

Original Article

The Warden procedure for partially anomalous pulmonary venous connection to the superior caval vein

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Abstract *Purpose:* When there is partially anomalous pulmonary venous connection to the superior caval vein, intracardiac repair alone can result in obstruction. Although the Warden procedure involving translocation of the superior caval vein is commonly performed as an alternative to atriocavoplasty, follow-up of a larger number of patients in the modern era is lacking. We report and discuss the experience of a single institution with the Warden procedure for correction of partially anomalous pulmonary venous connection to the superior caval vein. *Methods:* Since 1995, all 16 patients presenting with partially anomalous pulmonary venous connection to the superior caval vein underwent the Warden procedure at a mean age of 7.1 ± 4.2 years, with a range from 0.2 to 14.3 years, and a mean weight of 24.7 ± 14.0 kg, with a range from 4.1 to 52.9 kg. There were 9 males and 7 females. In 8 patients, we performed 10 concomitant procedures, including closure of an atrial or ventricular septal defect in 7, and advancement of the aortic arch in the other. *Results:* There were no deaths, and only one episode of postoperative sinus bradycardia with intermittent junctional rhythm, which resolved spontaneously during temporary atrial pacing. All patients were discharged home in normal sinus rhythm at an average of 4.1 ± 2.2 days after the procedure, with a range from 2 to 10 days. All are currently in the first grade of the New York Heart Association up to 5.6 years postoperatively. There is currently no evidence of sinus nodal dysfunction, nor obstruction of the superior caval vein, in any patient. *Conclusion:* The Warden procedure for partially anomalous pulmonary venous connection to the superior caval vein produces excellent results, preserves the function of the sinus node, and should be routinely considered for the repair of this lesion.

Keywords: Partially anomalous pulmonary venous return; sinus venosus atrial septal defect; intracardiac repair; atriocavoplasty

PARTIALLY ANOMALOUS PULMONARY VENOUS connection is a rare lesion, most commonly associated with a sinus venosus interatrial communication. When the anomalous pulmonary veins are draining to the superior caval vein, intracardiac repair alone is often not possible. In this setting, Shuster and associates¹ were the first to advocate patch atriocavoplasty to allow unobstructed intracardiac repair, and this approach was subsequently endorsed by others.^{2,3} Nowadays, however, it is more frequent to

use the Warden procedure, involving placement of an intracardiac baffle and translocation of the superior caval vein to the right atrial appendage. Follow-up of a larger series of patients undergoing this latter procedure, to the best of our knowledge, is lacking in the modern era. We report and discuss here the use of the Warden procedure for partially anomalous pulmonary venous connection to the superior caval vein at Texas Children's Hospital.

Methods

Characteristics of patients

Since the first of July 1995, 16 patients have presented with partially anomalous pulmonary venous

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Table 1. Symptoms of patients undergoing the Warden procedure for partial anomalous pulmonary venous return to the superior caval vein.

Symptom	Frequency	Percentage
Poor weight gain	n = 3	19
Easy fatigability	n = 3	19
Frequent upper respiratory tract infections	n = 2	13
Occasional shortness of breath	n = 2	13
Severe congestive heart failure	n = 1	6
Grunting and tachypnea	n = 1	6
Diaphoresis with feeds	n = 1	6

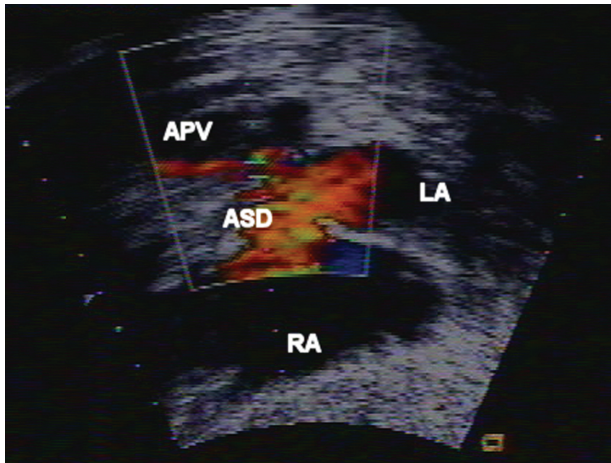


Figure 1.

Preoperative cross-sectional echocardiogram with Doppler flow interrogation demonstrating anomalous drainage of the right pulmonary veins to the superior caval vein. APV: aorta pulmonary vein; ASD: atrial septal defect; LA: left atrium; RA: right atrium.

connection to the superior caval vein. There were 9 males and 7 females. Mean age was 7.1 ± 4.2 years, with a range from 0.2 to 14.3 years, and mean weight was 24.7 ± 14.0 kg, with a range from 4.1 to 52.9 kg. Symptoms were present in 9 patients at the time of surgical referral (Table 1). Patients without symptoms were diagnosed after the discovery of a murmur, and put forward for surgery to limit the effects of chronic right heart overload. All patients underwent transthoracic cross-sectional echo-Doppler examination, while cardiac catheterization was required for further delineation of concomitant lesions and hemodynamic assessment in 5 patients (Fig. 1). Details concerning the precise segment of lung draining anomalously to the superior caval vein are listed in Table 2.

Operative technique

All patients underwent median sternotomy and aortobicaval cannulation. It is essential to cannulate

Table 2. Segments of lung with anomalous venous drainage the superior caval vein.

n	Lung segment
7	Right lung (all segments)
6	Right upper lobe
3	Right upper and middle lobes

Table 3. Operative data for patients undergoing the Warden procedure for partial anomalous pulmonary venous return to the superior caval vein.

Variable	Mean (min)	Range (min)
Cardiopulmonary bypass time	152.1 ± 47.6	83–288
Aortic cross-clamp time	76.5 ± 23.2	53–139
Deep hypothermic arrest (n = 1)	29	N/A
Concomitant Procedures	Frequency	Percentage
Patent Foramen Ovale closure	n = 5	42
Ventricular septal defect closure	n = 2	13
Ligation of aberrant duct	n = 1	6
Left pulmonary vein ostial resection	n = 1	6
Aortic arch advancement	n = 1	6

high at the junction of the superior caval vein with the brachiocephalic vein when planning the Warden procedure. After initiating cardiopulmonary bypass, the intracardiac anatomy is inspected, paying particular attention to the adequacy of the atrial septal defect. One patient required enlargement of the defect, and 1 patient with an intact atrial septum required atrial septectomy prior to construction of the intraatrial baffle. The superior caval vein is transected above the highest returning anomalous vein, the cardiac end being oversewn with a running suture. We utilize an autologous pericardial patch to baffle the orifice of the superior caval vein and the anomalous pulmonary venous return to the left atrium. After the completion of any additional intracardiac repair, the right atrium is closed, and the transected end of the superior caval vein is translocated to an opening made in the right atrial appendage. Prior to completing this anastomosis, it is critical to resect any potentially obstructing pectinate muscles from within the atrium. A total of 10 concomitant procedures were performed in 8 patients, including advancement of the aortic arch in one patient requiring 29 min of deep hypothermic circulatory arrest. Operative data are listed in Table 3.

Results

There were no deaths. The mean time to extubation was 0.5 ± 1.1 days, with a range from 0 to 3 days, and mean time to discontinuation of inotropes was

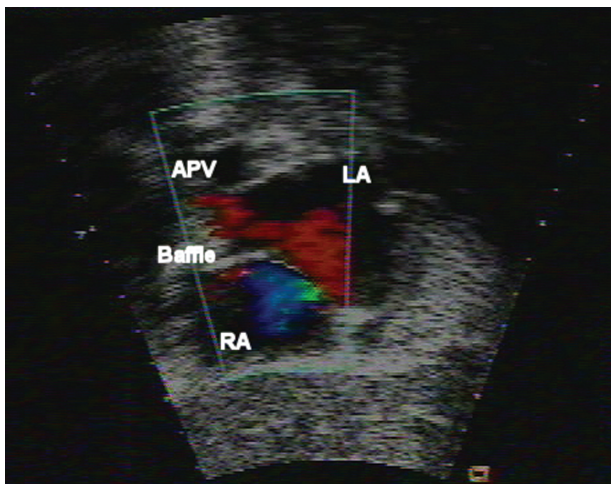


Figure 2.
Late postoperative cross-sectional echocardiogram of the same patient. Note the presence of the intraatrial baffle and unobstructed pulmonary venous flow to the left atrium. Abbreviations as in Figure 1.

0.3 ± 0.8 days, again with a range from 0 to 3 days. Stridor developed in one patient, necessitating reintubation for 2 days. Sinus bradycardia with intermittent junctional rhythm occurred in one patient, and resolved spontaneously after 3 days of temporary atrial pacing. All patients were discharged home in normal sinus rhythm at an average of 4.1 ± 2.2 days after the procedure, with a range from 2 to 10 days. All patients are currently in the first grade of the New York Heart Association functional classification up to 5.6 years postoperatively, with a range from 0.3 to 67.1 months. There is evidence of neither sinus nodal dysfunction, nor obstruction of the superior caval vein, in any patient (Fig. 2).

Discussion

Of 109 patients undergoing repair of a sinus venous interatrial communication reported by Kyger and associates⁴, atriacavoplasty was required in only 6 patients. Although the overall incidence of persistent sinus nodal dysfunction was 11%, this complication occurred in one-third of the patients undergoing atriacavoplasty. Trusler and associates⁵ have reported on 29 patients with partially anomalous pulmonary venous connection to the superior caval vein or the cavoatrial junction. Their atriotomy was only extended into the superior caval vein in 11 cases, 3 of which were closed primarily, and 8 of which underwent atriacavoplasty. In this series, 8 from 18 of these children having postoperative catheterization were found to have narrowing of the atriocaval junction, with gradients as high as 6 mmHg, while 6 patients were in junctional rhythm. These experiences demonstrate the dilemma of augmenting the atriocaval junction.

Patch atriacavoplasty can raise the risk of producing sinus nodal dysfunction, while failure to do so results in an unacceptable incidence of obstruction. Amongst others, DeLeon and associates⁶ found that atriacavoplasty was associated with a 13% rate of sinus node dysfunction, including sinus bradycardia and intermittent complete heart block requiring pacemaker placement, while Agrawal and associates⁷ recently reported an 8% rate of sinus nodal dysfunction, including junctional rhythm requiring placement of a pacemaker, on long-term follow-up of atriacavoplasty.

As far as we are aware, it was Gerbode and his colleagues⁸ who were the first to report animal experiments involving translocation of the superior caval vein. Lewis⁹ then suggested that the anastomosis may be useful in cases of partially anomalous pulmonary venous connection, but did not attempt the procedure in clinical practice. The first clinical experience was reported in 1958,¹⁰ with a second report appearing in 1967.¹¹ Pacifico and Kirklin¹² then utilized the atriocaval anastomosis in a patient requiring takedown of a Glenn anastomosis. Warden and his colleagues, however, had continued to use the technique for repair of partially anomalous pulmonary venous connection, and discussed the long-term outcome in their 14 survivors in 1984.¹³ Obstruction had developed at the atriocaval anastomosis in one patient at 11 months, requiring reoperation, while permanent sinus nodal dysfunction was evident in 3 of 13 patients for whom postoperative electrocardiograms were available.

Subsequent to this, surgeons using Warden's technique have achieved superior results. Williams et al.¹⁴ described using the technique in 6 patients, all of whom remained in normal sinus rhythm up to 18 months postoperatively, with no evidence of superior caval venous obstruction. Gaynor and associates¹⁵ reported comparable success in a series of 11 patients, all remaining in normal sinus rhythm 2 years or more after the operation. Obstruction at the baffle requiring reoperation occurred in 1 patient, but no patient had superior caval venous obstruction. Now, with our added experience using the Warden procedure, we conclude that it is a safe and effective technique for repairing partially anomalous pulmonary venous connection to the superior caval vein, avoiding as it does the need for patch atriacavoplasty, and preserving the function of the sinus node. In our opinion, it should be routinely considered for the repair of this lesion.

References

1. Shuster SR, Gross RE, Colodny AH. Surgical management of anomalous right pulmonary venous drainage to the superior vena cava associated with superior marginal defect of the atrial septum. *Surgery* 1962; 51: 805–808.

2. Kirklin JW, Barrett-Boyes BG. Atrial septal defect and partial anomalous pulmonary venous connection. In: Kirklin JW, Barrett-Boyes BG (eds). *Cardiac Surgery*, 2nd edn. Vol 1. New York, Churchill Livingstone, 1993; 1: 627–630.
3. Pathi V, Guerro R, MacArthur KJD, Jamieson MPG, Pollock JCS. Sinus venosus defect: Single-patch repair with caval enlargement. *Ann Thorac Surg* 1995; 59: 1588–1589.
4. Kyger ER, Frazier OH, Cooley DA, et al. Sinus venous atrial septal defect: Early and late results following closure in 109 patients. *Ann Thorac Surg* 1978; 25: 44–50.
5. Trusler GA, Kazenelson G, Freedom RM, Williams WG, Rowe RD. Late results following repair of partial anomalous pulmonary venous connection with sinus venous atrial septal defect. *J Thorac Cardiovasc Surg* 1980; 79: 776–781.
6. DeLeon SY, Freeman JE, Ilbawi MN, et al. Surgical techniques in partial anomalous pulmonary veins to the superior vena cava. *Ann Thorac Surg* 1993; 55: 1222–1226.
7. Agrawal SK, Khanna SK, Tampe D. Sinus venosis atrial septal defects: surgical follow-up. *Eur J Cardiothorac Surg* 1997; 11: 455–457.
8. Gerbode F, Yee J, Rundle FF. Experimental anastomosis of vessels to the heart. *Surgery* 1949; 25: 556–565.
9. Lewis FJ. High defects in the atrial septum. *J Thorac Surg* 1958; 36: 1–11.
10. Ehrnhoff JL, Theilen EO, Lawrence MS. The surgical treatment of partial and total anomalous pulmonary venous connections. *Ann Surg* 1958; 148: 249.
11. Groves CK. Correction of anomalous pulmonary venous drainage into the superior vena cava. *Ann Thorac Surg* 1967; 4: 301.
12. Pacifico AD, Kirklin JW. Takedown of cavopulmonary anastomosis (Glenn) during repair of congenital cardiac malformations. *J Thorac Cardiovasc Surg* 1976; 70: 272.
13. Warden HE, Gustafson RA, Tarnay TJ, Neal WA. An alternative method for repair of partial anomalous pulmonary venous connection to the superior vena cava. *Ann Thorac Surg* 1984; 38: 601–605.
14. Williams WH, Zorn-Chelton S, Raviele AA, et al. Extracardiac atrial pedicle conduit repair of partial anomalous pulmonary venous connection to the superior vena cava in children. *Ann Thorac Surg* 1983; 38: 345–354.
15. Gaynor JW, Burch M, Dollery C, Sullivan ID, Deanfield JE, Elliott MJ. Repair of anomalous pulmonary venous connection to the superior vena cava. *Ann Thorac Surg* 1995; 59: 1472–1475.