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Case Report

Modified Warden technique for repair of partial anomalous pulmonary venous drainage. A case report

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ABSTRACT

Partial anomalous pulmonary venous drainage is an uncommon condition representing 0.6% of all congenital malformations that may be associated with an atrial septal defect. In the present report, we describe a modification of the Warden technique for surgical repair of partial anomalous pulmonary venous drainage with atrial septal defect by using a superior vena cava flap and a right atrial appendage flap to create a new tension-free cavoatrial continuity (neo right superior vena cava), along with redirection of the anomalous pulmonary veins to the left atrium through the atrial septal defect using an autologous pericardial patch. The patient had a favorable postoperative course, with no evidence of residual shunt or obstructive gradient across the anastomosis, and was discharged on postoperative day six.

Keywords: Atrial Septal Defect; Anomalous Pulmonary Venous Return; Cardiac Surgical Procedures (Source: MeSH-NLM).

RESUMEN

Técnica de Warden modificada para corrección de drenaje venoso pulmonar anómalo parcial. Reporte de caso

El drenaje venoso pulmonar anómalo parcial es una enfermedad poco frecuente que representa el 0,6% de todas las malformaciones congénitas; puede estar asociado a un defecto septal atrial. En el presente reporte describimos una modificación de la técnica de Warden para la reparación quirúrgica del drenaje venoso pulmonar anómalo parcial con defecto septal auricular, mediante la utilización de un colgajo de vena cava superior y de un colgajo de apéndice auricular derecho, para crear una nueva continuidad cavo-atrial sin tensión (neovena cava superior derecha), además del redireccionamiento de las venas pulmonares anómalas a través del defecto atrial mediante un parche de pericardio autólogo. El paciente presentó una evolución posoperatoria favorable, sin evidencia de cortocircuito residual ni gradiente obstructivo en la anastomosis, siendo dado de alta al sexto día posoperatorio.

Palabras clave: Defectos del Tabique Interatrial; Venas Pulmonares; Procedimientos Quirúrgicos Cardiacos (Fuente: DeCS-BIREME).

Introduction

Normal pulmonary venous drainage, characterised by four separate veins with distinct ostia, is present in 60-70% of the population; anatomical variants include a single left ostium or the presence of five pulmonary veins [1].

Anomalous pulmonary venous drainage is a rare congenital cardiac malformation first described by Jacobus Bontius Winslow in 1739 [2], in which one or more pulmonary veins do not drain into the left atrium. This anomaly includes total anomalous pulmonary venous drainage (TAPVD), partial anomalous pulmonary venous drainage (PAPVD), and scimitar syndrome [3].

PAPVD is a recognised cause of left-to-right shunt and leads to dilation of the right-sided cardiac chambers; its prevalence is 0.4-0.7% of all congenital heart defects, based on autopsy findings [4]. In most cases, it is associated with atrial septal defects, particularly sinus venosus defects [5].

The right pulmonary veins are most commonly affected, and drainage into the superior vena cava (SVC) is not uncommon. When repairing PAPVD, the main objective is to create unobstructed pulmonary and systemic venous pathways while preserving sinus node function [6]. In cases of PAPVD where the anomalous pulmonary vein drains into the SVC at a high level relative to the right atrium, the Warden technique is one of the surgical approaches used.

Case report

A 12-year-old boy with a history of coarctation of the aorta successfully treated with percutaneous stent implantation presented with New York Heart Association (NYHA) class II dyspnoea of one year's duration. On physical examination, mild right jugular venous distension was observed, with venous oxygen saturation of 85-88%. Transthoracic echocardiography showed dilation of the right cardiac chambers, preserved left and right ventricular systolic function, and a 13 mm superior sinus venosus atrial septal defect with left-to-right shunt. Chest computed tomography angiography demonstrated drainage of the right superior pulmonary vein into the right SVC, a dilated coronary sinus, persistent left SVC, and dilation of the pulmonary artery trunk **(Figure 1)**. Right heart catheterisation revealed pulmonary hypertension with a mean pulmonary artery pressure of 26 mmHg and pulmonary vascular resistance of 0.48 Wood units. Given the diagnosis of sinus venosus atrial septal defect with PAPVD and signs of right ventricular volume overload without prohibitive pulmonary hypertension, surgical treatment using the Warden technique was indicated.

In the operating theatre, a median sternotomy was performed, and the pericardium was opened on the left side to preserve autologous pericardium, which was treated with 0.6% glutaraldehyde for later use as a patch **(Figure 2)**. Extensive dissection of the right SVC was carried out up to the level of the right subclavian and internal jugular veins, exposing the azygos vein and the anomalous pulmonary vein **(Figure 3)**.

Cardiopulmonary bypass was established by cannulation of the ascending aorta, the inferior vena cava via the right atrium, and direct cannulation of the persistent left SVC through the coronary sinus. The right SVC was clamped and divided immediately above the insertion of the anomalous pulmonary vein; the caudal stump was closed with a patch and sutured using 7/0 polypropylene. A right atriotomy was performed to visualise the atrial septal defect, and pulmonary

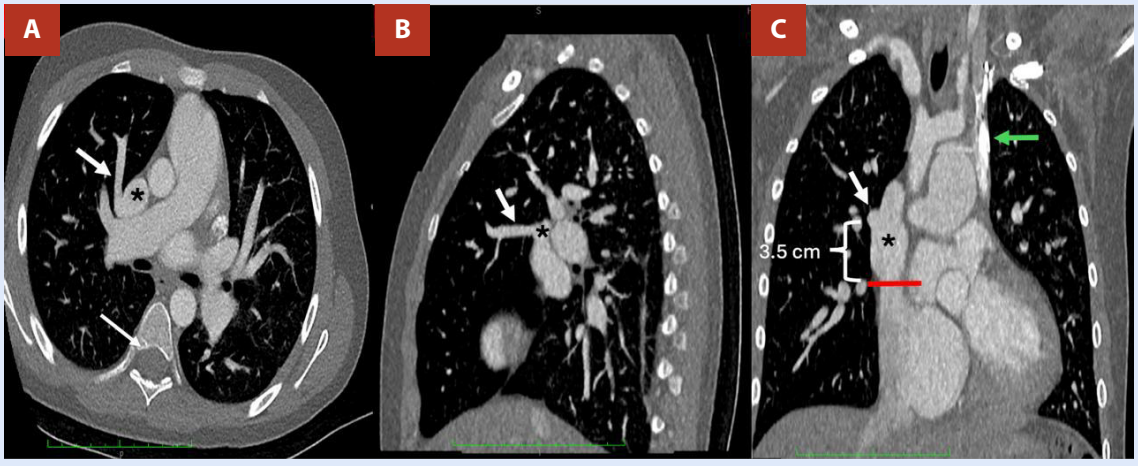

Figure 1. Cardiac and great vessel computed tomography angiography. Axial view showing the right superior pulmonary vein draining into the right superior vena cava **(A)**. Sagittal view **(B)**. Coronal view demonstrating a distance of 3.5 cm from the cavoatrial junction to the insertion of the right pulmonary vein **(C)**. White arrow: right superior pulmonary vein; asterisk: right superior vena cava. Green arrow: left superior vena cava. Red line: cavoatrial junction.

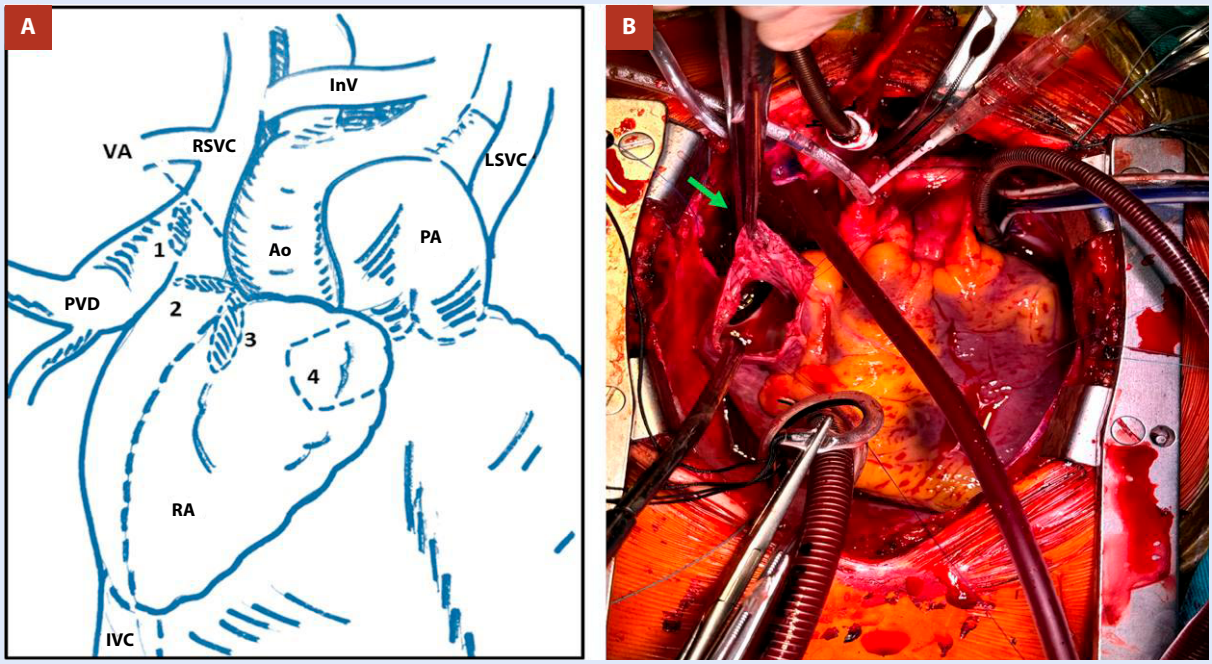

Figure 2. (A) Diagram of intraoperative findings. 1: anomalous cavopulmonary junction. 2: cavoatrial junction. 3: sinus venosus atrial septal defect. 4: atrial flap area. **(B)** Intraoperative findings. Green arrow: superior sinus venosus atrial septal defect.
RSVC: right superior vena cava. LSVC: left superior vena cava. IVC: inferior vena cava. PVD: pulmonary venous drainage. RA: right atrium. Ao: aorta. PA: pulmonary artery. InV: innominate vein.

venous flow was redirected to the left atrium through the septal defect using an autologous pericardial patch. The aortic cross-clamp was removed, and the cavoatrial anastomosis was performed on the beating heart. The atriotomy was extended towards the right atrial appendage, creating an atrial flap used as the posterior wall of the cavoatrial junction, while the anterior wall was augmented with an autologous pericardial patch **(Figure 4)**. Cannulas were removed and haemostasis was confirmed without complications. Cardiopulmonary bypass time was 173 minutes and aortic cross-clamp time was 70 minutes. Postoperative transthoracic echocardiography showed no residual shunt, no obstructive gradients at the anastomoses, and preserved biventricular function. The patient was discharged on postoperative day six.

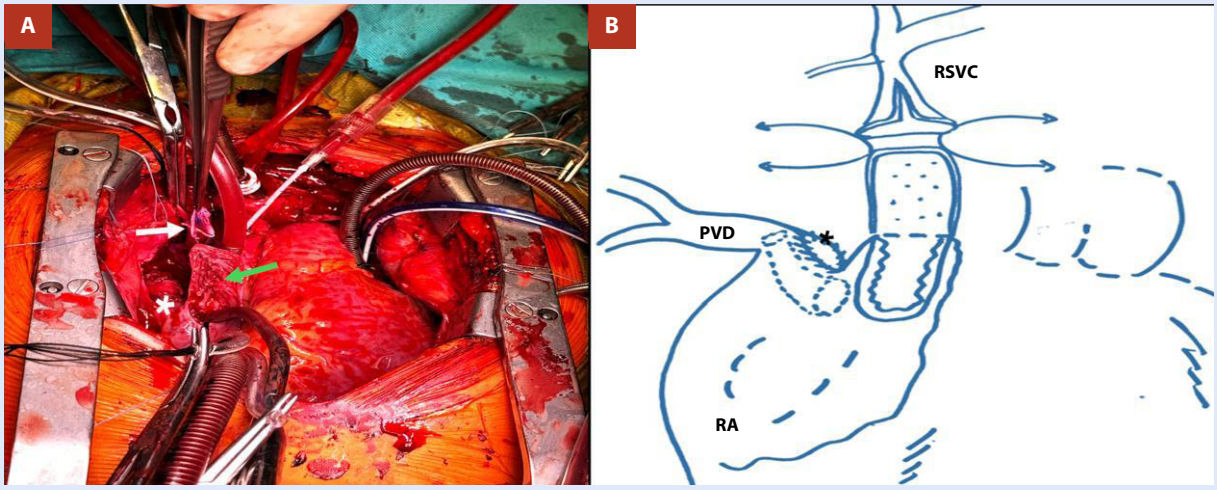

Figure 3. (A) Modified Warden procedure. Green arrow: right atrial flap serving as the posterior wall. White arrow: divided right superior vena cava (RSVC). White asterisk: remnant of the superior vena cava closed with a patch. **(B)** Diagram. Dashed lines indicate redirection of pulmonary venous drainage to the left atrium through the atrial septal defect. Anastomosis of the superior vena cava to the right atrial appendage flap is shown. RSVC: right superior vena cava. PVD: pulmonary venous drainage. RA: right atrium.

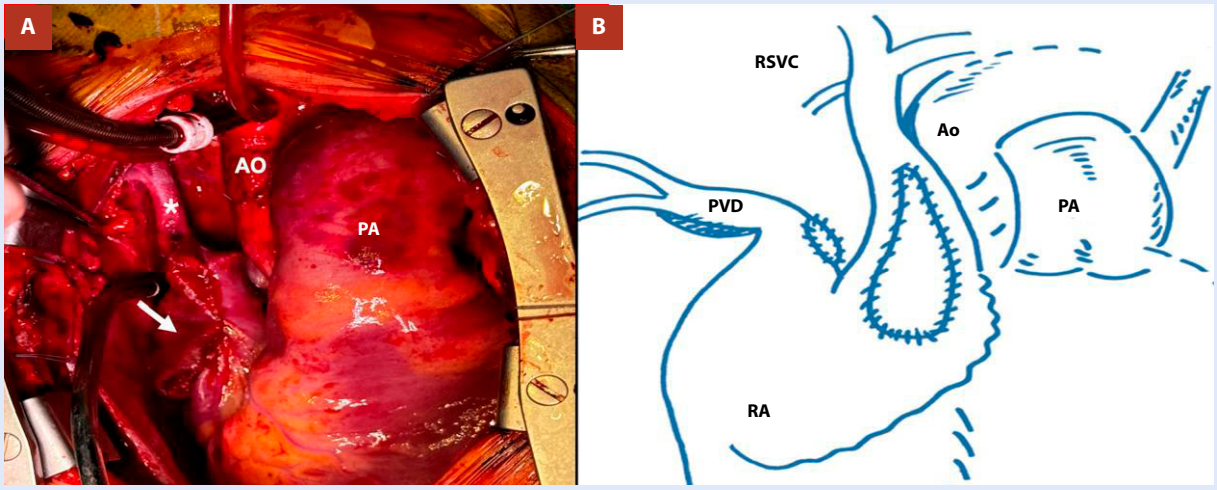

Figure 4. (A) Postoperative result. White asterisk: right superior vena cava anastomosed to the right atrium. White arrow: autologous pericardial patch. **(B)** Diagram showing the use of a pericardial patch at the anastomotic sites. RSVC: right superior vena cava. PVD: pulmonary venous drainage. RA: right atrium. Ao: aorta. PA: pulmonary artery.

Discussion

PAPVD accounts for less than 1% of all congenital heart diseases [6-8], with anomalous drainage of the right pulmonary veins being the most common subtype, representing approximately 90% of cases [6,8]. Furthermore, around 80% of PAPVD cases are associated with sinus venosus atrial septal defects, whereas fewer than 3% occur with an intact interatrial septum [8].

Surgical correction of PAPVD draining into the SVC can be performed using various techniques, including the single-patch technique, double-patch technique, and vena cava division techniques, among which the Warden technique is included. The choice of surgical approach depends on several factors, including the anatomy of anomalous pulmonary venous drainage, associated cardiac anomalies, and surgical expertise. The main complications of surgery include pulmonary vein obstruction, sinus node dysfunction, and stenosis of the vena cava [8].

In 1984, Warden *et al.* described a technique involving division of the SVC above the entry of the anomalous pulmonary vein; the cephalic segment is anastomosed to the right atrial appendage, while the caudal segment is used as a conduit to redirect pulmonary venous drainage into the left atrium through closure of the atrial septal defect [9,10]. This technique aims to reduce the risk of postoperative sinoatrial dysfunction and obstruction of the pulmonary venous pathway and cavoatrial channel, complications described in techniques requiring incisions near the cavoatrial junction, such as the double-patch technique [11,12].

However, one of the main limitations of the classical Warden procedure is the risk of stenosis or obstruction of the cavoatrial channel, reported in 10-20% of cases [13-15]. To minimise this risk, several modifications have been proposed to achieve a tension-free anastomosis.

Among these, Tao *et al.* described a technique using a right atrial flap combined with an autologous pericardial patch to construct a wider, tension-free cavoatrial channel, thereby reducing the risk of SVC stenosis [16]. Similarly, other modifications have been described using the interatrial septum or native atrial tissue to redirect pulmonary venous flow without the need for additional prosthetic material, aiming to preserve growth potential [17-20].

In the present case, a modified Warden procedure was performed using a right atrial flap and an autologous pericardial patch to reconstruct the cavoatrial anastomosis. This approach allowed the creation of a wide, tension-free venous channel. In addition, the predominant use of autologous tissue may help reduce the risk of late SVC stenosis. Another relevant aspect was the presence of a persistent left SVC, which posed an additional intraoperative challenge and required a venous cannulation strategy through the coronary sinus during cardiopulmonary bypass. Despite this complex anatomy, surgical repair enabled appropriate redirection of pulmonary venous flow to the left atrium without evidence of residual obstruction.

In conclusion, modifications of the Warden technique represent a safe and effective alternative for the treatment of PAPVD draining into the SVC, with satisfactory short- and mid-term postoperative outcomes. Techniques that incorporate native atrial tissue and autologous pericardial patching allow for wide, tension-free anastomoses, which may reduce the risk of venous stenosis and improve postoperative results.

Ethical aspects

Written informed consent was obtained from the patient's parents. The report was approved by the institutional ethics committee.

Author contributions

HAST: conceptualisation, data curation, formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, visualisation, original draft writing, and manuscript writing, review and editing. DMCH: conceptualisation, data curation, investigation, project administration, resources, supervision, validation, visualisation, original draft writing, and manuscript writing, review and editing. AJSR: project administration, software, validation, visualisation, original draft writing, and manuscript writing, review and editing.

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