

## Single-patch, 2-patch, and caval division techniques for repair of partial anomalous pulmonary venous connections: Does it matter?

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**Objective:** We reviewed our experience with the single-patch, 2-patch, and caval division techniques for repair of a partial anomalous pulmonary venous connection.

**Methods:** From 1990 to 2009, 124 patients (65 male patients; 52%) were identified. The single-patch, two-patch, and caval division technique was used in 60 (49%), 24 (19%), and 40 (32%) patients, respectively. The median age was 34.5 years (range, 1–76). Of the 124 patients, 99 (80%) had an atrial septal defect.

**Results:** There was no early mortality. Survival at 5, 10, and 15 years was 99%, 95%, and 82%, respectively. One patient (3%) in the caval division group required early reoperation for superior vena caval obstruction. All patients, except for 3, had regained sinus rhythm at discharge. Late superior vena caval obstruction developed in 3 patients (7.5%) in the caval division group, 3 (5%) in the single-patch group, and 1 (4%) in the 2-patch group ( $P = .5$ ). Two patients underwent reoperation for late pulmonary vein obstruction: 1 (2%) in the single-patch group and 1 (4%) in the 2-patch group ( $P = .08$ ). A permanent pacemaker was required in 3 patients (3%).

**Conclusions:** Surgical treatment of partial anomalous pulmonary venous connections is associated with excellent outcomes. The overall incidence of late superior vena caval or pulmonary vein stenosis is low. Although not significant, the 2-patch technique might be associated with a greater incidence of sinus node dysfunction and late pulmonary venous stenosis. The late development of superior vena caval obstruction is a concern with all techniques, necessitating close follow-up. (*J Thorac Cardiovasc Surg* 2012;143:896-903)

Partial anomalous pulmonary venous connection (PAPVC) includes those cardiovascular anomalies in which 1 or more, but not all, of the pulmonary veins connect to the right atrium directly or indirectly by way of different systemic venous connections. It occurs in about 0.6% to 0.7% of the population,<sup>1</sup> according to autopsy data, but the actual incidence could be greater,<sup>2</sup> because the finding of such an anomaly is not uncommon. PAPVC can occur as an isolated anomaly, although it is commonly associated with a sinus venosus type of atrial septal defect (ASD).

The main principle for anatomic repair of such anomalies usually requires the creation of an intra-atrial baffle to redirect the anomalous pulmonary venous drainage to the left atrium. A number of corrective procedures have been described, including single-patch, 2-patch, and caval division procedures. Surgical correction of such anomalous drainage has excellent outcomes overall. The main concern with

these techniques has been related to the risk of superior vena cava (SVC) or pulmonary venous obstruction and the occurrence of postoperative dysrhythmias or sinus node dysfunction.<sup>3</sup> We analyzed our results with these different surgical techniques for repair of PAPVC.

### METHODS

#### Patient Population

From February 1990 to August 2009, 178 patients with PAPVC were identified. Those with isolated left-sided PAPVC and those who had undergone previous PAPVC surgery were excluded from the present cohort. A total of 124 patients were identified who were undergoing surgical repair for right-sided PAPVC. Three different surgical techniques were used: the single-patch technique in 60 patients (49%), the 2-patch technique in 24 patients (19%), and caval division in 40 patients (32%). The mean age at repair was  $34.9 \pm 23$  years (range, 1–76). Of the 124 patients, 65 were males (52%) and 59 were females (48%); 36 (29%) were children. Using the caval division technique, 18 patients (45%) underwent the traditional Warden procedure, 17 (43%) underwent a modified version of Warden using a short interposition graft to lengthen the SVC, and 5 patients (12%) underwent caval division without reimplantation. The Mayo Clinic and Foundation institutional review board approved the present retrospective review.

#### Preoperative Data

The presence of symptoms or signs of right ventricular volume overload was the main indication for surgery. Of the 124 patients, 50 (40%) were asymptomatic. The most common symptoms were exertional dyspnea in 61 patients (49%) and fatigue in 25 (20%). Preoperative arrhythmias were present in 16 patients (13%), with atrial fibrillation in 14 (11%) and atrial flutter in 2 (2%). PAPVC was not identified during previous cardiac surgeries in 10 patients (8%). Preoperative echocardiographic data

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### Abbreviations and Acronyms

ASD	= atrial septal defect
PAPVC	= partial anomalous pulmonary venous connection
RAA	= right atrial appendage
SVC	= superior vena cava

were obtained for all patients. An ASD was found in 99 patients (80%), with 36 patients (29%) having more than 1 type of ASD. Sinus venosus was the most common ASD, found in 78 patients (63%), with a patent foramen ovale and ostium secundum ASD present in 38 (31%) and 18 (14%) patients, respectively. Anomalous drainage of the right upper and middle lobe veins was the most common PAPVC combination in 78 patients (61%). The mean number of the anomalous veins was 2.1 (range, 1–4). Persistent left SVC was present in 16 patients (13%), with 5 of these patients having well-developed bilateral SVC with a well-developed communicating vein. Associated left PAPVC was present in 5 patients (4%).

### Surgical Technique

Standard median sternotomy was the most common approach in 118 patients (95%), and minimally invasive approaches were used in 2 patients (2%; lower partial sternotomy in 1 and robotic-assisted in 1). Right thoracotomy was used in the remaining 4 patients (3%). In general, the pericardium was opened, and the heart was exposed. The SVC was dissected out to the innominate vein, and the azygous and anomalous pulmonary veins were adequately exposed. Cardiopulmonary bypass was established using standard ascending aortic and bicaval cannulation. The SVC cannula was placed as high as possible in the SVC or in the innominate vein. A persistent left SVC was managed by an additional suction line inserted into the coronary sinus through the right atrium. The mean cardiopulmonary bypass time was  $78 \pm 39$  minutes, with a mean aortic crossclamp time of  $40 \pm 23$  minutes. Normothermia was used in 72 patients (58%). A surgical ASD was created in those patients who had an intact atrial septum by excising the fossa ovalis and extending the incision upward, with removal of a portion of the septum secundum as needed to ensure an adequately size ASD with an unobstructed pathway for the anomalous pulmonary veins.

In cases of associated secundum type ASD, we typically extended the ASD superiorly, as described in the previous paragraph. The anomalous pulmonary veins were then baffled with an internal patch through the ASD into the left atrium. In the single-patch technique, the right atrium was closed primarily, and in the 2-patch technique, an autologous pericardial patch was used for closure of the SVC–right atrium junction (Figure 1). The most commonly used intra-atrial patch materials were untreated autologous pericardium in 65 patients (52%) and bovine pericardium in 43 patients (35%); glutaraldehyde-treated autologous pericardium, polytetrafluoroethylene (Gore-Tex; W. L. Gore & Associates, Flagstaff, Ariz) and Dacron patches were used in 11 (9%), 4 (3%), and 1 (1%) patient, respectively. To avoid isolating the sinus node from the rest of the right atrial wall during patch suturing and to minimize the risk of sinus node dysfunction, we believe that the depth of the suture bites should be partial thickness. These basic surgical principles did not differ among the 3 groups.

For those patients who underwent caval division, the azygous vein was divided and the right SVC was crossclamped and divided above the insertion of the highest anomalous pulmonary vein with oversewing of its caudal end. In 18 patients in the caval division group, the proximal portion of the SVC was anastomosed directly to the right atrial appendage (RAA) after cutting all the trabeculations, and in 17, a short segment of a ringed Gore-Tex graft was used as an interposition graft between the proximal SVC and the RAA (Figure 2). The graft sizes ranged from 14 to 20 mm.

In the remaining 5 patients with bilateral well-developed SVC and a communicating vein, we did not reimplant the right SVC into the RAA (Figure 3).

The most common associated procedures were the modified Cox-Maze procedure using cryoablation or radiofrequency in 17 patients (14%), tricuspid valve annuloplasty in 16 (13%), ligation of the left atrial appendage in 7 (6%), ventricular septal defect closure in 4 (3%), and pulmonary valve replacement in 3 (2%).

### Follow-up

The mean follow-up period from surgery to the last examination was  $6 \pm 5.8$  years, maximum of 20 years. This was shorter in the modified Warden group. This difference resulted from the recent application of this technique at our institution (2006). Follow-up echocardiographic data and electrocardiograms were available for 123 patients (99%). The electrocardiogram was considered early if it was obtained before hospital discharge and late if obtained after discharge. The electrocardiogram was interpreted as normal sinus rhythm, junctional rhythm, and supraventricular arrhythmias, which included atrial flutter, fibrillation, and multifocal atrial tachycardias.

### Statistical Analysis

Categorical variables are reported as the number and percentages. Continuous variables are expressed as the mean  $\pm$  SD or the median and interquartile range. The change in continuous variables was tested using a paired *t* test or signed rank test. The Kaplan-Meier method was used to estimate survival rate at 1, 5, and 10 years. Log-rank test was used to compare survival among the groups.

### RESULTS

There was no early mortality. Early reoperation was required in 3 adult patients (2%). The first patient was a 62-year-old man who underwent a classic Warden procedure that was complicated by SVC obstruction in the early postoperative period despite adequate SVC and RAA mobilization and a tension-free anastomosis. He required reoperation on the same day with conversion to a modified Warden with insertion of a 16-mm ringed Gore-Tex interposition graft. One patient in the single-patch group underwent reoperation for postoperative bleeding. Another patient in the Warden group underwent sternal debridement and rewiring because of sternal dehiscence.

A change in the normal sinus rhythm to a junctional rhythm was noted in 5 patients (21%) in the 2-patch group, 8 patients (20%) in the caval division group, and 7 patients (12%) in the single-patch group. This had recovered at discharge, with all but 3 patients remaining in sinus rhythm at late follow-up. Supraventricular arrhythmias (Figure 4, A) were noted in 9 patients (22%) in the caval division group versus 3 patients (12%) in the 2-patch group and 5 patients (8%) in the single-patch group. Sinus node dysfunction (Figure 4, B) occurred in 3 patients: 2 patients in the 2-patch group (8%) and 1 patient in the caval division group (2%). No patient in the single-patch group had sinus node dysfunction. Three patients required permanent pacemaker placement, 2 patients (1 in the caval division group and 1 in the 2-patch group) had preoperative atrial fibrillation and underwent concomitant modified Cox maze cryoablation

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