

# Long-term fate of the aortic valve after an arterial switch operation

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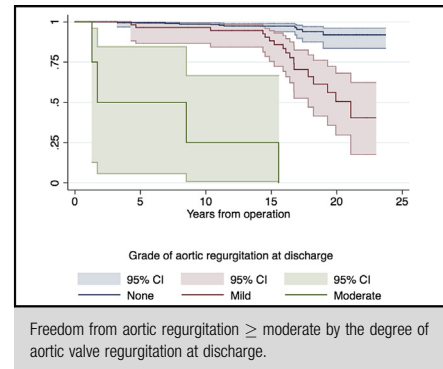
## ABSTRACT

**Objective:** To evaluate long-term performance of the aortic valve after an arterial switch operation (ASO), in terms of regurgitation and reoperation.

**Methods:** A longitudinal analysis of patients who underwent an ASO between 1988 and 1998 at the Birmingham Children's Hospital. Any type of aortic valve surgery after ASO was censored. To determine progression of aortic valve regurgitation, cardiologic follow-up and echocardiograms from the operation until 2012 were reviewed.

**Results:** A total of 362 patients underwent ASO; median age was 8 days. Ventricular septal defect was present in 151, aortic coarctation in 39, and interrupted aortic arch in 6 patients. The trap door technique was used for coronary translocation when possible; 4.1% had intramural coronaries. There were 331 alive patients; follow-up was complete at 93%; median duration was 16 years (interquartile range, 12-18.2 years). Overall survival at 10 and 20 years was 97.6% and 95.2%, respectively. Aortic valve reoperation occurred in 5 patients, giving freedom from aortic surgery of 99.3% and 97.7% at 10 and 20 years, respectively. Reoperations were aortic valve replacement (3), Bentall operation (1), and aortic valve repair (1). Freedom from  $\geq$ moderate regurgitation at 10 with 20 years was 97% to 80%, respectively. Degree of regurgitation immediately after ASO was strongly predictive of late aortic valve function: patients discharged with mild regurgitation had a significantly increased risk of progression compared with those with no regurgitation (20 years of freedom from  $\geq$ moderate regurgitation, 50% vs 96%,  $P = .0000$ ).

**Conclusions:** Reoperation on the aortic valve is rarely necessary, even late after an ASO, but a significant number of patients do have late aortic regurgitation and continue to need observation. (J Thorac Cardiovasc Surg 2015;149:1089-94)



### Central Message

Aortic valve reoperation is rarely necessary (1.6%) but late regurgitation develops in a significant number of patients (20%) even late after ASO. It is more common in patients with mild regurgitation immediately after ASO compared with patient's competent valve. Follow-up is essential because aortic regurgitation can develop 20 years after ASO.

### Perspective

Aortic valve competence represents the most impacting complication in the long-term patient's outcome after ASO. In the current era, aortic valve reoperation is a rare event but our data show that a progressive deterioration of aortic regurgitation tends to occur after 15-20 years from the initial repair if patients had only mild regurgitation initially. This finding highlights the importance of a close long-term cardiac follow-up and health care planning because we will face an increased number of patients who will require aortic valve surgery in the next future after ASO.

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The first successful arterial switch operation (ASO) was described by Jatene and colleagues<sup>1</sup> in 1976 and rapidly replaced the atrial switch operations that had been performed prior to that point for treatment of transposition of the great arteries (TGA). The ASO is considered the standard procedure for correction of TGA, with low mortality and morbidity.<sup>2-5</sup> Despite the excellent surgical results and the

high quality of life<sup>6</sup> that comes after ASO, a small proportion of patients have required reintervention for right ventricular tract obstruction,<sup>7</sup> left ventricular outflow tract obstruction, coronary artery problems, aortic root dilatation, and aortic valve regurgitation.<sup>8</sup>

Studies on large cohorts of patients have shown, in a midterm follow-up, a significant dilatation of the aortic root in the majority of patients, but with a low incidence of aortic valve regurgitation.<sup>9</sup> As we now approach the fourth decade since the first ASO, we have an opportunity to focus on the older patients and examine the longer-term impact of this operation on aortic valve function. This study aimed to concentrate on the cohort of patients who are 15-25 years past their ASO, to define the incidence and progression of aortic valve problems.

## MATERIALS AND METHODS

The aim of the study is to investigate long-term performance of the aortic valve; for this reason, we perform a retrospective longitudinal

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**Abbreviations and Acronyms**

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| ASO | = arterial switch operation                |
| Cx  | = circumflex coronary branch               |
| IQR | = interquartile range                      |
| LAD | = left anterior descending coronary artery |
| R   | = right coronary artery                    |
| TGA | = transposition of the great arteries      |

analysis of all the patients who underwent ASO for TGA between January 1988 and December 1998 at the Birmingham Children's Hospital, Birmingham, United Kingdom. Patients who died in the hospital were excluded from aortic valve performance analysis because long-term valve performance could not be assessed in those cases.

The end points were: (1) the grade of aortic valve regurgitation; (2) aortic valve stenosis; (3) aortic valve reoperation (aortic valve plasty or replacement, aortic root surgery); and (4) long-term survival. Patients' history, demographic data, diagnosis, pre-ASO procedures, hospital course, and discharge echocardiogram results were obtained from hospital records. Follow-up data were obtained by reviewing cardiologic charts and echocardiograms from Birmingham Children's Hospital and from the Grown-Up Congenital Heart Unit of the Department of Cardiology at the Queen Elizabeth Hospital of Birmingham, Birmingham, United Kingdom, where the patients were transitioned for follow-up at age 16 years. If patients were followed outside the Birmingham hospital network, data were retrieved from the other involved hospital cardiology departments.

Review of echocardiograms and reports, covering the period from the time of the operation to the most recent available, was performed for each patient. Degree of aortic valve regurgitation (classified as none, mild, moderate, or severe), aortic stenosis, and the presence of left ventricular outflow tract obstruction were recorded. Progression of aortic valve regurgitation was defined by the first echocardiogram in which worsening of the previous regurgitation class was recorded, and the worsening had to be confirmed in the later echocardiograms. Progression was noted only when confirmed by subsequent reports, to eliminate differences among echocardiogram operators for borderline cases.

The study was approved by the Scientific Committee of the Department of Cardiac Surgery at the Birmingham Children's Hospital. Data were analyzed using Stata, Release 12 (StataCorp, College Station, Tex). Data were expressed as mean  $\pm$  SD, and as median and range when appropriate. Tests used were the Student *t* test,  $\chi^2$  analysis, and Fisher exact test; Kaplan-Meier method analysis was performed for event-free and survival curves; the log-rank test and Cox regression were used for freedom-from-event-curve group comparison.

**RESULTS**

From 1988 to 2012, at the Birmingham Children's Hospital, 662 patients underwent an ASO for TGA. The population of interest for the study, from January 1988 to December 1998, consisted of 362 patients; 264 (73%) were male, and 98 (27%) were female. Median weight was 3.45 kg (range, 1.8-22.4, interquartile range [IQR]: 3-3.8 kg), and median age at operation was 8 days (range, 1 day to 10.7 years; IQR: 5-17 days); the older patients underwent ASO later, owing to complex anatomy.

The main diagnoses were TGA with intact ventricular septum in 211 (58.3%) patients, and TGA with ventricular septal defect in 151 (41.7%). Among the last group, 30 patients had Taussig-Bing malformation. Other minor

associated cardiac anomalies are listed in Table 1. Coronary pattern was normal (1LAD,Cx;2R) in 79% of the patients, and among these, 11 (3%) had an early take-off of the Cx from the LAD. In another 34 patients (9.3%), the Cx originated from the right coronary artery (1LAD;2R,Cx); the remaining coronary patterns are summarized in Table 1. Coronary intramural course affected 15 (4.1%) patients in the entire group.

The majority of the patients (302 [83.4%]) underwent balloon atrial septostomy before ASO; in 21 patients (5.8%), pulmonary artery banding was used as palliation before the complete repair that was performed at older ages (median: 240 days; range, 16 days to 10.7 years). All patients underwent an ASO and associated lesion treatment (ie, ventricular septal defect closure and atrial septal defect closure); the trap door technique, as described elsewhere,<sup>10</sup> was routinely used, except for cases of intramural coronaries in which coronaries were reimplanted using a patch technique. Mean cardiopulmonary bypass time was 112  $\pm$  47 min, and mean aortic cross-clamp time was 77.8  $\pm$  23 min.

After the ASO, the chest was left open in 97 (26.8%) patients, for a median time of 1 day (range, 1-5 days, IQR: 1-2 days). Patients were discharged from the intensive-care unit after a median time of 3 days (range, 1-45 days, IQR: 2-4 days) and from the hospital after a median time of 8 days (range, 4-56 days, IQR: 7-12 days).

A total of 31 (8.56%) in-hospital deaths occurred, and those patients were excluded from further analysis. The majority of the deaths (23 of 31 patients) were cases of complex transposition including Taussig-Bing with arch obstruction (10 of 31 patients) and/or were brought to the operating room in emergency condition. Two-thirds of the hospital deaths (23 of 31) occurred during the first 5 years of the ASO program at the Birmingham Children's Hospital, from 1988 to 1993, giving a hospital mortality of 6.3%. In the subsequent 5 years, the mortality dropped to 2.2% (8 of 31 patients).

Among the 331 patients discharged at home, 10 (3%) late deaths occurred, so survival after discharge was 98%, 97.6%, and 95.2%, at 5, 10, and 20 years, respectively (Figure 1). Median follow-up duration was 16 years (IQR: 12-18.2 years) and was complete at 93.3%; for 22 patients, retrieving consistent information about clinical and aortic valve status after discharge was not possible.

**Aortic Valve Status**

Among the 331 patients discharged from the hospital, the grade of aortic regurgitation was none in 269 (81.3%) patients, mild in 58 (17.5%), and moderate in 4 (1.2%); no patient was discharged with severe aortic valve regurgitation. Status of the aortic valve for the duration of the entire follow-up period was available in 309 patients, and the grade of regurgitation at last follow-up was none in 212

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