Early and Late Complications after Arterial Switch Operation for Transposition of the Great Arteries -7 Year Experience

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=국문초록=

대혈관 전위증에서 동맥치환술 후의 합병증

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1985년 3월 이후 Oklahoma University Health Sciences Center에서 대동맥전위증에 대해 시행했던 44례의 Jatene 술식 중 심실중격결손의 동반 유무에 따라 1군과 2군으로 분류하여 검토한 바, 단순형인 1군에서 수술 사망 14.3%(4/28), 심실중격결손군인 2군에서 6.25%(1/16)로 전체에서 11.4%(5/44)로 나타났으며, 생존군에서의 7년 생존율은 1군에서 85±3.2%, 2군에서 94±3.5%이었다. 술후 합병증으로는 1례에서 경한 좌심실유출로 협착, 5례에서 우심실유출로 협착이 관찰되어 1례에서 재수술이 필요하였으며, 1례에서 신 대동맥 판막에 경증의 폐쇄부전이 관찰되었으나 모든 생존자가 약물 투여없이 현재 동조율로 NYHA class I인 양호한 상태이다. 이 Jatene 술식은 이제는 경험의 축적으로 높은 수술위험 요소를 보이는 환아에서도 비교적 낮은 사망율과 훌륭한 중간 결과를 보이고 있다.

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Key words : 1. Transposition of great vessels
2. Postoperative complications

INTRODUCTION

The arterial switch operation (ASO) has come to be viewed as the operation of choice for treatment of transposition of the great arteries (TGA) in many centers[1~5]. The theoretical advantage of this anatomic repair is that with the left ventricle (LV) as the systemic ventricle, many of the adverse side-effects associated with a physiologic repair such as arrhythmias, systemic ventricular dysfunction, and systemic atrioventricular valve insufficiency may be avoided[6~8]. The initial high mortality "learning curve" associated with the ASO has largely been overcome[1, 9, 10], but medium-to-long term follow-up after the ASO is still being documented, particularly with regard to functional integrity of the neoaortic valve, and the integrity of the coronary anastomotic suture line[9, 11].

This report is intended to contribute to the growing body of information related to the medium-term follow-up of patients who have previously undergone the ASO.

PATIENTS AND METHOD

During the seven year period between March 1985 and July 1992 a total of 44 patients have undergone ASO for

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Table 1. Age distribution of the patients for ASO and mortality in group I (simple TGA) and group II (complex TGA)

	group I	group II	total
less than 1 week	3/25 (12%)	1/9 (11.1%)	4/34 (11.8%)
−1 month	0/2	0/2	0/4
−1 year	1/1	0/2	1/3
over 1 year old	0	0/3	0/3
	4/28 (14.3%)	1/16 (6.25%)	5/44 (11.4%)

hospital mortality in parenthesis
neonate < 1 month old
infant < 1 year old
ASO: Arterial Switch Operation
TGA: Transposition of Great Arteries

simple and complex TGA at The Children's Hospital of Oklahoma. These patients form the basis of this report.

We reviewed the medical records, echocardiograms, cardiac catheterization data and operation records of all patients. Recent follow-up (within six months) was complete for all patients.

There were 30 male and 14 female patients. Twenty-eight patients had simple TGA (group I), and 16 patients had a significant ventricular septal defect (VSD) associated with the TGA (group II). The median age at operation was 3 days, and ranged from one day to 3 years old. Thirty-four patients were less than 1 week of age at operation, and 3 patients were older than 1 year (Table 1). The body weight ranged from 1.8 to 15.6 kg (mean 3.9 ± 2.3 kg).

Associated lesions other than VSD included atrial septal defect in 28 (63.6%) and coarctation of the aorta in one. One patient had double outlet right ventricle of the Taussig-Bing variety. Apart from the balloon atrial septostomy, one patient underwent Blalock-Hanlon septectomy and 4 patients pulmonary arterial banding (PAB) prior to the ASO.

Coronary anatomy was the usual in 37 patients (84.1%). The circumflex artery arose with the right coronary artery from sinus 2 with the left anterior descending artery arising from sinus 1 in 3 cases (6.8%), and all three branches had a common origin from sinus 2 in 4 patients (9.0%).

From the preoperative echocardiograms, we recorded the diastolic dimensions of both right and left ventricular cavity (RVEDD, LVEDD), LV posterior wall thickness (LVpw) and ejection fraction (EF). We also recorded the preoperative pressure in the both ventricles (RVP, LVP), pulmonary artery (PAP) and aorta (SAP) from cardiac catheterization. Several of the variables recorded differed between Group 1 and Group 2 (Table 2).

The mean follow up period was 3.3 years, and ranged from 1 month to 8 years. During the postoperative follow-up period, the patients were followed clinically, with regular echocardiograms, with 24 hours Holter monitor recording, and with cardiac catheterization if indicated. Recent follow-up was achieved in all patients.

All recorded values were expressed as mean ± standard deviation. Data were analysed statistically with student T-test and Fisher exact test and considered significant if the p-value was less than 0.05. A stepwise logistic regression analysis was undertaken to identify possible risk factors associated with hospital death.

RESULTS

Early and late outcome

Overall operative mortality for these patients was 11.4% (5/44). In Group I, 4 of 28 patients died (14.3%): A preterm 1.8 kg boy died immediately after operation due to the LV infarction − at operation there was a major discrepancy in size between aorta and pulmonary artery, two of four patients with single coronary artery from sinus 2 died postoperatively, and the last patient died from a major cerebral infarction. A one week old girl from group II also died with low output failure (1/16, 6.25%).

We could not identify any risk factors independently associated with hospital death. However, 2 of 4 patients with single coronary artery (50%) died versus 3/40 for other coronary anatomy (7.5%, $p = 0.08$). Associated VSD was not a risk factor in this analysis.

There have been no late deaths, and the actuarial survival at 8 years postoperatively is 88 ± 3% for the study group.

Right ventricular outflow tract obstruction (RVOTO)

We considered RVOTO to be present when a peak gradient greater than 25 mmHg existed between the RV and the central PA. By this definition five patients developed significant RVOTO (13.2%, 5/39) postoperatively, 2 in group I (8.3%) and 3 in group II (20%). Only one of these patients has required reoperation for severe RVOTO and this patient had a PAB done prior to the ASO. Of these 5 patients with significant RVOTO, three were diagnosed soon after discharge and the remaining two patients were diagnosed within one year of their operation. No new case of RVOTO has been diagnosed since 1988 about which time the surgical technique of PA

Table 2. Patients profile for simple TGA (group I) and complex TGA (group II)

	group I	group II	p-value
age (months)	0.23 ± 0.32	5.43 ± 10.79	$p < 0.05$
body weight (kg)	3.38 ± 0.58	4.87 ± 3.58	ns
hemoglobin (gm%)	15.97 ± 2.38	15.54 ± 3.21	ns
O_2 saturation (%)	65.92 ± 19.10	68.00 ± 16.73	ns
SAP (mmHg)	72.40 ± 13.45	82.00 ± 8.46	$p < 0.05$
PAP (mmHg)	56.5 ± 2.25	68.0 ± 9.9	$p < 0.05$
LVP (mmHg)	66.43 ± 16.90	77.86 ± 26.36	$p < 0.05$
RVP (mmHg)	67.33 ± 6.95	86.38 ± 13.91	$p < 0.01$
LVP/RVP	1.03 ± 0.38	0.89 ± 0.16	$p < 0.05$
LVEDD (mm)	16.77 ± 3.68	19.71 ± 3.55	$p = 0.1$
RVEDD (mm)	14.43 ± 1.40	14.50 ± 2.38	ns
LVpw (mm)	3.50 ± 0.76	3.33 ± 0.58	ns
EF (%)	66.73 ± 13.09	67.80 ± 8.96	ns
CPB time (min.)	107.88 ± 45.69	133.19 ± 44.12	$p < 0.05$
Aortic X time (min.)	65.84 ± 12.63	80.00 ± 25.67	$p < 0.05$
DHCA time (min.)	57.58 ± 9.45	57.80 ± 19.73	ns
Postop. LVP (mmHg)	100.45 ± 11.07	103.40 ± 18.78	ns
RVP (mmHg)	33.82 ± 9.14	50.20 ± 25.74	$p < 0.05$
LVP/RVP	2.73 ± 0.51	2.60 ± 1.05	ns
LVEDD (mm)	23.00 ± 4.31	27.87 ± 7.51	$p < 0.05$
RVEDD (mm)	13.43 ± 2.94	15.29 ± 4.72	ns
LVpw (mm)	5.13 ± 1.30	5.42 ± 2.66	ns
EF (%)	69.47 ± 9.86	67.71 ± 8.19	ns

SAP systolic aorta pressure; PAP systolic pulmonary arterial pressure; LVP systolic left ventricular pressure; RVP systolic right ventricular pressure; LVP/RVP ratio of LVP to RVP, LVEDD LV end diastolic dimension; RVEDD RV end diastolic dimension; LVpw LV posterior wall thickness; EF ejection fraction; CPB cardiopulmonary bypass; Aortic X time aortic ischemic time; DHCA deep hypothermic circulatory arrest; Postop. postoperative
TGA: Transposition of Great Arteries

Table 3. univariate analysis of hospital survival for patients undergone ASO for TGA

	survival group	nonsurvival group	p-value
age (months)	2.39 ± 7.13	0.4 ± 0.25	ns
body weight (kg)	4.05 ± 0.39	3.08 ± 0.36	$p = 0.09$
hemoglobin (gm%)	15.9 ± 0.5	15.2 ± 1.1	ns
O_2 saturation (%)	67.1 ± 2.9	64.2 ± 11.6	ns
SAP (mmHg)	76.7 ± 12.7	72.0 ± 4.36	ns
PAP (mmHg)	63.15 ± 8.8	53.5 ± 1.05	ns
LVP (mmHg)	70.0 ± 6.5	85.0 ± 15.0	ns
RVP (mmHg)	78.4 ± 3.6	60.5 ± 4.5	$p = 0.10$
LVP/RVP	0.90 ± 0.18	1.42 ± 0.33	ns
LVEDD (mm)	18.3 ± 0.8	13.0 ± 2.0	$p < 0.05$
RVEDD (mm)	14.3 ± 0.6	15.0 ± 0.5	ns
LVpw (mm)	3.6 ± 0.2	3.0 ± 0.5	ns
EF (%)	65.9 ± 3.2	75.0 ± 3.0	ns
CPB time (min.)	114.5 ± 6.6	141.0 ± 37.4	ns
Aortic X time (min.)	70.4 ± 3.1	76.2 ± 12.7	ns
DHCA time (min.)	57.1 ± 2.4	60.6 ± 6.5	ns

SAP systolic aorta pressure; PAP systolic pulmonary arterial pressure; LVP systolic left ventricular pressure; RVP systolic right ventricular pressure; LVP/RVP ratio of LVP to RVP, LVEDD LV end diastolic dimension; RVEDD RV end diastolic dimension; LVpw LV posterior wall thickness; EF ejection fraction; CPB cardiopulmonary bypass; Aortic X time aortic ischemic time; DHCA deep hypothermic circulatory arrest; Postop. postoperative
ASO: Arterial Switch Operation, TGA: Transposition of Great Arteries

reconstruction was changed to incorporate a single pantaloon pericardial patch.

Left ventricular outflow tract obstruction (LVOTO)

One patient who underwent reoperation for closure of a residual VSD, has a 30 mmHg peak gradient over his LVOT. He is currently asymptomatic without medication.

Aortic valve regurgitation

The patients were evaluated with 2-dimensional and pulse colour Doppler echocardiography and/or cardiac catheterization to detect significant neoaortic valve regurgitation. Significant (grade 2/4) neoaortic valve regurgitation is present in one patient (1/39, 2.6%). This patient is currently asymptomatic without medication.

Systemic ventricular function

When comparing the LV ejection fraction by echocardiogram, there was no significant change between preoperative and postoperative value (67 ± 11% preoperatively versus 69 ± 9% postoperative).

Postoperative peak LVP and the ratio of LV to RV peak pressure (LVP/RVP) increased appropriately and significantly compared to preoperative values (72 ± 22 mmHg to 102 ± 15 mmHg, and 0.96 ± 0.2 to 2.67 ± 0.8, both $p < 0.05$). These values reflect a well preserved LV which is able to function normally at systemic pressures after the ASO.

Arrhythmias

Two patients developed transient postoperative arrhythmias; one developed supraventricular tachycardia, and the other developed three episodes of acute transient atrioventricular dissociation. All patients were in sinus rhythm without medication at their last follow-up.

Reoperation

Two patients (5.1%, 2/39) required reoperation during the follow-up period. One patient underwent closure of a residual VSD, and the other had a patch angioplasty of the main pulmonary artery for RVOTO. Both these patients are currently in NYHA Class I without medication.

DISCUSSION

The ASO has become the standard repair for neonates presenting with TGA and intact ventricular septum (IVS), and for young infants with tansposition with associated VSD[3, 12, 13]. Motivation for changing from the established physiological repair, either Mustard or Senning operation, to this anatomic repair stemmed from the inordinately high reported incidence of late arrhythmias and systemic ventricular failure associated with the former[7, 14].

Recent mortality rates for the ASO were reported to vary from 3 to 20%[1, 3, 8, 9, 12, 13, 15], and higher when a VSD was present. In addition, many unusual late complications were reported, including RVOTO, aortic regurgitation, LV dysfunction, late coronary artery occlusion and proximal aortic aneurysm[15~19]. As familiarity with the operation improved and patients were operated upon at a younger age, the early results have improved and the complications have become less prevalent[2, 19]. Currently the early mortality is about 10%, with institutions doing large volumes reporting hospital mortalities under 5%[2, 8, 20].

The patient selection has also evolved with time. Patient factors identified as being associated with significantly higher risk of early death after the ASO include prematurity, low-birth weight, low LVP, underdeveloped LV wall thickness, small LV and difficult coronary artery anatomy i.e.single coronary artery or intramural coronary arteries[4, 5, 21, 22]. Many of these risk factors may be nullified with more recent experience. Certainly, patients with TGA and IVS who present beyond 4 weeks of age, and those with underdeveloped LVs may benefit from the rapid two-stage switch[1, 23, 24]. Our experience would support these assumptions; of the 5 early deaths, two were related to single coronary artery anatomy, and one to prematurity (1.8 kg neonate), and the LVEDD of the non-survivors was significantly smaller than the survivors (13 ± 2 mm versus 18 ± 1 mm, $p < 0.05$).

The incidence of supravalvular pulmonary stenosis has been reported to vary between 10 and 20%[16, 21], and factors associated with a higher incidence include undue tension on the suture line, use of a double rather than a single patch for reconstruction, and size mismatch between the proximal and distal PA[9, 13, 15, 19]. The use of single large pantaloon shaped pericardial patch has been associated with a significant reduction in the incidence of this complication. This has also been our experience.

Aortic regurgitation can be related with the method of coronary transfer, age and staged operation like primary PAB. Yamaguchi reported 12% in patients younger than six months old at operation and 29% in older patients, and others reported 15%[18, 19]. However we only identified one case of aortic regurgitation (2.6%) in our series.

In contradistinction to the 10 year follow-up data of patients undergoing the Mustard operation in which the average peak O_2 uptake was 78% of that of age-matched controls and systemic RV dysfunction was present in 86%[20], the LV function and EF of young patients undergoing the ASO was well maintained in most patients[7, 10, 25]. The normalization of LV dimensions and function was most apparent in patients younger than 18 months, and decreased with increasing age[11, 25]. We have not identified any patients in this series with LV dysfunction.

In conclusion, our study indicates that the ASO may be performed with low risk and good medium-term follow-up in properly selected patients, even in units not doing a very high volume of this operation. In this context, certain patients with single coronary artery anatomy and others with extreme low birth weight currently still remain at higher risk of not surviving the operative precedure. Using current techniques, the incidence of late complications may be expected to decrease with time and with the acquisition of further experience.

=Abstract=

We reviewed our entire experience of 44 consecutive patients undergoing the arterial switch operation (ASO) for transposition of the great arteries (TGA) since March 1985. There were 28 patients with simple TGA (group I) and 16 with associated ventricular septal defect (VSD) (Group II). There were five hospital deaths (11.4%, 5/44), two related to single right coronary artery anatomy. There have been no late deaths. For group I hospital mortality was 14.3% (4/28), and for group II this was 6.25% (1/16). Mean follow-up was 3.3 years (range 1 month to 8 years) and was completed for all patients. Actuarial survival at 7

years for hospital survivors was 85 ± 3.2% in group I and 94 ± 3.5% in group II. One patient has mild asymptomatic left ventricular outflow tract obstruction, and five patients (12.8%, 5/39) have right ventricular outflow tract gradients (RVOTO) exceeding 25 mmHg; only one patient has required reoperation for RVOTO. Mild neoaortic regurgitation is present in one patient. All survivors are currently in NYHA class I without medication, and all are in sinus rhythm.

The ASO is associated with low operative risk and excellent medium-term outcome in most subsets of patients undergoing this operation. With more experience, improved results can be expected also in those patients currently at higher risk.

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