Long-Term Outcome of Arterial Switch Operation Conversion After Failed Senning/Mustard Procedure

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Background. We evaluated long-term outcomes of the arterial switch operation (ASO) conversion after a failed Senning/Mustard operation among patients with dextro-transposition of the great arteries.

Methods. Between 1986 and 2006, 9 patients with dextro-transposition of the great arteries underwent ASO conversion at our institute. All patients had systemic right ventricle failure, 6 had supraventricular tachycardia, and 8 had moderate or severe tricuspid valve regurgitation. All patients had New York Heart Association classification II or III. The median age of patients at the ASO conversion operation was 7.4 years (range, 0.6 to 32.4 years). Pulmonary artery banding for left ventricle training was performed in 8 of the 9 patients before conversion.

Results. There was 1 early death from low-output syndrome at 5 days postoperatively and 1 late sudden death at 5 months. Median follow-up time was 23.1 years (range, 0.08 to 28.0 years). The actuarial survival rate was 76.1% at 20 years. Long-term survivors revealed good New York Heart Association classification (class I, 6 patients; class II, 1 patient), with less than mild tricuspid regurgitation and brain natriuretic peptide levels of 40.6 ± 16.2 pg/mL. Cardiac catheterization revealed significant improvements of right ventricle end-diastolic volume (decreased from 243.2% to 117.7% of normal), and right ventricle ejection fraction (increased from 0.42 to 0.572; $p < 0.05$). Three patients underwent new pacemaker implantation for sick sinus syndrome, and moderate neoaortic valve regurgitation developed in 1 patient.

Conclusions. Excellent long-term outcomes can be achieved after ASO conversion; however, careful observation for new-onset sick sinus syndrome and aortic regurgitation is mandatory.

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Atrial switch operations for dextro-transposition of the great arteries (d-TGA) using the Senning and Mustard procedures were introduced in 1958 and 1963, respectively [1, 2]. These operations were performed for many patients until the late 1980s, when the surgical strategy was changed to the arterial switch operation (ASO), with good results. Late complications after Senning and Mustard operations include atrial arrhythmia, systemic right ventricle (RV) failure, and baffle complications [3–5]. ASO conversion is an epochal procedure for RV failure patients after the atrial switch operation. Mee [6] reported the first 2 successful ASO conversions after left ventricle (LV) training in 1986. During the same period, which was more than 30 years ago, we also performed our first ASO conversion for a patient with a failed Senning [7, 8]. The purpose of the present study was to compare clinical status and ventricular function before and after ASO conversion and evaluate the long-term outcomes of this surgical strategy.

Patients and Methods

We have performed 160 atrial switch operations for patients with d-TGA at our institute since 1966, and 9 patients underwent ASO conversion between 1986 and 2006. The initial diagnosis was d-TGA with an intact ventricular septum for 4 patients, and d-TGA with a ventricular septal defect for 5 patients (Table 1). Initial atrial switch operations were performed at the median age of 14 months (range, 1 to 87 months), where the Senning procedure was performed in 6 patients and the Mustard procedure in 3. The indication for conversion for all patients was systemic RV failure. Pulmonary venous channel stenosis was recognized in 1 Senning patient (patient 2), and baffle leakage and LV outflow tract stenosis occurred in one Mustard patient (patient 9). Six patients had supraventricular tachycardia, and 8 patients showed moderate or severe tricuspid valve regurgitation

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Abbreviations and Acronyms

I = intact ventricular septum
II = ventricular septal defect
ASO = arterial switch operation
BNP = brain natriuretic peptide
cc-TGA = congenitally corrected transposition of the great arteries
CTR = cardiothoracic ratio
d-TGA = dextro transposition of the great arteries
EDV = end-diastolic volume
EF = ejection fraction
LV = left ventricle
LVp/RVp = left ventricular pressure ratio for right ventricular pressure
NYHA = New York Heart Association
PAB = pulmonary artery banding
PM = pacemaker
RV = right ventricle
SVT = supraventricular tachycardia
TR = tricuspid valve regurgitation
TVP = tricuspid valvoplasty

(TR) before ASO conversion (Table 2). With respect to RV function before ASO conversion, mild RV failure (RV ejection fraction [RVEF] 0.50 to 0.55) was recognized in 2 patients, moderate RV failure (RVEF 0.40 to 0.50) in 3 patients, and severe RV failure (RVEF <0.40) in 4 patients.

Before ASO conversion, 5 patients had New York Heart Association (NYHA) classification II, and 4 patients had class III. At the time of ASO conversion, the median age of patients was 7.4 years (range, 0.6 to 32.4 years), including 3 patients who were older than 15 years. There was a tendency toward patients with d-TGA with ventricular septal defect undergoing ASO conversion at an older age. Some patients underwent additional procedures concomitantly with ASO conversion: 7 patients also underwent tricuspid valvuloplasty, and 1 underwent mitral valve replacement.

All but 1 patient had undergone pulmonary artery banding (PAB) for LV training before ASO conversion (Fig 1). PAB was performed through a left thoracotomy while LV pressure was monitored. The median ratio of LV pressure to RV pressure (LVp/RVp) before PAB was 0.41 (range, 0.32 to 0.62). Four of 8 patients required additional PAB, after which the definitive LVp/RVp increased to 0.93 (range, 0.81 to 1.07). The median interval from initial PAB to ASO conversion was 2.8 months (range, 0.9 to 8.8 months). In 1 patient, mitral chordae eventually produced LV outflow tract stenosis, resulting in natural LV training; in this patient, the LVp/RVp was 1.0 without PAB.

Clinical and follow-up data were retrospectively retrieved from medical records. This study was approved by the Ethics Committee of Tokyo Women's Medical University, and patient consent was waived because of the retrospective study.

Statistical analyses were performed with JMP Pro 11.2.0 software (SAS Institute Inc, Cary, NC). The data are reported as median (range) or as mean ± standard deviation. The survival rate after ASO conversion was estimated according to the Kaplan-Meier method. Paired *t* tests were used for the comparison of clinical data before and after ASO conversion. *P* values of less than 0.05 were considered statistically significant.

Results

Operative Deaths

Postoperatively, there was 1 early death and 1 late death. The median follow-up period was 23.1 years (range, 0.08 to 28.0 years). The actuarial survival rate after ASO conversion was 76.1% at 10 and 20 years (Fig 2). The early death occurred in a patient aged 18 years (patient 7) who died 5 days after ASO conversion of low cardiac output syndrome. The late death occurred 5 months after conversion in a child aged 5 years (patient 8) who died suddenly at home. The cause of death in this patient might have been arrhythmia.

Table 1. Patient Characteristics

Case	TGA Type	Initial Operation (age)	Indication[a]	Age at ASO (years)[b]	Concomitant Procedure
1	II	Senning (1 y)	RV failure	6.1	TVP
2	I	Senning (7 mo)	RV failure + pulmonary venous channel stenosis	0.7	…
3	II	Mustard (5 mo)	RV failure	8.9	TVP
4	I	Senning (2 y)	RV failure	3.7	TVP
5	I	Senning (3 mo)	RV failure	7.4	TVP
6	II	Mustard (1 y)	RV failure	17.1	TVP
7	II	Senning (7 y)	RV failure	18.6	TVP
8	I	Senning (1 mo)	RV failure	5.1	TVP
9	II	Mustard (2 y)	RV failure + baffle leakage + LV outflow stenosis	32.4	Mitral valve replacement

[a] Indication of conversion was systemic RV failure in all patients. [b] Our list included 3 patients aged older than 15 years.

I = intact ventricular septum; II = ventricular septal defect; ASO = arterial switch operation; LV = left ventricle; RV = right ventricle; TGA = transposition of the great arteries; TVP = tricuspid valvuloplasty.