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Key Points

Question: What are the outcomes of pregnancy in women with transposition of the great arteries following arterial switch surgery?

Findings: In this cohort study that included 15 women there were 24 completed pregnancies with live well infants and no adverse maternal cardiac events. No neo-aortic root progression was seen and only 2 delivery modes were dictated by maternal cardiac considerations.

Meaning: Pregnancy is well tolerated, with good maternal and fetal outcomes, in women with transposition of the great arteries and previous arterial switch surgery.

Abstract

Importance

A growing number of women are approaching childbearing age following arterial switch surgery for transposition of the great arteries. Pre-pregnancy counselling requires up to date, but currently unknown knowledge of the additional cardiovascular risks pregnancy poses for this cohort of women and the impact upon their offspring.

Objective

To determine the pregnancy outcomes in women and their offspring following the arterial switch operation.

Design

This cohort study assessed women with arterial switch surgery performed from 1985 onwards, who in January 2018 were aged 16 or above.

Setting

Level One Congenital Cardiology centre and joint cardio-obstetric clinic, Birmingham, UK.

Participants

All women with a previous arterial switch surgery for transposition of the great arteries with completed or ongoing pregnancy were included.

Exposures

Patients were assessed pre, during and after pregnancy.

Main outcome(s) and measure(s)

Adverse maternal cardiac events (arrhythmia, heart failure, aortic dissection or acute coronary syndrome). Aortic root dilatation, aortic regurgitation and left ventricular function pre and post pregnancy. Mode of delivery and fetal outcomes.

Results

25 pregnancies were identified in 15 women; 8 women had one pregnancy, whilst 7 were multiparous. There were no adverse maternal cardiac events. Pre-pregnancy, 53% of women had no aortic regurgitation, 7% trivial, 26% mild and 14% moderate. Post pregnancies, only one woman had minor progression of her aortic regurgitation. 5 (36%) women had mild neo-aortic root dilatation pre-pregnancy, but none developed progressive dilatation up to one year post-partum. 24 pregnancies were completed by study end with all infants born alive and well. 37% of deliveries were Caesarean sections, 11% recommended for aortic dilatation and 26% for obstetric indications.

Conclusions and Relevance

Pregnancy is well tolerated following the arterial switch operation without adverse maternal cardiac events or early progression of neo-aortic root dilatation or aortic regurgitation. These results provide evidence to allow reassurance of women with previous arterial switch surgery planning pregnancy.

Introduction

The arterial switch operation has been the surgical correction of choice for transposition of the great arteries (TGA) for over thirty years(1). Hence, there are a growing number of women at or approaching childbearing age. Pregnancy represents a state of sustained physiological stress(2), which may exacerbate complications following ASO including neo-aortic root dilatation, aortic regurgitation and myocardial ischaemia due to coronary abnormalities(3, 4). Much care is taken in pre-pregnancy counselling of these patients(5), but there is a paucity of contemporaneous information about pregnancy outcomes as the largest published case series only contains nine women with 13 successful pregnancies and two experiencing cardiac complications(6). We aimed to determine the pregnancy outcomes for our larger cohort of women following ASO.

Methods

Female patients with previous ASO under follow-up at the Queen Elizabeth Hospital Birmingham were identified. Women who had completed pregnancies or were currently pregnant were identified from medical records and the joint obstetric/cardiology clinic. Medical notes were reviewed for demographic data. Imaging data from echocardiography were obtained pre, during and post pregnancy where available. Left ventricular size and systolic function, aortic root dimensions at the sinuses of Valsalva, and severity of any aortic regurgitation, pulmonary valve stenosis/regurgitation and tricuspid regurgitation were recorded. Aortic dilatation was defined as a diameter greater than the 95th centile for gender and age(7, 8). Neo-aortic root z-scores were calculated as both non – normalised values(9) and values normalised for body surface area, as described by Devereux *et al*(10).Valvular lesions were graded according to American Society of Echocardiography guidelines(11). Maternal and fetal outcomes were obtained from medical notes. Evidence of adverse maternal cardiac events (arrhythmias, heart failure, aortic dissection and acute coronary syndromes) were sought. This study was registered with our institution: individual informed consent was not

required in accordance with the UK National Research Ethics Service guidance as this was a retrospective analysis of data collected for routine clinical care.

Results

Fifty-five women over the age of 16, with a mean age of 23.6±5.1 (range 17-41) years, who had undergone ASO were identified. Of these, 15 women (27%) had been or were pregnant with a total of 25 pregnancies. Twenty-four pregnancies were completed by the study end with one ongoing. The mean age at first delivery was 23.0±3.9 (range 17-31) years. Eight women had one pregnancy, 7 women were multiparous. Demographics are shown in Table 1.

Ten (67%) women had a diagnosis of transposition with intact ventricular septum, 3 had transposition with ventricular septal defects (VSD) and 2 had complex TGA with associated cardiovascular lesions [1 with right ventricular outflow tract (RVOT) obstruction, and 1 with coarctation of the aorta]. Most arterial switch operations (67%) were performed in the neonatal period, apart from in five patients who had surgery at 3 and 8 months, 2.5, 6.1 and 8.5 years respectively. These five patients were born in the early era of arterial switch surgery; four of these patients (three with TGA VSD) underwent prior pulmonary artery banding; the fifth patient (complex TGA) presented late at 3 months of age. Six (40%) of the women had undergone further surgery/interventions following ASO prior to their first pregnancy, with the most common indication (four women) as branch pulmonary artery stenosis.

No patients experienced adverse cardiac events; namely, no episodes of heart failure, arrhythmias, coronary ischaemia, aortic dissection, nor maternal deaths.

Twelve (80%) women had serial echocardiography that included a study following their last pregnancy. Of these, only one had progression in the degree of aortic regurgitation from none to mild between her first and third pregnancy over a 12 year period. There was no change in neo-aortic root dilatation for the 12 women with serial imaging, including the 5 women who pre-pregnancy had mildly dilated neo-aortic roots. The mean neo-aortic root diameters and z-scores pre and post

pregnancy are shown in Table 2.Three women underwent cardiac magnetic resonance (CMR) examination whilst pregnant to fully evaluate aortic dimensions; there was no progressive neo-aortic root dilatation.

All 15 women had normal left ventricular (LV) systolic function prior to their first pregnancy, 2 patients were noted to have mildly dilated LV end diastolic dimensions, but these did not change following pregnancy. One woman had a decline in left ventricular function from normal to mildly impaired following her second pregnancy. Third trimester echocardiography during her second pregnancy demonstrated normal LV function; mildly impaired LV systolic function was noted eight months post-partum. However, this patient had a complex surgical history having undergone three operations since ASO prior to her two pregnancies, 1)resection of a pulmonary artery aneurysm, 2)pulmonary valve replacement with RVOT patch enlargement and 3) right coronary artery bypass grafting.

Neonatal data was available for 22 (92%) of the delivered pregnancies. The mean gestation at delivery was 38.5±2.0 (range 35-42) weeks. One delivery was preterm (<37 weeks); a spontaneous labour at 35 weeks with an emergency Caesarean section (C-section) for breech presentation.

The mean birth weight was 3184±447g (range 2270-4167g). The mode of delivery was available from 19 of deliveries (79%). Eight women had a normal vaginal delivery, 4 instrumental births and 7 C-sections. Two of the C-sections were emergencies for delay in second stage and breech presentation respectively. The remaining 5 C-sections were elective; 2 for breech presentations, 2 advised for dilated aortic root dimensions and 1 for maternal choice. There were no neonatal deaths. No cardiac disease was noted in any children.

Discussion

This study is the largest to date of pregnancy outcomes in women who have undergone arterial switch surgery for transposition of the great arteries. We found that pregnancy was well tolerated with no adverse cardiac maternal events.

The largest previous study by Tobler *et al* (6)found a 15% rate of cardiac events within their cohort consisting of mechanical valve thrombosis and non-sustained ventricular tachycardia. They additionally found two women with reduction in their left ventricular ejection fraction, as we found in one patient. In both cohorts, neo-aortic root dimensions were stable during and after pregnancy. We additionally found one patient with minor deterioration in their degree of aortic regurgitation from none to mild.

The patients studied by Tobler *et al* (6) represent a more complex and earlier surgical cohort, which may account for the high (67%) rates of re-interventions following the ASO and maternal complications; in our patients, the rate of surgical re-intervention was 40%.

In our cohort, only 2 C-sections were dictated by maternal cardiac considerations. There were less normal vaginal deliveries in our cohort (42.1%) compared to a national average of 59.4%, whilst there was a higher rates of C-sections (36.8%) versus the national average of 27.8%(12).

Re-implantation of the coronary arteries remains one of the main challenges during ASO(13). However, despite coronary ischaemia being a well-recognised late complication following ASO(3), none of our patients developed any coronary ischaemia, even with the additional physiological stress and pro-coagulant state pregnancy confers.

The need for serial assessment of women with aortic root dilatation during pregnancy is extrapolated from observational studies in women with aortopathies that demonstrated increased rates of aortic dilatation and dissection during pregnancy(14, 15). Our five patients with neo-aortic dilatation pre-pregnancy all underwent post-partum imaging that did not demonstrate any further dilatation.

This study is limited by the retrospective design and the small number of pregnancies that have occurred to date in these women. Additionally, we do not have further data on neonatal outcomes or infant growth and development. Understanding of the long-term paediatric outcomes will require

careful evaluation of these children as they grow. Larger multi-centre studies with longer postpartum follow up will be required to fully evaluate the long-term consequences of pregnancy in women following ASO. In conclusion, our data provide evidence that pregnancy is well tolerated with good maternal outcomes following arterial switch surgery for transposition of the great arteries in the setting of multidisciplinary obstetric cardiology care and thorough pre-conceptual assessment and counselling.

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Table 1 Baseline demographics pre-pregnancy

Variable	**Number=15**
Age at time of ASO, months	0.3 [0.2-5.2]
Associated cardiac lesions/interventions	
VSD	5 (33)
PA band	4 (27)
PA interventions	6 (40)
Age at first delivery, years	23.0±3.9
Number of pregnancies	
1	8 (53)
2	4 (27)
3	3 (20)
Cardiac lesions pre first pregnancy	
Aortic regurgitation	
None	8 (53)
Trivial	1 (7)
Mild	4 (27)
Moderate	2 (13)
Neo-aortic root dilatation present	5 (33)
Pulmonary stenosis	

None	11 (73)
Mild	4 (27)
Pulmonary regurgitation	
None	9 (60)
Trivial	2 (13)
Mild	3 (20)
Moderate	1 (7)
Tricuspid regurgitation	
None	4 (27)
Trivial	6 (40)
Mild	3 (20)
Moderate	2 (13)

Data are mean ± SD, median [IQR], or number (%)

ASO, arterial switch operation; PA, pulmonary artery; VSD, ventricular septal defect

Table 2 Pre and post-pregnancy aortic root dimensions and z-scores

	Pre-pregnancy (n=15)			Post-pregnancy (n=12)		
	Aortic root diameter (mm)	Z score (not normalised)	Z score (normalised for BSA)	Aortic root diameter (mm)	Z score (not normalised)	Z score (normalised for BSA)
Entire group	33±5	1.85±1.96	1.35±1.8	34±5	2.19±1.86	1.73±1.76
No neo-aortic root dilation present	29±2.8	0.64±1.32	0.12±1.06	30±2.3	0.98±1.05	0.39±0.91
Neo-aortic root dilatation present	38±2	3.66±1.25	3.20±0.89	38±2	3.71±1.51	3.40±0.96

Data are mean ± SD

BSA, body surface area