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Atrial switch (Senning procedure) in the era of the arterial switch operation: current indications and results

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Abstract *Objective.* Since 1990, the policy at Oregon Health Sciences University is to perform an arterial switch for all patients with transposition of the great arteries. In the last four years we have performed the Senning operation in two patients. Our impression is that the long-term results with the Senning procedure at our center are quite good. This prompted a review of our experience with this procedure.
Methods. A retrospective review of all patients' charts was undertaken to document preoperative and operative clinical variables. During follow-up, emphasis was placed on reviewing all cardiology clinic charts, transthoracic echocardiograms and ambulatory holter monitor logs. Transthoracic echocardiograms and 24 hour Holter monitoring were performed yearly on all patients during follow-up.
Results. Since September, 1982, 54 patients underwent the Senning operation for transposition of the great arteries. All patients were palliated at birth with the Rashkind atrial septostomy. The interatrial septum was reconstructed with a dacron patch, and the systemic and pulmonary venous baffles were constructed with autogenous atrial tissue. All but 2 patients underwent profound hypothermia and total circulatory arrest during their operative repair. Of 54 patients, early mortality occurred in 5 patients (9%). Follow-up is complete for the 49 operative survivors. The length of follow-up ranges from 6.0 months to 12.1 years (mean 6.4 ± 0.5 years). There are no late deaths. Forty-five patients (94%) are in NYHA Class I. All late survivors are in sinus rhythm with brief episodes of junctional rhythm (32 patients).
Conclusions. Our series demonstrates that the Senning operation can be safely performed in early infancy. Further, it provides excellent symptomatic and clinical outcomes during late follow-up. Thus, in the era of the arterial switch procedure, close and complete late follow-up results with the Senning procedure, as in this series, should be considered the benchmark in the continued evaluation of the arterial switch operation. [Eur J Cardio-thorac Surg (1996) 10:546–550]

Key words Transposition of great arteries · Senning procedure · Outcomes

Introduction

Several surgical options are currently available for the correction of Transposition of the great arteries (TGA). Physiologic correction of TGA at the atrial level was first proposed by Albert in 1954 [1]. In 1958, Ake Senning successfully performed an atrial switch utilizing autogenous atrial tissue to construct the interatrial baffles [22]. Hoping to enlarge the atrial pathways, Mustard introduced an atrial switch procedure utilizing prosthetic patch material to create the interatrial baffles in 1964 [18]. Long-term follow-up demonstrated a higher incidence of baffle-related complications after the Mustard operation [2, 4, 6, 24, 26].

However, systemic ventricular dysfunction is a serious concern and the determinant of late survival following atrial switch procedures.

To overcome these complications, Rastelli, Stansel, and Jatene explored other corrective procedures on the arterial side [13, 21, 23]. In 1975, Jatene accomplished the first arterial switch. Subsequently, the arterial switch procedure was technically simplified by Lecompte [15]. In the current era, the arterial switch procedure is the accepted standard procedure for the correction of TGA. However, both immediate and long-term results with this operation should ideally be compared to concomitant series of atrial switch procedures. Further, atrial switch procedures will occasionally be necessary for TGA with complex coronary anatomy and should not be totally abandoned. This review includes a recent group of patients who underwent the Senning procedure.

Patients and methods

From September, 1982 to June, 1994, 54 patients underwent the Senning operation for TGA. Forty-four patients had TGA intraventricular septum (IVS). Ten patients had TGA ventricular septal defect (VSD); however, only one patient required VSD patch closure. The male to female ratio was 2 : 1. The mean gestational age at birth was 38.5±1.7 weeks (range 34–42 weeks). The mean birth weight was 3.3±0.6 kg (range 1.9–4.5 kg). All patients were tachypneic and cyanotic at birth. All underwent balloon atrial septostomy (BAS) within 48 h of their birth. The mean aortic saturation at birth was 57±12.5% (range 35–82%). Following BAS, mean aortic saturation improved to 77±8.3% (range 61–91%). Balloon septostomy was unsuccessful in four neonates who then underwent an urgent Senning repair within the 1st month of life.

There was no preoperative mortality. The mean age at operation was 5.2±0.6 months (range 3 days–28.7 months). The mean operative weight was 6.0±1.9 kg (range 3.1–13.6 kg). The four neonates who underwent urgent operative management were all intubated, and required inotropic support and diuretic therapy. Our group of patients was predominantly in NYHA Class III (38 patients) or Class IV (11 patients), with only five patients in NYHA Class II. The majority of these patients required digoxin and diuretic therapy. No patients required supplemental oxygen therapy. All patients were in sinus rhythm preoperatively.

Our preferred technique for the Senning operation is to use profound hypothermia and total circulatory arrest. Hyperkalemic cold, crystalloid cardioplegia was utilized for myocardial protection. Fifty-two patients underwent profound hypothermia with the mean circulatory arrest time of 59±8 min (range 42–82 min). The remaining two patients underwent their repair under moderate hypothermia with cardiopulmonary bypass (CPB). The mean CPB time was 52±4 min (range 24±216 min). In all cases, the interatrial septum was repaired with the use of Dacron patch material. The systemic and pulmonary venous baffles were constructed utilizing autogenous atrial tissue. Care was taken to avoid placing sutures in the region of the sino-atrial node and its artery. De-airing was performed in the usual manner. All patients received temporary ventricular pacing wires. All but two patients were weaned successfully from CPB with the liberal use of inotropic agents.

Results

The mean period of ventilatory support was 53.6±8.6 h (range 16 h–16 days). The mean duration of inotropic support with dopamine was 80.5±9.2 h (range 18 h–12.5 days). The mean ICU stay was 5.3±0.8 days (range 2–35 days). Five patients required pleural chest tubes for the mean duration of 5.7±2.1 days (range 2–17 days). Obvious head swelling occurred postoperatively in 12 patients. Central venous pressure (CVP) was measured on postoperative days 1–3 in 50 patients. The mean CVP was 15±2 cm H_2O (range 12–19 cm H_2O) in those 12 patients with obvious head swelling. In the remaining 40 patients, the mean CVP was 12±2 cm H_2O (range 8–18 cm H_2O).

The most common postoperative morbidity was rhythm disturbances with temporary junctional rhythm occurring in 30 patients (56%), and temporary complete heart block in three patients (6%). Two patients (4%) underwent re-exploration for postoperative bleeding.

Two patients (4%) had pneumonia and one patient (2%) required temporary dialysis for acute renal failure. No patients required permanent pacemaker placement.

Early mortality was 9% (5 patients). Two patients failed to be weaned from CPB due to low cardiac output. Of the remaining three patients, one died within 48 h of operation from systemic ventricular failure, another patient had cardiac arrest following endotracheal suctioning and could not be resuscitated, and the last patient died 3 weeks after operation from sepsis. The Fisher's exact 2-tail test was used to assess potential risk factors for early mortality. Low birth weight, early age at operation, and preoperative NYHA Class IV were significant risk factors for early death (Table 1). Weight at operation was suggestive as a risk factor for early death; however, gestational age, preoperative intubation, emergent surgery, arrest time, CPB time, postoperative CVP, the hours of inotropic use and ventilator support were not risk factors for early mortality.

Follow-up is complete in all 49 operative survivors, and has consisted of clinical examination and echocardiography at regular intervals. Twenty-four hour Holter monitoring tests are performed on all patients at yearly intervals. The mean follow-up time is 6.4±0.5 years (range 6 months–12 years) at the time of writing. There have been no late deaths. Rhythm disturbances are common, but

Table 1 Risk factors for early mortality

	P value *
Age at operation	0.002
NYHA class IV	0.03
Birth weight	0.05
Weight at operation	0.06
Gestational age	NS
Preoperative intubation	NS
Emergent surgery	NS
Arrest time	NS
Hours of inotropic use	NS
Hours of ventilator support	NS

Potential incremental risk factors for early mortality (*Fisher's exact 2-tailed t-test used to assess significance)

asymptomatic. Seventeen patients (35%) have no rhythm abnormalities. Thirty-two patients (65%) have brief episodes of junctional rhythm which last from seconds to minutes in duration. Twelve (38%) of these patients also have sinus bradycardia. Four patients (8%) have occasional ventricular ectopies.

Echocardiography demonstrated mild systemic atrioventricular regurgitation in eight patients (16%), and moderate to severe regurgitation in three patients (6%). Systemic ventricular function was normal on echocardiography in 43 patients (88%). Subpulmonic stenosis has been identified in six patients (12%). Four patients have left ventricular outflow tract (LVOT) gradients of less than 30 mmHg on echocardiography, and are being followed. The remaining two patients have required left ventricle (LV) to pulmonary artery (PA) conduit placement for gradients of 80 and 100 mmHg. There have been no baffle-related complications. All patients are in NYHA Class I, except those three patients with moderate to severe systemic atrioventricular regurgitation on digoxin and diuretic therapy, who are in NYHA Class II.

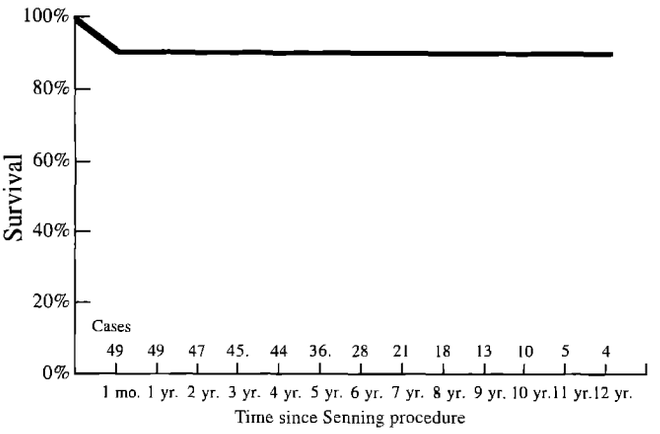

Fig. 1 Actuarial survival following the Senning procedure

Discussion

The current standard of practice is an arterial switch procedure for TGA. At OHSU, from 1965 to 1982, the Mustard operation was the procedure of choice for correction of simple TGA. In 1982, a review of this institution's results with the Mustard operation revealed a high incidence of baffle-related complications [6]. Due to these complications and the experience of others, the Senning operation became our procedure of choice for the correction of simple TGA in 1982 [2, 4, 6, 24, 26]. In the late 1980s, both the Senning procedure and the arterial switch operation were utilized. Since 1990, our preferred procedure for the correction of TGA has been the arterial switch operation. However, in the last 4 years, 2 patients who presented with TGA and complex coronary anatomy were deferred for the Senning operation.

Early death occurred in five patients in our group. This mortality of 9% compares favorably to other reported series [5, 10, 11]. We agree with others that the Senning operation may be performed safely on small neonates who are critically ill [10, 12, 27]. In our series, there were four patients with failed BAS who underwent the Senning operation on an emergent basis with only one early death. This death was due to thrombotic occlusion of the superior vena cava (SVC) secondary to a large SVC catheter, and it was potentially preventable.

In our series, the incidence and type of dysrhythmias detected during follow-up is comparable to other reported series [9, 12, 16]. Further, we agree with these authors that the development of dysrhythmias is multifactorial. In our group the most common rhythm disturbances are non-sustained junctional bradyarrhythmias and tachyarrhythmias, but these are of very short duration and the patients are asymptomatic. No patient in our series has required antiarrhythmic medication or the placement of a permanent pacemaker. In addition, there have been no late deaths related to dysrhythmias. Several authors have reported an incidence of sudden death (5–6%) during long-term follow-up of dysrhythmias [16, 27]. Therefore, ongoing follow-up is mandatory in these patients.

Long-term survival following the Senning operation is primarily dependent on systemic ventricular function. In the series reported by Senning, only 14 of 254 patients (6%) died of systemic ventricular failure with a mean follow-up time of 10 years [27] Roger Mee reported a 10% incidence of systemic ventricular failure with a mean follow-up time of 7 years [7]. In our series, no patients have required surgical intervention for declining systemic ventricular function. However, three patients (6%) require digoxin and diuretic therapy for systemic atrioventricular valve regurgitation and moderate systemic ventricular dysfunction at the time of writing.

The arterial switch operation has been performed in large numbers in only the last decade. Therefore, true long-term results are rare. However, Kirklin et al. have published short- and intermediate-term clinical outcomes of patients following an arterial switch at several institutions with a mean follow-up time of 37.5±14.2 months [14]. Of 895 patients, one-third underwent an atrial switch operation due to complex coronary anatomy and surgeons' preference. The remaining 513 patients had an arterial switch procedure. The hazard function for death following an arterial switch had a rapidly declining single phase that approached zero by 12 months after surgery. In our series, death has only occurred in the perioperative period (Figure 1). Therefore, the clinical outcomes of our patients following an atrial switch procedure for TGA/IVS compare favorably to patients following an arterial switch procedure, performed during the concomitant time period.

Re-operation following the Senning operation may be related to either systemic venous or pulmonary venous obstruction. The reported incidence of systemic venous obstruction varies from 3–10%. With regards to pulmonary venous obstruction, the reported incidence is also 3–10% [1, 10]. These baffle-related complications tended to occur more frequently in the neonatal age group. Our group of patients, who have been operated upon in a more recent time frame as compared to those patients reported in the literature, have neither systemic or pulmonary venous obstruction as evidenced by clinical and echocardiographic evaluation with a mean follow-up of 6 years.

Norwood and Castaneda has reported the incidence of LVOT obstruction (LVOT) following the Senning operation to be 31%. Severe LVOT obstruction requiring surgical intervention occurred in 6% of their patients [10]. Their group approached this problem by relieving LVOT obstruction by trans-pulmonary artery techniques. Their results were disappointing with significant residual obstruction in a majority of their patients. They suggested the placement of a LV to PA allograft conduit to relieve LVOT obstruction. We have performed a LV to PA allograft conduit placement in two patients with no mortality. Our remaining four patients have mild LVOT gradients with no evidence of left ventricular hypertrophy.

Since 1990, two patients have been recommended for the Senning operation, due to complex coronary anatomy, at this institution. One patient had the right coronary artery arising from the ascending aorta, clearly 1 cm above sinus 1, with an initial, intramural course. The other patient had single coronary ostium with a commissural origin between sinus 1 and 2. Several recent series have documented an increased risk for early mortality following an arterial switch operation if the patient has either single coronary ostium, commissural origin of a coronary, or high origin of a coronary [8, 17, 19, 29]. However, some institutions advocate complex technical maneuvers for coronary transfer, irrespective of the coronary anatomy [3, 20, 25, 28]. These techniques invariably require the use of patch material and extensive suture lines. The effects of these techniques with regards to aortic valve competence and coronary growth still remain to be determined. Due to this uncertainty, our approach is to perform the Senning operation for patients with complex coronary anatomy. The experience from other institutions supports this approach [8, 17].

Our series demonstrates that the Senning operation can be safely performed in early infancy. Further, it provides excellent symptomatic and clinical outcomes during late follow-up. The low incidence and mild degree of dysrhythmias do not translate into detectable patient incapacity. Late follow-up is particularly important to identify and treat patients with systemic ventricular dysfunction and tricuspid regurgitation. We advocate the placement of a LV to PA allograft conduit in patients with LVOT obstruction. In the current era of the arterial switch procedure, results such as in this recent series with the Senning operation should be taken into account in determining the surgical effectiveness and late outcomes for patients with TGA.

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