVC in the immediate postoperative setting is not universally indicated and should be guided by clinical assessment and imaging confirmation.

All 3 patients underwent catheter insertion using a 5–Fr catheter. The CVC size was selected based on the patient's age. Catheters measuring 4–5 Fr are recommended for infants younger than 6 months, 5 Fr for children aged 6 months to 5 years, and 7 Fr for children older than 5 years. Recommended insertion depths are 5 cm for children weighing less than 15 kg, 8 cm for those weighing 16–40 kg, and 13 cm

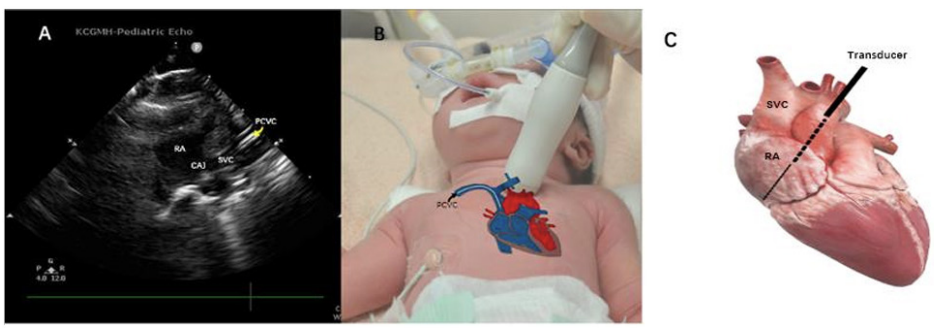

Figure 3 Visualization of the CVC and SVC using Transthoracic Echocardiography (TTE)[12]

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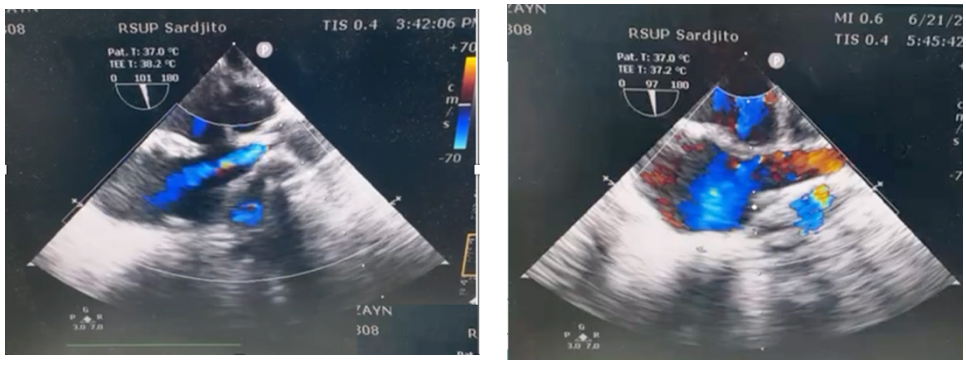

(A) **(B)**

Figure 4 (A) TEE Bicaval View Visualization in Patient MHA Before Obstruction Release (B) TEE Bicaval View Visualization in Patient MHA After Obstruction Release

for children weighing more than 40 kg.[7].

Patients A and K had an additional anatomical anomaly: a PLSVC. It results from the failure of the left superior cardinal vein to regress during embryonic development.[8]. The presence of PLSVC may influence the size and function of the right superior vena cava. PLSVC is a congenital venous anomaly in which venous drainage from the left side of the upper body flows into a left–sided superior vena cava (Figure 2). This condition is often asymptomatic but may be associated with other congenital heart defects and complications during medical procedures. The presence of PLSVC can result in anatomical variations that affect the size of the right SVC, potentially rendering it smaller or altering its function due to venous redistribution.

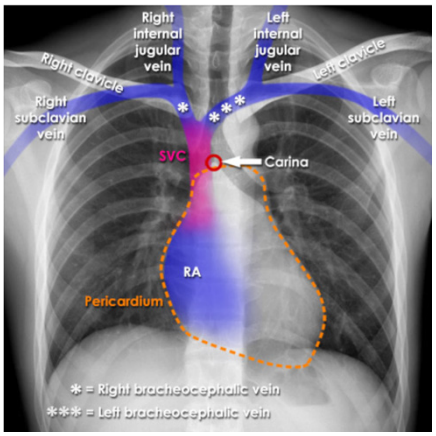

Figure 5 Anatomical Position of The SVC on Chest Radiography[13]

Careful reconsideration of catheter size is necessary in patients with congenital anomalies, those with a PLSVC, those with a history of small–caliber vessels (e.g., after previous catheterization), and those undergoing cardiac surgery. In these patients, a smaller CVC should be considered.

In Patients A and M, catheter repositioning was performed by withdrawing the CVC to the level of the innominate vein junction (Zone B). Positioning the catheter tip at the junction of the SVC and the left brachiocephalic vein may represent a potential strategy to prevent superior vena cava obstruction.

Ultrasound (US) guidance for CVC tip position is a promising technique that improves the accuracy and safety of catheter placement. Ultrasound provides a real–time visualization method that has traditionally been used to confirm correct catheter tip positioning. This technique can be performed using transthoracic echocardiography (TTE) or transesophageal echocardiography (TEE). Using a cardiac probe, TTE can be performed in the parasternal long–axis (PLAX) view with the infant right–tilted to visualize the CVC and SVC, as shown in Figure 3. Alternatively, TEE can be used in the bicaval view, as illustrated in Figure 4. Ultrasound can also be used to assess for obstruction after CVC placement. Alternatively, the distance from the puncture

site to approximately 1 cm above the carina can be measured directly on a chest radiograph to position the CVC tip in the upper SVC.[11]

Conclusion

This case series reports three pediatric patients with congenital heart disease who developed SVC obstruction following cardiac surgery. Mechanical factors, including improper venous cannula placement, retractor–induced compression, or thrombus formation on intravascular catheters, may contribute to the development of SVC obstruction. In addition, surgical procedure–related complications can result in SVC obstruction, particularly after interventions such as TAPVD/PAPVD, the Mustard or Senning procedure, cardiac transplantation, and arterial switch operations.

Careful reconsideration of CVC size is warranted in patients with congenital anomalies, those with a PLSVC, those with a history of small–caliber vessels (e.g., prior catheterization), and those undergoing cardiac surgery, as smaller CVCs may be required. Ultrasound can be used from the puncture site to approximately 1 cm above the carina to assess for obstruction following CVC placement and provides a real–time visualization method for accurate determination of CVC tip position. Additionally, direct measurement of the distance on chest radiography may be utilized to guide optimal CVC tip positioning.

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