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Outcome in adult patients after arterial switch operation for transposition of the great arteries

Aleksander Kempny [a,*], Kerstin Wustmann [a], Francesco Borgia [a], Konstantinos Dimopoulos [a,b], Anselm Uebing [a], Wei Li [a], Sylvia S. Chen [c], Adam Piorkowski [d], Rosemary Radley-Smith [e], Magdi H. Yacoub [f], Michael A. Gatzoulis [a,b], Darryl F. Shore [g], Lorna Swan [a], Gerhard-Paul Diller [a,b]

[a] Adult Congenital Heart Centre and Centre for Pulmonary Hypertension, Royal Brompton and Harefield NHS Foundation Trust, London, UK
[b] National Heart and Lung Institute, Imperial College School of Medicine, London, UK
[c] CMR Unit, Royal Brompton Hospital and Imperial College, London, UK
[d] Department of Geoinformatics and Applied Computer Science, AGH University of Science and Technology, Cracow, Poland
[e] Royal Brompton and Harefield NHS Foundation Trust, Harefield, Middlesex, UK
[f] Imperial College London, Heart Science Centre, Harefield, Middlesex, UK
[g] Department of Cardiac Surgery, Royal Brompton and Harefield NHS Foundation Trust, London, UK

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ABSTRACT

Background: The arterial switch operation (ASO) is currently the treatment of choice in neonates with transposition of the great arteries (TGA). The outcome in childhood is encouraging but only limited data for long-term outcome into adulthood exist.

Methods and results: We studied 145 adult patients (age > 16, median 25 years) with ASO followed at our institution. Three patients died in adulthood (mortality 2.4/1000-patient-years). Most patients were asymptomatic and had normal left ventricular function. Coronary lesions requiring interventions were rare (3 patients) and in most patients related to previous surgery. There were no acute coronary syndromes. Aortic root dilatation was frequent (56% patients) but rarely significant (>45 mm in 3 patients, maximal-diameter 49 mm) and appeared not to be progressive. There were no acute aortic events and no patient required elective aortic root surgery. Progressive neo-aortic-valve dysfunction was not observed in our cohort and only 1 patient required neo-aortic-valve replacement. Many patients (42.1%), however, had significant residual lesions or required reintervention in adulthood. Right ventricular outflow tract lesions or dysfunction of the neo-pulmonary-valve were frequent and 8 patients (6%) required neo-pulmonary-valve replacement. Cardiac interventions during childhood (OR 3.0, 95% CI 1.7–5.4, $P<0.0001$) were strong predictors of outcome (cardiac intervention/significant residual lesion/death) in adulthood.

Conclusions: Adult patients with previous ASO remain free of acute coronary or aortic complications and have low mortality. However, a large proportion of patients require re-interventions or present with significant right sided lesions. Life-long cardiac follow-up is, therefore, warranted. Periodic noninvasive surveillance for coronary complications appears to be safe in adult ASO patients.

1. Introduction

Transposition of the great arteries (TGA) is one of the most common neonatal cyanotic heart defects. Most patients require palliative or reparative interventions shortly after birth. Definitive surgery, allowing the majority of patients to survive to adulthood, can either consist of a physiologic or anatomic "correction". The former (i.e. atrial switch), was introduced in 1958 by Senning and later modified by Mustard [1–3]. Although early survival prospects are excellent, this procedure leaves the right ventricle (RV) supporting the systemic circulation. This leads to complications such as progressive RV dysfunction, ensuing tricuspid regurgitation, arrhythmia, heart failure and early mortality [4–6]. Several attempts were made to perform an "arterial switch" operation even before the atrial switch was introduced [7,8]. This was, however, a technically more challenging operation and initial results were disappointing, mainly due to fatal coronary complications [8,9]. In 1975, Jatene reported a method for switching the great arteries and re-implanting the coronary arteries [10]. This method, with subsequent modifications, has nowadays become the method of choice for repairing TGA [11]. The pediatric outlook for patients surviving the operation has been excellent, but uncertainty and some concerns about long-term complications in adulthood remain. These include late coronary complications, progressive aortic

* Corresponding author at: Adult Congenital Heart Centre, Royal Brompton and Harefield NHS Foundation Trust, Sydney Street, SW3 6NP London, UK. Tel.: +44 207351 8602; fax: +44 207351 8629.
E-mail address: a.kempny@rbht.nhs.uk (A. Kempny).

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regurgitation and RV outflow tract obstruction, all of which may necessitate reintervention. Limited data exist on adult patients after arterial switch operation (ASO). We aimed to assess the clinical outcome of a large number of contemporary ASO patients under tertiary adult congenital care.

2. Patients and methods

We performed a retrospective analysis using our electronic patient database and review of medical records. We included all patients who underwent an ASO for TGA between 1976 and 1994 and continued to be followed in our clinic for Adults with Congenital Heart Disease at the Royal Brompton and Harefield NHS Foundation Trust, London. Clinical and demographic characteristics were collected for all patients. The coronary pattern was recorded at the time of surgery and coded based on mode of origin, course and branching pattern of the coronary arteries, as described in detail by Yacoub and Radley-Smith [12].

All echocardiographic and magnetic resonance imaging studies (MRI) were performed at our centre and interpreted according to internal protocols in agreement with current guidelines [13–16]. Aortic regurgitation was graded semiquantitatively as mild, moderate or severe based on transthoracic echocardiography, and this was supplemented by data acquired on cardiac magnetic resonance imaging in patients with more than mild regurgitation. The analysis of the aortic dimensions is based on the MRI results, supplemented by echocardiographic measurements in patients who did not undergo MRI. All cardiopulmonary exercise tests (CPET) were performed at the Royal Brompton Hospital as described previously [17]. Echocardiographic data were available in all patients, while MRIs were available in 77% of patients. ECGs were available in digital form and were analysed using custom made software. Symptoms were graded according to the New York Heart Association functional class (NYHA) classification.

2.1. Statistical analysis

The distribution of data was assessed for normality using the D'Agostino–Pearson test. In case of normal distribution, comparison between groups was performed using unpaired two-tailed *t*-test and Welch-test in case of unequal variances. For data with a non-normal distribution, the Mann–Whitney *U* test was used. The relation between continuous variables was assessed using Pearson's or Spearman's rho, depending on data distribution. Outcome was assessed as the combined endpoint of significant valve/outflow tract disease (moderate or severe stenosis or regurgitation), percutaneous or surgical cardiac intervention, as recorded on their last clinical follow-up, or death during adulthood. The relationship between various clinical or demographic parameters and the predefined outcome variable was assessed using univariate logistic regression analysis. Parameters predictive of outcome on univariate logistic regression analysis were further assessed on multivariate logistic regression analysis. Moreover, freedom from percutaneous or surgical cardiac intervention during adulthood was used to construct Kaplan–Meier curves. For the scope of this study we defined the start of adulthood as age >16 years. Statistical analyses were performed using MedCalc for Windows, version 11.6.1.0 (MedCalc Software, Mariakerke, Belgium) and R-package version 2.13.0. A two-sided P-value of <0.05 was considered statistically significant.

3. Results

3.1. Demographics and mortality

In total, 145 adult patients were included. Table 1 depicts demographic and clinical characteristics of the population. The median age at last follow up was 25 years (IQR 20.6–28.0 years) and median follow up in adult life (i.e. beyond 16 years of age) was 9.0 years (IQR 3.7–12.3). During this period 3 patients (2.1%) died. This corresponds to a mortality rate of 2.4/1000 adult patients-years. One patient was asymptomatic, at the latest assessment before death, while 2 were severely symptomatic [NYHA classes III and IV, respectively]. Table 2 provides clinical details of the patients who died. It should be noted that the asymptomatic patient died in a road traffic accident, while the two severely symptomatic patients died of cardiac reasons (sudden cardiac death and heart failure) thus, supporting the notion that excess mortality in this population is concentrated in symptomatic patients and those with residual complications.

Table 1
Demographic, ECG, anatomic and basic surgical data.

Demographic parameter		
Age	Years	24.7 ± 4.9
Female	n	41 (28%)
Height	cm	172.6 ± 9.0
Weight	kg	67.2 ± 14.4
BMI	kg/m2	22.1 ± 4.7
ECG		
QRS duration	ms	102 ± 19
QTc	ms	421 ± 35
Surgical details		
TGA with IVS	n	95 (65.5%)
TGA with VSD	n	49 (33.8%)
Taussig–Bing	n	1 (0.7%)
Aortic coarctation	n	12 (8.3%)
Coronary pattern (A/B/C/D/E)	%	79/4/0/14/3
Age at ASO	days	15.5 (IQR 5–218)
Two-stage repair	n	35 (24.1%)
Lecompte maneuver at ASO	n	128 (88.3%)

BMI, body mass index; QTc, corrected QT interval on ECG at last follow-up; TGA, transposition of the great arteries; IVS, intact ventricular septum; VSD, ventricular septal defect; ASO, arterial switch operation, PA, pulmonary artery; (*), coronary pattern according to Yacoub and Radley-Smith. Data shown as mean ± standard deviation, median and interquartile range (IQR) or number and percent in general study population. Single and two-stage repair as described previously [44].

3.2. Functional status

Most patients reported a normal exercise tolerance on their last clinical assessment (91% in NYHA class I), while 6% were in NYHA class II, 2% in class III. Only one (0.7%) patient who had not undergone closure of the ventricular septal defect due to pre-existing pulmonary hypertension was in NYHA class IV. This patient died at the age of 38 years. All 3 patients in NYHA class III had significant systolic dysfunction of the left ventricle (LV).

3.3. Coronary complications

Information on the coronary pattern, as documented at the time of ASO, was available in all patients (Table 1). In contrast, subsequent diagnostic coronary imaging was performed on clinical grounds in selected patients and was available in only 23% of cases. No patient underwent percutaneous coronary intervention in childhood. In adulthood, 13 patients (9%) were suspected of having coronary artery disease based on symptoms. Myocardial perfusion scintigraphy was performed in 4 patients, 5 patients underwent coronary angiography (including 2 patients who had both), and the remaining 6 cases were investigated using exercise testing and coronary computer tomography. Coronary disease could be confirmed in only 3 patients (2.1%). In 1 patient this was likely related to previous surgery (subtotal ligation) as he was found to have significant stenosis of the circumflex artery arising from the RCA and required percutaneous intervention with stent implantation. He also had chronic LAD occlusion with long-standing severe LV dysfunction. Two additional patients who underwent surgical pulmonary valve replacement had coronary artery bypass