Obstetric outcomes following atrial and arterial switch procedures for transposition of the great arteries (TGA) – A tertiary referral centre experience over 20 years

Anna Fabre-Gray[1] (iD), Stephanie Curtis[2,3] and Johanna Trinder[3,4]

Abstract

Repair of transposition of the great arteries usually involves an atrial switch or arterial switch operation, which can complicate physiological adaptation to the demands of pregnancy and adversely affect the fetus. We retrospectively compared outcomes of 48 completed pregnancies in 23 women with surgically corrected transposition of the great arteries (38 atrial switch/10 arterial switch operation) under joint cardiac-obstetric care in our tertiary referral clinic between 1997 and 2017. Most women delivered vaginally (85%). The pre-term delivery rate was high (atrial switch 39%; arterial switch operation 40%). Small for gestational age occurred in 56% of babies, significantly more in the atrial switch group (66%) than arterial switch operation (20%), $p = 0.013$. Women with surgically corrected transposition of the great arteries wishing to become pregnant are at high risk of obstetric complications, primarily pre-term delivery and small for gestational age baby. They require more careful ultrasound surveillance beyond 36 weeks' gestation and/or may benefit from early induction of labour.
Trial registration: Not applicable.

Introduction

Congenital heart disease (CHD) affects 8 in 1000 live births.[1] More affected women are surviving into adulthood, having undergone complex cardiac surgery in childhood and are undertaking pregnancy.

Complete transposition of the great arteries (TGA) or dextro-transposition of the great arteries (d-TGA) accounts for approximately 5%–7% of CHD.[2] In d-TGA, there is ventricular–arterial discordance with the aorta arising from the morphological right ventricle (RV) and the pulmonary artery from the morphological left ventricle (LV). The atrial switch procedure, developed by Mustard[3] and Senning,[4] was the first operation to enable survival beyond infancy. It involves redirection of venous blood flow within the atrial compartment, leaving the morphological right ventricle supporting the systemic circulation.

Pregnancy outcomes in women with an atrial switch have been described in the literature.[5–9] Cardiac risks include deterioration of ventricular function, heart failure and arrhythmias.[10] Obstetric risks include pre-term delivery and small for gestational age babies (SGA, defined as birthweight below the 10th centile).

The atrial switch procedure was superseded by the arterial switch operation (ASO). First successfully performed in 1975 by Jatene et al.,[11] it involves transection and 're-plumbing' of the great arteries to restore near normal anatomy and physiology. The pulmonary arteries come to lie anterior to the aorta and the coronary arteries are re-implanted into the neo-aorta. Survival has increased with refinement of surgical techniques and 20-year survival now approaches 90%.[12] Long-term complications include (supra) pulmonary stenosis, neo-aortic valve regurgitation, neo-aortic dilatation and coronary artery complications.

Adult survivors of the ASO are now undertaking pregnancy. The first reported outcome was in 2006 in a woman who had an ASO in 1978 and subsequent replacement of the pulmonary valve

[1]Department of Maternal and Fetal Medicine, St Michael's Hospital, University Hospitals Bristol, Bristol, UK
[2]Adult Congenital Heart Disease, University Hospitals Bristol, Bristol, UK
[3]Department of Maternal Medicine, University Hospitals Bristol, Bristol, UK
[4]Department of Obstetrics, University Hospitals Bristol, Bristol, UK

Corresponding author:
Anna Fabre-Gray, Department of Maternal and Fetal Medicine, St Michael's Hospital, University Hospitals Bristol, Southwell Street, Bristol BS28EG, UK.
Email: a.fabre-gray@nhs.net

without further complications or significant haemodynamic sequelae. An SGA baby was successfully delivered at term by emergency caesarean section for fetal distress.[13]

With limited data, it was assumed that that preservation of the left ventricle as the systemic 'pump' would mean fewer cardiac events and obstetric complications in pregnant women. The only published series to date by Tobler et al.[14] states a 15% (2/13) rate of adverse cardiac events and incomplete obstetric outcome data.

As an adult congenital heart disease (ACHD) centre and tertiary level maternal medicine service, our unit has over 20 years' experience in the multi-disciplinary team management of women with surgically corrected TGA in pregnancy.

We report and compare obstetric outcomes in women with congenital TGA, corrected by either an atrial switch procedure or an ASO. We have previously published our cardiac complications experienced during pregnancy after atrial switch.[15] Therefore, here, we aim to compare the obstetric and neonatal outcomes between the two surgical repair groups, and provide advice for the safe obstetric management for such women.

Methods

This was a retrospective cohort study. Women with TGA that had been surgically corrected with either an atrial switch procedure or an ASO and had undertaken pregnancy were identified from the database at our tertiary cardiac/maternal medicine antenatal clinic at St Michael's Hospital, Bristol. Patient records were reviewed for those who delivered beyond 24 weeks' gestation between 1997 and 2017. Cases prior to 1997 were not included as databases were not well established and data were incomplete.

Data collection involved multiple sources: hard copies and electronic patient records from different systems: Evolve, PODS viewer, Medway, Medway Maternity, the cardiac/maternal medicine clinic and Viewpoint databases.

Baseline data were recorded for both groups, including age, parity, smoking status, body mass index (BMI), type of primary repair, age at primary surgery and pre-pregnancy medications.

Obstetric outcome data were recorded, including gestation at delivery, birthweight and birthweight centile. SGA neonates were sub-divided into those predicted by antenatal ultrasound assessment and those not predicted, induction of labour (IOL) and reasoning, mode of delivery and analgesia. Birthweight centiles were taken from WHO growth charts and adjusted for gender.[16]

Neonatal outcome data included: live births, pre-term delivery (under 37 weeks), presence of pre-labour, pre-term rupture of membranes (PPROM) or pre-labour rupture of membranes (PROM), APGAR scores, admission to neonatal intensive care unit (NICU) and neonatal morbidity.

Obstetric complications included: post-partum haemorrhage (PPH), antepartum haemorrhage (APH), PPROM, PROM, preterm delivery, spontaneous pre-term labour, obstetric cholestasis, intrapartum sepsis, thromboembolic events, pre-eclampsia (also

known as pre-eclamptic toxaemia or PET), defined by NICE as new onset hypertension of over 140/90 mmHg after 20 weeks of gestation with significant proteinuria (urinary protein: creatinine ratio greater than 30 mg/mmol)[17] and gestational hypertension, defined as new hypertension >140/90 mmHg after 20 weeks of gestation, without significant proteinuria.[17]

Miscarriages were not included as it was not possible to ensure inclusion of all cases retrospectively.

Statistical methods

Median values and ranges were calculated for continuous variables where appropriate. Descriptive statistics for nominal data were expressed in absolute numbers and percentages. Comparison of the occurrence of complications between the two groups was performed using Fisher's exact test and the Mann–Whitney U test. A p-value <0.05 was considered statistically significant. Data were presented as mean ± standard deviation for parametric data and median and range for non-parametric data.

Results

There were 48 completed pregnancies in 23 women. Nineteen women who had undergone an atrial switch procedure delivered 38 babies and 4 women who had undergone an ASO had 10 babies. Baseline characteristics of both groups are shown in Table 1, and there were no statistically significant differences between the two groups.

Obstetric outcomes

Obstetric outcomes are shown in Table 2. Most women delivered vaginally (85%), significantly more in the atrial switch group than the ASO group (92% vs. 60%, $p = 0.027$).

Of the women who had an atrial switch and a vaginal delivery 25/35 (71%) delivered normally and 10/35 (29%) had an instrumental delivery, 9 of which were following a reduced second stage or planned, elective instrumental delivery. A reduced second stage consisted of 30 min of active pushing, whilst a passive second stage consisted of an early epidural, 2 h of passive descent (once fully dilated) and an elective forceps delivery without maternal effort. The decision for a reduced or passive second stage was based on maternal antenatal cardiac status. In the ASO group, only one woman had instrumentation, again this was performed electively, for cardiac reasons. Regarding epidural use, 19/35 (54%) of women who delivered vaginally in the atrial switch group had an epidural, as did 4/6 (67%) of the ASO group. All caesarean sections were performed for obstetric reasons (previous caesarean section, breech presentation).

Most women were induced (79% atrial switch vs. 60% ASO, $p = 0.24$), there was no significant difference between the two groups. The most common reason for induction in both groups was fetal concern (suspected IUGR consisting of reduced growth

Table 1. Baseline characteristics of women undergoing pregnancy after atrial switch or ASO.

	Atrial switch, n	ASO, n	p Value
Women	19	4	
Pregnancies >24 weeks	38	10	
Smoker	4 (20%)	2 (50%)	0.27
Age (years; median + range)	24.5 (16–36)	25.5 (21–30)	0.40
BMI (kg/m²; median + range))	22.6 (17.9–40)	24.5 (15.5–28)	0.40
Parity	19 primagravidae (50%)	4 primagravidae (40%)	0.73
Cardiac medication during pregnancy	8 (21%)	2 (20%)	1.00

Table 2. Obstetric outcomes.

	Atrial switch, $n = 38$ (%)	ASO, $n = 10$ (%)	p Value
Induction of labour	30 (79)	6 (60)	0.24
Geography	6	4	
Fetal concerns	13	3	
Maternal cardiac condition	10	0	
Maternal obstetric reasons	8	2	
Maternal and fetal indications	7	3	
Vaginal delivery	35 (92)	6 (60)	0.03
Normal vaginal delivery	25 (71)	5 (50)	
Instrumental delivery	10 (29)	1 (10)	
Forceps delivery	8 (23)	1 (10)	
Ventouse delivery	2 (6)	0	
Caesarean section	3 (8)	4 (40)	0.03
Elective	3	1	
Emergency	0	3	
Total post-partum haemorrhage (PPH)	9 (24)	2 (20)	1.00
PPH 500–1000 ml	6 (16)	0	0.32
PPH > 1000 ml	3 (8)	2 (20)	0.28
Antepartum haemorrhage	5 (13)	0	0.57
Pulmonary embolus	2 (5)	0	1.00
Malpresentation (breech)	1 (3)	0	1.00
Idiopathic thrombocytopenic purpura	1 (3)	0	1.00
Manual removal of placenta	0	2 (20)	0.04
Pre-eclampsia	1 (3)	0	1.00
Pregnancy-induced hypertension	1 (3)	0	1.00

Table 3. Neonatal outcomes.

	Atrial switch, $n = 38$	ASO, $n = 10$	p value
Birth weight (g; mean + range)	2515 (1460–3530)	2630 (1700–3310)	0.94
Gestation at delivery (weeks; mean + range)	37 + 1 (32 + 2 to 40)	36 + 2 (32 + 0 to 38 + 3)	0.22
SGA (birthweight <10th centile)	25 (66%)	2 (20%)	0.01
US detected SGA	9 (24%)	1 (10%)	0.66
PPROM	4 (11%)	0	0.57
PROM	0	1 (10%)	0.21
Pre-term delivery	15 (39%)	4 (40%)	1.00
Induction of labour	11	2	
Spontaneous	4	2	
APGAR scores ≤7 at 1 min	5 (13%)	1 (10%)	1.00
Admission to NICU	8 (21%)	1 (10%)	0.66
	5/8 under 37 weeks	1/1 under 37 weeks	
Transitional care admission	12 (32%)	3 (30%)	1.00
>34 weeks ± <2.5 kg	10/12 under 37 weeks	3/3 under 37 weeks	

NICU: neonatal intensive care unit; PPROM: pre-term, pre-labour rupture of membranes; PROM: pre-labour rupture of membranes; SGA: small for gestational age; US: ultrasound.

velocity, and/or oligohydramnios, and/or abnormal Dopplers suggesting arterial or venous dysfunction) (43% atrial switch vs. 50% ASO, $p = 1.00$). Maternal concern (largely deterioration in cardiac status) was more often the cause for IOL in the atrial switch group than in the ASO group (33% vs. 0%, $p = 0.16$) and some women were induced for multiple reasons.

Overall the rate of post-partum haemorrhage was higher than background rate of 12.7%,[18] the reason for this is unclear but it seems similar to published rates of PPH in women with cardiac disease.[5] There was no difference between the two groups (atrial switch 9/38 (24%) vs. ASO 2/10 (20%), $p = 1.00$). Antepartum haemorrhage was more common in the atrial switch group (atrial switch 5/38 (13%) vs. ASO 0/10 (0%), $p = 0.57$) but not significantly so. Other obstetric complications were rare in both groups.

Neonatal outcomes

Neonatal outcomes are reported on Table 3. All pregnancies resulted in live births and there were no neonatal deaths. There was no difference in mean gestation at delivery (atrial switch 37 + 1 vs. ASO 36 + 2 weeks, $p = 0.218$) or mean birthweight (atrial switch 2515 g vs. ASO 2630 g, $p = 0.939$).

The number of SGA babies was high overall, 27/48 (56%) but significantly higher in the atrial switch group (atrial switch – 25/38 (66%) vs. ASO 2/10 (20%), $p = 0.013$). Only 10/27 (37%) were diagnosed at <10th centile by ultrasound prior to delivery.

The number of pre-term deliveries was similar in each group (atrial switch 15/38 (39%) vs. ASO 4/10 (40%), $p = 1.00$) and there was no difference in the finding of an APGAR scores of less than 7 at

1 min (atrial switch 5/38 (13%) vs. ASO 1/10 (10%), $p = 1.00$) or the number of admissions to NICU (atrial switch 8/38 (21%) vs. ASO 1/10 (10%), $p = 0.66$) or transitional care (atrial switch 12/38 (32%) vs. ASO 3/10 (30%), $p = 1.00$).

Additional neonatal morbidity included two cases of cerebral palsy (both in the atrial switch group). The first was born at 36 weeks' gestation, following PPROM at 30 weeks; the fetus was SGA and delivery was out of area. The second was born at 34 weeks' gestation, following IOL for deteriorating maternal cardiac condition. No CHD was diagnosed in the neonates.

Discussion

With improvement in survival following surgical correction of TGA, more women are choosing to undertake the challenge of pregnancy. It is therefore increasingly important to understand the associated risks and offer such women the safest care possible.

Vaginal delivery is preferred following corrected TGA. We were encouraged to see that 85% women overall delivered vaginally and that all caesarean sections were performed for obstetric indications. Instrumental delivery was more commonly used in the atrial switch group to permit a cardio-protective second stage.

IOL was common for fetal reasons in both groups but a quarter of women in the atrial switch group were induced for maternal cardiac reasons compared to none in the ASO group, reflecting the different cardiac anatomy.

The rate of PPH was higher than the background rate[18] in both groups, the reason for this is not clear but it did not appear to be associated with mode of delivery.

The 39%–40% rate of preterm delivery was high in both groups and significantly higher than the background risk.[19] As shown in Table 4, this has previously been reported as between 25% and 50% post-atrial switch.[5,6,8,9] Women in our series typically delivered their babies at 36–37 weeks, earlier than reported in other studies.[6,7]

A striking finding was the number of SGA babies born in this cohort. In the only other published series of pregnancies in women with ASO, Tobler et al.[14] reported 8% SGA, compared to our 20%, however birthweight was only reported for 7/13 births in that series.

Although SGA is widely reported in the infants of women post-atrial switch, rates have ranged from 8% to 22%,[4,5] and 26% in our previously reported data[10] whereas in this cohort 66% babies of our post-atrial switch mothers were SGA.

The high rate of SGA could be explained in part by other risk factors for SGA, such as smoking and age.[17] However, the number of smokers was similar in both groups and only two mothers in our cohort (both in the atrial switch group) were aged 35 years or older.

We hypothesise that the sub-optimal maternal physiological adaptation to pregnancy, following surgical correction of TGA, results in fetuses being unable to meet their growth potential.

Disappointingly only 37% SGA babies in the atrial switch group were diagnosed antenatally. This is concerning as these women had regular fetal growth surveillance (usually every month from 28 weeks' gestation). It is likely that the SGA in these women is secondary to placental insufficiency, occurring late in the third trimester and therefore not always recognised by routine clinical assessment and ultrasound.

The risks associated with SGA and prematurity have been well described.[20] Structurally normal, SGA fetuses are at increased risk of perinatal mortality and morbidity, hence the preoccupation with their identification and early delivery.

Therefore, we recommend that these women have more intensive obstetric and fetal surveillance and the obstetric management outlined below (see Box 1).

Strengths and limitations

This study represents the largest single centre experience of women with TGA corrected by ASO with detailed obstetric outcomes and the

Table 4. A comparison of reported obstetric outcomes.

	ASO		Atrial switch					
	Tobler et al.[14]	Current study	Drenthen et al.[5]	Trigas et al.[6]	Guedes et al.[7]	Canobbio et al.[8]	Metz et al.[9]	Current study
$n =$ (women/pregnancies)	9/13	4/10	28/49[a]	34/44	16/28	54/40	10/14	19/38
Age at delivery (years)	22	26	25.8	25	–	–	23.4	25
Gestation at delivery (weeks)	–	36 + 2	36 + 5	39 + 0	38 + 1	–	35 + 6	37 + 1
Pre-term delivery	0	4 (40%)	16(31%)	11(25%)	–	19(39%)	7 (50%)	15 (39%)
Spontaneous pre-term labour	–	2 (20%)	12(24%)	–	–	–	2 (14%)	4 (11%)
SGA	1 (8%)[b]	2 (20%)	11(22%)	5(8.3%)	–	–	–	25 (66%)
US detected SGA	–	1 (10%)	–	–	–	–	–	9 (24%)
PPROM	–	0	7(14%)	10(16.7%)	–	–	2 (14%)	4 (11%)
Postpartum haemorrhage	–	2 (20%)	7(14%)	–	–	–	–	9 (24%)
Pregnancy-induced hypertension	–	0	4(8.2%)	–	–	–	–	1 (3%)
Pre-eclampsia	–	0	5(10.2%)	1(1.7%)	–	–	1 (7%)	1 (3%)
Thromboembolic events	–	0	2(4.1%)	–	–	–	–	2 (5%)
NICU admission	–	1 (10%)	–	–	–	–	–	8 (21%)
APGARS <7 at 1 minute	–	1 (10%)	–	–	–	–	–	5 (13%)
Neonatal morbidity	–	0	–	–	–	–	–	0
Perinatal mortality	0	0	2(4%)	–	–	–	0	0
CHD recurrence	0	0	0	0	0	0	0	0

CS: Caesarean section; SGA: small for gestational age; US: ultrasound; PPROM: pre-term, pre-labour rupture of membranes; NICU: neonatal intensive care unit; CHD: congenital heart disease.
[a]Obstetric outcomes only available for 48 pregnancies.
[b]Birthweight data only available for 7/13 births.

Table 5. Maternal cardiac status and outcomes.

Patient no./ pregnancies	Cardiac status	Systemic ventricular function	NYHA class Preg/class	O$_2$ Sats. >96%	Maternal complications	Cardiac medication	IUGR
	ASO						
1/4	RVOT and PA patch mod. TR mod. PR (between 2nd and 3rd pregnancy – TVT and PVR)	Good	1-1 2-1 3-2 4-2	No	1-No 2-No 3-No 4-No	1-No 2-No 3-No 4-Yes furosemide	1-No 2-No 3-No 4-No
2/2	RVOT patch mod PR mod TR	Good	1-2 2-2	No	No	No	1-No 1-Yes
3/1	PA patch repair CABG	Good	1	No	No	1-Yes bisoprolol	1-Yes
4/2	1-severe PR between 1 and 2 – PVR TVR	Good	1	No	1-post-natal BV failure 2-No	No	1-No 2-No
	Atrial switch						
1/2	Normal	Good	1	No	No	No	1-No 2-Yes
2/3	Normal	Good	1	No	No	No	1-Yes 2-No 3-No
3/2	Intermittent nodal rhythm	Mild impairment	2	No	No	1-digoxin 2-digoxin	1-No 2-No
4/3	Atrial tachycardia mild TR	Good	1	No	No	1-digoxin 2-digoxin 3-digoxin	1-Yes 2-Yes 3-No
5/3	Mild TR	Moderate impairment	1	No	1, 2-No 3-angina	No	1-Yes 2-No 3-Yes
6/1	Intermittent nodal rhythm	Mild impairment	1	No	No	No	1-Yes
7/3	Baffle leak, pulmonary venous baffle dilatation	Good	1	No	No	No	1-Yes 2-Yes 3-Yes 4-Yes
8/2	Mild SVC baffle obstruction	Good	1	No	No	No	1-Yes
9/1	SVT – ablated	Good	1	No	SVT baffle thrombus	1-digoxin and labetalol	1-Yes
10/4	Small baffle leak	Good	1	No	No	No	1-Yes 2-No 3-Yes 4-Yes
11/2	Mild TR	Mild impairment	1	No	No	No	1-No 2-Yes
12/4	Normal	1-good 2-mild 3-moderate 4-severe impairment	1-1 2-1 3-2 4-3	1-No 2-No 3-Yes 4-Yes	1-4 escalating RV impairment 4 – angina and nodal rhythm	1-No 2-No 3-No 4-digoxin/ ISMN	1-Yes 2-No 3-No 4-Yes
13/1	Mild TR	Mild impairment	1	No	No	No	1-Yes
14/1	Mild TR	Mild impairment	1	No	Frequent ectopy	1 bisoprolol	1-Yes
15/1	Normal	Good	1		Nodal rhythm	No	1-Yes
16/2	Moderate TR NSVT, AT	Moderate impairment	1	No	No	1-Yes 2 bisoprolol	1-No 2-No

(continued)

Table 5. Continued

Patient no./ pregnancies	Cardiac status	Systemic ventricular function	NYHA class Preg/class	O$_2$ Sats. >96%	Maternal complications	Cardiac medication	IUGR
17/1	Mild TR	Mild-moderate impairment	I	No	No	No	1-Yes
18/1	Baffle obstruction	Good	I	No	No	1 labetalol	1-Yes
19/1	Normal	Mild impairment	I	No	Reduced VF	1 bisoprolol	1-Yes

NYHA: New York Heart Association; RVOT: right ventricular outflow tract; PA: pulmonary artery; TR: tricuspid regurgitation; PR: pulmonary regurgitation; TVR: tricuspid valve replacement; PVR: pulmonary valve replacement; CABG: coronary artery bypass graft; SVC: superior vena cava; SVT: supra-ventricular tachycardia; NSVT: non-sustained ventricular tachycardia; AT: atrial tachycardia; BV: bi-ventricular; RV: right ventricle; VF: ventricular function; ISMN: isosorbide mononitrate.

- Manage pregnancy in a joint obstetric/cardiac antenatal clinic
- Counsel about the high risk of SGA and pre-term delivery
- Offer regular fetal growth assessment from 28 weeks' gestation and continue until delivery with USS assessment for placental insufficiency
- Consider uterine artery Doppler assessment at 20–24 weeks' gestation as a marker of poor placentation as this may represent an additional risk factor
- Consider other risk factors for SGA, such as low pregnancy-associated plasma protein A (PAPP-A)
- 2018 ESC recommendations are for delivery at 40 weeks' gestation, although they specify that timing of IOL is dependent on maternal cardiac status and fetal wellbeing. Earlier delivery (from 36 weeks' gestation) may, however, be warranted as the risk of potentially unrecognised SGA is high in these women.[21]
- For atrial switch, consider an early epidural and passive second stage

Figure 1. Recommendations for obstetric care for women with surgically corrected TGA.

only study comparing outcomes by type of TGA repair. The findings are limited by the retrospective nature of the study and by small numbers, as the condition is rare. Due to the low statistical power and small numbers conclusions must be drawn with caution. However, this paper may be useful in the clinical management of such patients.

Conclusion

Women with surgically corrected TGA who wish to become pregnant are at high risk of obstetric complications, primarily pre-term delivery and delivering an SGA baby. The risk of SGA is greatest after atrial switch, but is still prevalent after the ASO. Mothers with surgically corrected TGA therefore require more careful ultrasound surveillance beyond 36 weeks' gestation and/or may benefit from early induction of labour. Our data suggests that a high rate of vaginal delivery can be achieved, even in this high-risk group.

These women need specialised pre-pregnancy counselling, antenatal and intrapartum care in a combined cardiac/obstetric antenatal clinic. Recommendations for care of these women are described in Figure 1.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

This retrospective review was undertaken as part of clinical service evaluation and adhered to local audit protocols and ethical approval. Written, informed consent from patients was therefore not sought.

Informed consent

Not applicable.

Guarantor

JT

Contributorship

All authors are involved in the preparation of this manuscript.

ORCID iD

Anna Fabre-Gray http://orcid.org/0000-0003-0469-3046

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