Analysis of Arrhythmias After Correction of Partial Anomalous Pulmonary Venous Connection

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Background. **Several methods for surgical repair of partial anomalous pulmonary venous connection have been described. Sinus node dysfunction is known as a cause of morbidity after surgical repair. In this retrospective study, we attempted to determine the incidence of arrhythmias after use of two different techniques for repair of partial anomalous pulmonary venous connection.**

Methods. **Between 1988 and 2006, 119 patients (61 male, 58 female; aged 5 months to 66 years) with anomalous drainage of the pulmonary vein into the superior vena cava or the right atrium were analyzed. All patients had sinus rhythm before operation. In 64 patients (group 1), rerouting of the pulmonary veins was accomplished through a right atriotomy; and in 54 patients (group 2), the atriotomy incision was extended into the superior vena cava through the cavoatrial junction.**

Results. **There were no perioperative deaths. New-onset nodal rhythm and atrial dysrhythmias developed significantly more often in patients with extended incision through the cavoatrial junction (group 1, 26.5%, versus group 2, 54.5%; $p < 0.004$). At discharge, the rate of dysrhythmias was 14% in group 1 and 32.7% in group 2 ($p < 0.01$). The hospital stay was longer in group 2. At 1-year follow-up of 58 patients, the rate of arrhythmias was 6.25% in group 1 versus 18.1% in group 2.**

Conclusions. **Extended incision through the cavoatrial junction increases atrial dysrhythmias, especially early postoperatively, but the incidence of such sinus node dysfunction decreased with time.**

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Partial anomalous pulmonary venous connections (PAPVC) is frequently associated with sinus venosus atrial septal defect (ASD) [1]. The most common type of PAPVC is the defect present in sinus venosus syndrome, in which the right upper and middle lobe pulmonary veins (right superior pulmonary vein) attach to the low superior vena cava (SVC) or the SVC–right atrial junction. The basic principle of repair is redirection of the blood flow from anomalous pulmonary veins through the interatrial communication into the left atrium. Various surgical techniques have been described to repair this defect, including incisions across the cavoatrial junction [2], right atrial free wall muscle flaps [3], and the Warden technique (transection and relocation of the SVC to the right atrial appendage) [4].

Although surgical repair of PAPVC has been performed with improving results over many years, the operation carries the risk of stenosis of the SVC or pulmonary veins and residual shunting, and may be complicated by sinus node dysfunction or other rhythm disturbances, especially in patients with high PAPVC [2, 5]. Retrospectively, we investigated the incidence of arrhythmias after surgical repair of PAPVC with respect to two different techniques.

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Patients and Methods

Between March 1988 and August 2006, 164 patients who underwent primary surgical repair of PAPVC were identified from our computerized database. The study included only the patients with preoperative sinus rhythm and without preoperative arrhythmia. Therefore, 119 patients were included in this study. There were 61 men and 58 women aged from 5 months to 66 years. The median age was 13 years. Of 119 patients, 100 patients (84%) had a sinus venosus ASD, 7 (6%) an ostium secundum defect, 8 (7%) a fossa ovalis defect, and 4 (3%) intact atrial septum. The pattern of anomalous pulmonary venous connection to the SVC and right atrium (RA) was determined by inspection at the time of repair or by cardiac catheterization and is summarized in Table 1.

Cardiac catheterization was performed in 100 patients before the operation. Pulmonary blood flow was increased in all patients, with a mean pulmonary–systemic blood flow ratio (Qp/Qs ratio) of 2.3 ± 1.5 and a mean pulmonary artery pressure of 26 ± 18 mm Hg.

In 64 patients (group 1), rerouting of the pulmonary veins was accomplished through a right atriotomy, and in 55 patients operated on before 1995 (group 2), the incision

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Table 1. Drainage of Partial Anomalous Pulmonary Venous Connection With Origin of Pulmonary Veins

Origin of Pulmonary Vein	Drainage to SVC	Drainage to RA
RUL	81 (68%)	7 (5.8%)
RUL, RML	9 (7.5%)	3 (2.5%)
RUL, RML, RLL	5 (4.2%)	14 (11.7%)

RA = right atrium; RLL = right lower lobe; RML = right middle lobe; RUL = right upper lobe; SVC = superior vena cava.

was extended into the SVC through the cavoatrial junction (Fig 1). In 9 patients, the sinus venosus defect had to be enlarged during correction. The demographic data of both groups are shown in Table 2. There were no statistically significant differences between groups in sex, age, pulmonary pressure, or Qp/Qs ratio.

Surgical Technique

The surgical procedures were performed through either a median sternotomy or a right anterolateral thoracotomy using normothermic or moderate hypothermic (28° to 32°C) cardiopulmonary bypass with bicaval venous cannulation. Cardiac arrest was achieved with cold crystalloid cardioplegia and topical cooling with slush saline.

In 55 patients with drainage into the SVC (group 2) operated on before 1995, the right atriotomy was extended upward through the cavoatrial junction and posterior-lateral wall of SVC (Fig 1), and continuity between the anomalous pulmonary veins and the left atrium was then reestablished with an autologous nontreated pericardial baffle incorporating the anomalous pulmonary vein, thus redirecting the pulmonary vein into the left atrium. The SVC was enlarged with a pericardial patch. In 64 patients (group 1), redirection was performed within the RA, also with a nontreated pericardial patch.

In cases of small sinus venosus defect (9 patients), this was enlarged by an incision in the atrial septum toward the fossa ovalis before placement of the patch. When septal incision was made during patch placement, epithelization of the edges of the incised septum was performed to prevent thrombus formation in this area.

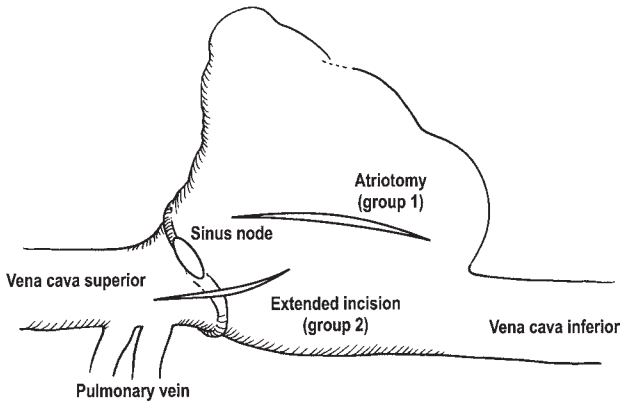

Fig 1. Surgical technique of compared groups.

Table 2. Demographic Data of Patients

	Group 1 n = 64	Group 2 n = 55
Sex (female/male)	30/34	28/27
Age		
Less than 18 years	39	28
18 to 50 years	22	20
More than 50 years	3	7
PAP system (mean ± SD)	25 ± 7	26 ± 18
Qp:Qs, median	2.3:1	2.3:1
Range	1.3–5.2	0.28–3.7

PAP = partial anomalous pulmonary; Qp:Qs = pulmonary–systemic blood flow ratio.

All available electrocardiography (ECG) records were analyzed retrospectively. All patients had at least one 12-lead standard ECG recording directly before the operation and several postoperative records. During the immediate postoperative period, continuous ECG monitoring with the possibility of online and offline analysis as well as optional printout was utilized to detect and document rhythm disturbances. The information about arrhythmias in follow-up was obtained by questionnaires sent to the patients' cardiologists or at the most recent outpatient visit.

Sinus node dysfunction was defined as sinus nodal abnormalities that include (1) persistent spontaneous sinus bradycardia inappropriate for the physiologic circumstances, (2) apparent sinus arrest or sinus exit block, (3) combinations of sinoatrial and atrioventricular conduction disturbances, or (4) alternation of paroxysms of rapid regular or irregular atrial tachyarrhythmias and periods of slow atrial and ventricular rates.

Results

There were no perioperative deaths and no residual atrial septal defects. One patient required reexploration postoperatively because of pericardial effusion. We have seen late stenosis of the SVC in 1 patient and of the upper pulmonary vein in 1 patient in the follow-up (group 2). These patients underwent reoperation.

New-onset nodal rhythm and atrial dysrhythmias developed significantly more often in patients with extended incision through the cavoatrial junction (group 1, 26.5%, versus group 2, 54.5%; $p < 0.004$). At discharge, the rate of dysrhythmias was 14% in group 1 and 32.7% in group 2 ($p < 0.01$). At 1-year follow-up of 58 patients (group 1, 30 patients, and group 2, 28 patients), the rate of arrhythmias was 6.25% in group 1 versus 18.1% in group 2 (Fig 2). The rate of new-onset nodal rhythm was comparable in the two groups, whereas atrial rhythm and supraventricular tachyarrhythmias were more common in group 2 (Table 3). A permanent pacemaker was required in 1 patient in group 1 at the fourth postoperative day because of sinus arrest, and in 1 patient in group 2 during follow-up because of bradyarrhythmia with sinus pause. Of 11 patients without ASD, 4 patients had nonsinus rhythm immediately postoperatively

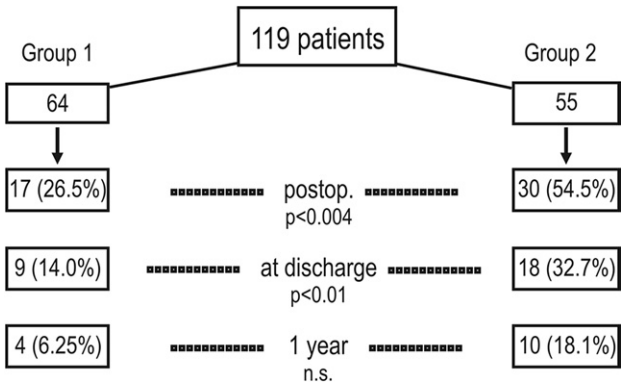

Fig 2. Number of patients with arrhythmias postoperatively (postop), at discharge, and at 1-year follow-up. (n.s. = not significant.)

and 2 patients, at discharge. Eight patients in group 2 and 2 patients in group 1 were discharged with antiarrhythmic drugs (β-blockers and digitalis), respectively. No patients underwent catheter ablation. Table 3 shows the types of arrhythmias postoperatively, at discharge, and at 1-year follow-up. The duration of hospital stay was shorter in group 1 than in group 2 (median, 7 ± 3.2 versus 9 ± 5.0 days).

Comment

There are several methods of surgical repair of sinus venosus defect and PAPVC: single patch closure of defect, patch closure of defect with patch augmentation of SVC–right atrial junction, patch closure of defect with SVC reimplantation into the RA, and transcaval closure. The choice of method depends on the anatomy of the individual patient. There are several publications on long-term arrhythmias after correction of PAPVD [5–7].

In cases of pulmonary veins entering the RA close to the sinus venosus defect, the surgical repair consists of closing the defect while including the orifice of the pulmonary veins, which then drain into the left atrium through the atrial septal defect. Kirklin and colleagues [8] described the technique of rerouting of the pulmonary venous blood toward the atrial septal defect using a patch sutured in the SVC. The creation of these intracaval conduits can be associated with the development of SVC and pulmonary vein obstruction, which are the main complications of this surgical repair technique. If the pulmonary veins enter very high in the SVC, or in patients with left SVC drainage into the coronary sinus and a small right SVC, placement of the patch into the right SVC to divert pulmonary venous blood into left atrium may result in significant stenosis at the cavoatrial junction. In such a situation, division and reimplantation of the SVC with cavoatrial anastomosis can be a useful technique [4, 9]. This method, popularized by Warden and colleagues [4, 10], was originally proposed by F. John Lewis in 1958 [11–13]. Our experience with this technique is limited (4 patients). Therefore, these patients were excluded from the analysis.

In the present study, we compared patients with PAPVC repaired with two different techniques: patients with only atriotomy and patients who underwent repair with extended incision across the cavoatrial junction. The main purpose of the study was to analyze the postoperative arrhythmias in accordance with these surgical techniques. The results of the study demonstrate that the surgical repair of PAPVC with sinus venosus ASD is associated with a low incidence of SVC or pulmonary vein stenosis after single-patch and double-patch technique; the rate of stenosis of the SVC and pulmonary vein was 1.6% (2 of 119 patients). However, the incidence of postoperative arrhythmias was significant in both groups. The rate of postoperative new-onset nodal rhythm and atrial dysrhythmias, especially shortly after the operation, was statistically significantly higher among patients with extended incision through the cavoatrial junction than among patients with only right atriotomy (54% versus 26%). In the postoperative course and at the 1-year follow up, the incidence of sinus node dysfunction fell significantly and more patients were in sinus rhythm, but the incidence of arrhythmias between the two groups remains different.

Rhythm disturbances and atrial arrhythmias are known complications after surgical repair of atrial septal defects such as sinus venosus and are more frequent than after closure of an ostium secundum septal defect. Russel and coworkers [14] observed an incidence of sinus node dysfunction of 10% after repair of sinus venosus ASD versus 0.3% after repair of secundum type atrial septal

Table 3. Types of Arrhythmias (n) Postoperatively, at Discharge, and at 1-Year Follow-Up

	Nodal Rhythm	Atrial Rhythm	Supraventricular Tachyarrhythmias	Bradyarrhythmias	Nonsinus Rhythm Total
Postoperative					
Group 1	12	2	1	2	17
Group 2	15	10	5	0	30
At discharge					
Group 1	2	6	0	1	9
Group 2	3	12	3	0	18
At 1-year follow-up					
Group 1	0	3	0	1	4
Group 2	2	5	2	1	10

defect. The high incidence of sinus node dysfunction in our study is consistent with published data from other authors. The paper recently published by Stewart and associates [15] also describes a rate of 55% sinus node dysfunction after double-patch repair. Kyger and associates [2], in a review of 109 patients, described 23 patients (21%) with postoperative arrhythmias, 10 of whom (44%) did not revert to sinus rhythm. The rate of persistent new postoperative arrhythmias was 33% in patients in whom the cavoatrial junction was enlarged with a pericardial patch. Trusler and coworkers [5] reported 29 patients who underwent repair of sinus venosus syndrome; 71% of these patients remained in sinus rhythm and 5 had junctional rhythm, 4 of whom had an atriotomy incision across the cavoatrial junction. In the recently published paper by Takahashi and coworkers [16], the incidence of postoperative sinus node dysfunction was 93% in patients who had repair with an atrial flap and 44% in patients who had repair without atrial flap.

In general, an incision through the cavoatrial junction must be avoided, as the sinus node and its arterial supply may be compromised during repair. Twenty-five years ago, Anderson and colleagues [17, 18] stated, "... it therefore behoves the surgeon to treat the entire superior cavoatrial junction with the utmost respect if he is to avoid damage to the sinus node and postoperative arrhythmic sequelae."

The sinus node artery can be injured during incision through cavoatrial junction irrespective of position of incision because of its remarkably variable course in the region of the cavoatrial junction or in the lateral free wall of the RA [17, 18]. Tung and coworkers [19] found that an incision in the SVC or across the cavoatrial junction may cause sinus node dysfunction in follow-up even without injury to the node or the artery because of fibrosis in that area. Usually, the sinus node artery reaches the node precavally across the crest of the appendage. The second possibility is retrocaval course of the artery, with it intimately related to the superior rim of the fossa ovalis. The third possibility is for the artery to form a circle around the cavoatrial junction [20]. The atriocaval anastomosis technique avoids direct injury to the sinus node or the sinus node artery, regardless of its course. Nevertheless, this modification involves transection of the SVC with anastomosis to the RA appendage, and therefore has the disadvantage of a venous anastomosis with the possibility of acute thrombosis or subsequent stenosis [21].

In conclusion, extended incision through the cavoatrial junction for correction of sinus venosus ASD with PAPVC carries a risk for sinus node dysfunction, especially early postoperatively, but the incidence of such dysfunction decreased with time. In general, an incision through the cavoatrial junction must be avoided to preserve the function of the sinus node and its blood supply.

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