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Persistent superior exercise performance and quality of life long-term after arterial switch operation compared to that after atrial redirection

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ABSTRACT

Background: In the end of the last century arterial switch operation (ASO) replaced atrial redirection according to Senning or Mustard as the surgical technique for infants with transposition of the great arteries (TGA). Better survival with the new technique has been shown. However, exercise performance and quality of life have not yet been compared directly.

Methods and results: All consecutive patients aged sixteen years or older that had undergone ASO for TGA at our institution and had performed a cardiopulmonary exercise test as part of their routine follow-up were included into the study. Those twenty-eight patients (20 male, median age 18.8 years) were matched for age and gender with twenty-eight patients (20 male, median age 18.9 years) who underwent atrial redirection in the same surgical period at our institution.

Peak oxygen uptake was higher in patients after ASO (median 38.1 [quartiles 30.3; 44.5] ml/kg/min vs. 29.8 [23.5; 33.9] ml/kg/min; $p<.0001$) representing 92.0% predicted and 66.1% predicted ($p<.0001$), respectively. In addition, patients after ASO presented a better ventilatory efficiency ($\dot{V}_E/\dot{V}_{CO_2}$ slope, $p=.029$), ventilatory threshold ($p=.006$), peak O_2 pulse ($p=.0001$), and oxygen saturation ($p=.016$), as well as a superior blood pressure ($p=.046$) response to exercise.

Self-estimated quality of life was rather good in both groups but with better results in the physical functioning and general health domains in patients after ASO.

Conclusions: Adolescents and young adults with TGA still have an improved exercise performance and quality of life in the long-term follow-up after ASO than those patients after atrial redirection.

1. Introduction

In 1975 Jatene [1] introduced the arterial switch operation (ASO) as a new approach to treat patients with transposition of the great arteries (TGA). The expectation of this operation, after which the morphologic left ventricle is the systemic ventricle, made it the treatment of choice for patients with TGA. However initially, that new surgical technique had a substantial prevalence of perioperative deaths and potential complications associated with inadequate coronary perfusion [2–5]. Nowadays, this is outperformed by an improved long-term survival [2]. Many studies report on an excellent exercise performance [6–8] and quality of life [9–12] in children and adolescents after ASO. But studies suggest that exercise performance of patients after ASO might worsen with increasing age as it is seen in patients after atrial redirection [13,14].

In most centers there was a sudden switch from atrial redirection to ASO in the early 1990s [2]. In our institution there was an overlap from 1983 to 1993 and the respective surgical treatment was determined by the preference of the surgeon. One surgeon favored the new technique and performed ASO with very low mortality from the beginning on; the other one stuck to the old technique that he had performed for several years without mortality at all. Thus, during that period of time there was an almost random selection in surgical technique.

The present study aimed to compare exercise capacity and quality of life in adolescents and young adults with TGA, who had either undergone ASO or atrial redirection during the transition period of these two surgical strategies.

2. Patients and methods

2.1. Study subjects

All consecutive patients aged sixteen years or older at the time of the study, who underwent ASO for TGA during 1983 to 1993 in our institutions and who were referred for a cardiopulmonary exercise test (CPET) as part of their routine follow-up, were included in the study. They (20 male, 8 female, median age 18.8 years) were matched for

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age and gender with twenty-eight patients (20 male, 8 female, median age 18.9 years) who underwent atrial redirection for TGA according to the Senning procedure during the same period of time in our institution. Patients with TGA and pulmonary stenosis and patients with a pacemaker were excluded.

Medication in the atrial redirection group consisted of sotalol (1), beta-blocker (1), ACE inhibitor (2), a combination of sotalol and ACE inhibitor (1), and a combination of beta-blocker, digoxin and ACE inhibitor (1). In the ASO Group only two patients took warfarin after aortic valve replacement.

The study was in accordance with the declaration of Helsinki (revision 2008). Patients agreed to the anonymous publication of their data.

The authors of this manuscript have certified that they comply with the Principles of Ethical Publishing in the International Journal of Cardiology.

2.2. Cardiopulmonary exercise test (CPET)

All patients underwent a symptom limited cardiopulmonary exercise test on a bicycle ergometer in upright position as previously described [15].

In short, after a 3 minute rest to define baseline, patients had a 3 minute warm up without load, followed by a ramp wise increase of load with 10, 15, 20, or 30 W/min depending on the expected individual physical capacity estimated by the investigator. The aim was to reach a cycling duration of about 8 to 12 min after warm up. The end of the CPET was marked by symptom limitation and was followed by a 5-minute recovery period, with the first 2–3 minute cycling with minimal load.

The exercise test featured a breath-by-breath gas exchange analysis using a metabolic chart (Vmax 229, SensorMedics, Viasys Healthcare, Yorba Linda, California). Peak oxygen uptake ($\dot{V}O_2$) was defined as the highest mean uptake of any 30-second time interval during exercise. Reference values for age, body mass, body height, and gender, expressed in "% predicted" were calculated like previously described [15]. Ventilatory threshold was estimated manually with the V-slope method according to Beaver et al. [16] and corrected by the $\dot{V}_E/\dot{V}_{CO_2}$ curve. Ventilatory efficiency was displayed as $\dot{V}_E/\dot{V}_{CO_2}$ slope confined to the linear part of the curve, excluding values beyond the respiratory compensation point. Peak O_2 pulse was defined as peak $\dot{V}O_2$ divided by peak heart rate. The reference value was calculated from the peak $\dot{V}O_2$ reference value divided by 200 bpm, which is the expected peak heart rate of that age group.

2.3. Quality of life

The medical outcomes study 36 item short form (SF-36) was used. It has an acceptable internal consistency and has proven useful in various specialties of medicine without any bias for symptoms of a specific disease. The SF-36 measures eight health constructs with scores ranging from 0 (worst) to 100 (best) using subscales with two to 10 items per subscale and one single item about health transition. We used the German version of the self-report form with a window of four weeks. Individual age- and sex-related reference values were drawn from the German evaluation study [17].

2.4. Data analyses

Since data were skewed, all descriptive data were expressed in median values and interquartile ranges (Q1; Q3). Non-parametric Mann–Whitney-U tests und Chi-square tests were calculated to find differences between patients after ASO and those after atrial redirection. The primary question was, whether there is a difference in peak $\dot{V}O_2$. Secondary questions were the quality of life scales and other CPET variables.

All analyses were performed using PASW Statistics 18.0 (SPSS Inc, Chicago, Illinois, USA). P-values <0.05 in a two-sided analysis were considered significant.

3. Results

3.1. Patients

Patient's characteristics are displayed in Table 1. The subgroup of patients who received atrial redirection did not differ on age, gender and the appearance of a preceding palliation, complex or simple TGA (presence of a ventricular septal defect or not) and body mass index.

3.2. Exercise capacity

Peak $\dot{V}O_2$ was significantly higher after ASO (92.0 [80.8; 105.2] % of predicted) than after atrial redirection, (66.1 [60.0; 77.0] % of predicted; $p<.0001$). The $\dot{V}_E/\dot{V}_{CO_2}$ slope was significantly lower in the ASO group. Furthermore, ventilatory threshold, peak O_2 pulse, peak workload, peak systolic blood pressure, and SpO_2 at peak exercise were higher in the ASO group (Table 1). Respiratory exchange ratio showed adequate exhaustion at the end of exercise without a significant difference in the diagnostic subgroups (1.10 [1.06; 1.13] in atrial redirection vs. 1.10 [1.05; 1.13] in ASO; $p=.831$). Results of all CPET variables are displayed in detail in Table 1.

3.3. Quality of life

Self-estimated quality of life was fairly good in both groups and in many scales, the best imaginable result was achieved in many patients (Table 2).

The differences between the groups were only marginal. Statistical significance was reached in the dimension "physical functioning" ($p=.004$) and "general health" ($p=.049$), where the ASO patients reported the better results.

4. Discussion

This study showed the persistent superior long-term outcome regarding exercise performance of young adults almost two decades after arterial switch operation in comparison with patients who underwent atrial redirection for transposition of the great arteries in infancy.

Table 1
Study subjects and exercise data according to diagnostic subgroups.

		Senning (n = 28)	Arterial switch (n = 28)	p-values[a]
Sex	♂/♀	20/8	20/8	–
Age	years	18.9 (17.7; 20.0)	18.8 (17.1; 19.5)	0.611
BMI		20.2 (18.9; 24.4)	21.3 (19.6; 24.2)	0.283
Ventricular septal defect	n	4	9	0.205
Preceding atrial septostomy	n	6	3	0.469
Peak $\dot{V}O_2$	ml/min/kg	29.8 (23.5; 33.9)	38.1 (30.3; 44.5)	<***0.0001***
	% predicted	66.1 (60.0; 77.0)	92.0 (80.8; 105.2)	<***0.0001***
Ventilatory threshold	ml/min/kg	16.2 (13.4; 19.8)	21.7 (14.9; 24.8)	***0.006***
Peak O_2 pulse	% predicted	78.6 (66.6; 91.7)	101.2 (89.0; 115.7)	<***0.0001***
Peak work load	W	173 (135; 188)	201 (149; 266)	***0.034***
	W/kg	2.7 (2.3; 3.1)	3.2 (2.5; 3.7)	***0.023***
$\dot{V}_E/\dot{V}_{CO_2}$ slope		29.3 (25.3; 32.0)	26.3 (25.0; 28.4)	***0.029***
Peak heart rate	bpm	174 (160; 183)	181 (171; 187)	0.133
Systolic blood pressure at peak exercise	mm Hg	168 (152; 181)	185 (168; 200)	***0.046***
SpO_2 at peak exercise	%	92 (89; 96)	96 (92; 98)	***0.016***
RER at peak exercise		1.10 (1.05; 1.13)	1.10 (1.06; 1.13)	0.831

Data is presented as median and interquartiles.
RER (respiratory exchange ratio).
[a] Comparing the groups by a two-sided Mann–Whitney *U* test.