Coronary artery augmentation with the right subclavian artery for single coronary artery variants of dextro transposition of the great arteries treated by an arterial switch operation

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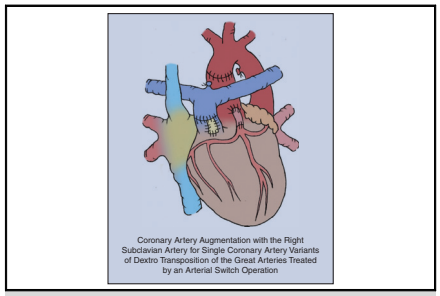
ABSTRACT

Objective: Single coronary artery variants in dextro transposition of the great arteries increase the technical demands of performing coronary translocations during the arterial switch operation (ASO). Coronary augmentation using the right subclavian artery as an interposition graft is a viable option in certain cases. The aim of this study is to describe this operative technique and review outcomes.

Methods: Of 59 patients who underwent an ASO, from July 2015 to May 2021, 6 had single coronary variants in which the right subclavian artery was used as an interposition graft. Mean follow-up was 21.5 months.

Results: Patients mean age and weight at the time of surgery were 7.1 ± 3.8 days and 2.84 ± 0.76 kg, respectively. Four patients had the left anterior descending coronary artery and right coronary artery coming from the left sinus and the circumflex coronary artery coming from the right sinus. One patient had a single ostium arising from the left sinus and another patient had a single ostium coming from the right sinus. All patients are alive and free of cardiac symptoms at follow-up.

Conclusions: Single coronary artery variants in dextro transposition of the great arteries can pose technical challenges for coronary translocation during ASO. The augmentation of coronary buttons using a segment of the right subclavian artery is an option which should be considered in selective cases. (JTCVS Techniques 2022;13:139-43)



ASO with coronary augmentation using the right subclavian artery as interposition graft.

CENTRAL MESSAGE

Coronary anomalies in D-TGA can pose technical challenges for coronary translocation. Coronary button augmentation using a right subclavian artery graft is a viable option in selective cases.

PERSPECTIVE

Augmentation of coronary buttons using a segment of the right subclavian artery is applicable when a translocated coronary is susceptible to extrinsic stretching or compression. The use of a subclavian artery graft allows for native growth and has minimal negative short-term consequences. The technique is simple, reproducible, and does not depend on clear delineation of coronary anatomy preoperatively.

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Abbreviations and Acronyms

ASO = arterial switch operation
D-TGA = dextro transposition of the great arteries
ECG = electrocardiogram
LAD = left anterior descending
RCA = right coronary artery

Video clip is available online.

Dextro transposition of the great arteries (D-TGA) is one of the most common cyanotic congenital heart malformations.[1] The arterial switch operation (ASO) has been the treatment of choice for D-TGA since the procedure was conceived in 1975 by Jatene and colleagues.[2-4] Coronary artery transfer is a critical step in this technique. The presence of coronary anomalies can increase the technical challenges of coronary artery translocation. Multiple techniques have been described to deal with coronary anomalies during the ASO, such as the trap-door technique, aortocoronary flaps, tube reconstructions, and coronary augmentations.[5,6]

Among the coronary anomalies associated with D-TGA, single coronary artery variants may be risk factors for adverse postoperative outcomes.[5,6] Most commonly, when the right coronary artery (RCA) emanates from the left facing sinus, it predisposes to ischemia from stretch following transfer. To mitigate this risk, we have routinely harvested a segment of the right subclavian artery to augment the button in single left coronary artery and its variants during an ASO. This technique has not previously been well described in the literature. We describe this technique and review the operative and follow-up outcomes for patients who have undergone this technical modification.

TABLE 1. Preoperative data

Age at the time of surgery, d, mean (SD)/range	7.1 (3.86)/3-14
Sex, male/female	1/5
Birth weight, kg, mean (SD)/range	2.84 (0.76)/1.6-3.8
Gestational age, wk, mean (SD)/range	38.14 (2.14)/34-39.14
Prebirth diagnosis of D-TGA, %	66.6%
Preoperative diagnosis of coronary anomalies by echocardiogram, %	16.6%

SD, Standard deviation; *D-TGA*, dextro transposition of the great arteries.

METHODS

From July 2015 to May 2021, 59 patients with D-TGA underwent an ASO at our institution, of whom 6 had a true single coronary ostium or a single coronary artery variant requiring use of a right subclavian artery graft to augment the effective length of the coronary button. This study was approved by the Ethics Review Board of the British Columbia Children's Hospital (H21-01856) on August 17, 2021, and patient consent was waived because patients were followed in our institution.

The technique is illustrated in Figure 1, and an example of a case can be seen on Video 1. After sternotomy, the coronary pattern is defined (Figure 1, *A*). A right subclavian artery graft is harvested (Figure 1, *B*) when the RCA emanates from the left sinus or the left anterior descending coronary (LAD) emanates from the right sinus, crossing anterior to the aorta. Operations are performed using hypothermic cardiopulmonary bypass. Myocardial protection is provided by a single dose of antegrade cold blood cardioplegia. Bicaval venous cannulation is performed in the presence of a ventricular septal defect; otherwise, single venous cannulation is used and the atrial septal defect is repaired using a short period of circulatory arrest. Next, the aorta is transected, and the coronary branches are generously mobilized to prevent future complications following translocation. The main pulmonary artery is then transected. An anterior opening is made in the neoaorta with a 4-mm punch. To this opening, the subclavian interposition graft is anastomosed end-to-side. To the end of the subclavian interposition graft, the coronary button is anastomosed. This allows an augmentation of about 3 to 5 mm in the effective length of the coronary button. Following the coronary anastomosis, a LeCompte maneuver is performed and the aorta is translocated posterior to the

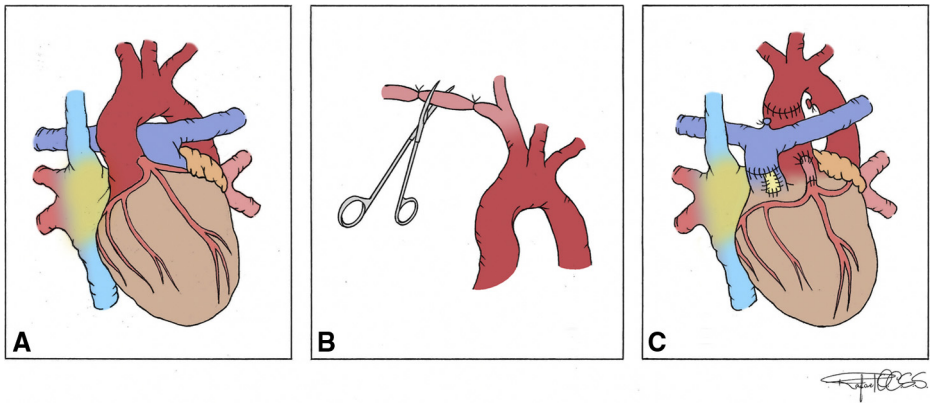
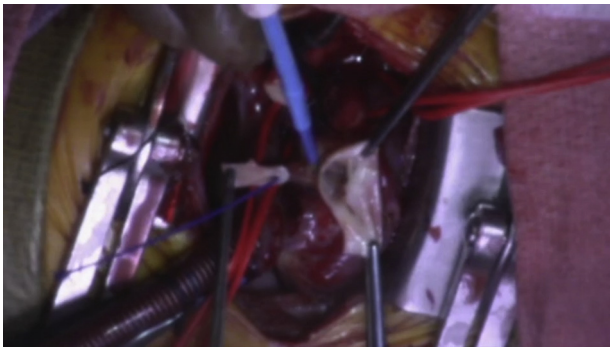


FIGURE 1. Technique for coronary augmentation. A, Definition of the coronary pattern in dextro transposition of the great arteries. The figure represents a true single ostium emerging from the left coronary sinus. B, A segment of right subclavian artery is harvested. C, Final result after the arterial switch operation with coronary augmentation using the right subclavian artery as an interposition graft.



VIDEO 1. This video highlights a 3-day-old female with D-TGA with the coronary pattern of 1LAD,R; 2Cx. An interposition subclavian artery graft was used to augment the effective length of the left coronary button and prevent compression from the underlying pulmonary artery. *D-TGA*, Dextro transposition of the great arteries. *1LAD,R; 2Cx*, left anterior descending coronary artery and right coronary artery emerging from the left sinus and Cx emerging from the right sinus. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00143-2/fulltext.

pulmonary bifurcation. The aortic anastomosis is then performed. Next, the atrial septal defect and, when present, the ventricular septal defect, are repaired, through a separate right atriotomy. After right atriotomy closure, the neopulmonary root is then reconstructed with cryopreserved pulmonary homograft tissue. Following this, the aortic crossclamp is removed and deairing maneuvers are performed. Next, the neopulmonary anastomosis, between the bifurcation and the reconstructed root, is completed and the patient is weaned off cardiopulmonary bypass (Figure 1, *C*).

Table 1 outlines the preoperative clinical data of the patients in whom a subclavian interposition graft was used to achieve coronary augmentation during the ASO. All patients underwent a balloon atrial septostomy in their first hours of life. One patient had concomitant partial anomalous pulmonary venous return and, in 2 patients, a ventricular septal defect was present; one was a Taussig-Bing variant. No patients required mechanical ventilation preoperatively, and prostaglandin was required preoperatively in 50% of the patients.

Table 2 shows operative data. Four patients had the LAD and RCA coming from the left sinus and the circumflex coronary artery coming from the right sinus. In these cases, the RCA passed anterior to the aorta (Figure 2, *A*). One patient had a true single left ostium arising from the left sinus. Similarly, in this case, the RCA passed anterior to the aorta (Figure 2, *B*). One patient had a true single right ostium from the right sinus, in which the LAD crossed anterior to the aorta (Figure 2, *C*). Postoperative follow-up is complete for all patients, with clinical assessment, echocardiography, and electrocardiogram (ECG). Patients who undergo an arterial switch operation at our institution have an echocardiogram and ECG before discharge, at the first postoperative visit, and every 3 months thereafter for the first postoperative year and annually after that. Adequacy of coronary perfusion was assessed by ECG ischemic changes and by echocardiographic interrogation of ventricular function, segmental wall motion abnormalities, and coronary flow, intraoperatively and during postoperative follow-up.

TABLE 2. Operative data

Cardiopulmonary bypass time, min, mean (SD)/range	143.1 (22.2)/121-181
Cross clamp time, min, mean (SD)/range	83.5 (5.2)/73-90
Total circulatory arrest time, min, mean (SD)/range	5.5 (1.3)/4-7
VSD repair (%)	33.3%
PAPVR repair (%)	16.6%

SD, Standard deviation; *VSD*, ventricular septal defect; *PAPVR*, partial anomalous pulmonary vein return.

RESULTS

All procedures were performed by a single surgeon. No operative deaths occurred. Three patients required delayed sternal closure. One patient required a reoperation for hemidiaphragm paralysis. The mean length of stay in the intensive care unit after the index surgical intervention was 4 ± 2.05 days. The mean length of stay in hospital after the index surgical intervention was 7 ± 2.45 days. Table 3 shows postoperative data.

All patients were followed in our hospital for a mean time of 21.5 ± 18.89 months, ranging from 3 to 50 months. All patients are currently alive and are free of cardiac symptoms, right arm ischemia, and neurologic symptoms. No late reinterventions have been required. Echocardiography demonstrated normal ventricular function with no wall motion abnormalities and normal coronary flow in all 6 patients. ECG showed no ischemic changes in all patients. One patient has developed mild supravalvar pulmonary artery stenosis but has been asymptomatic and has not required intervention. For this patient, a computed tomography scan was done to assess the pulmonary artery anatomy. The coronary arteries were assessed and reported to be normal.

DISCUSSION

Coronary anatomy variants are common in D-TGA.[6] A normal coronary pattern is present in approximately 67% of cases of D-TGA (Figure 2, *D*) and coronary artery anomalies are present in approximately 33% of children.[5,6] Among all coronary anomalies, the pattern of the LAD and RCA coming from the left sinus and the circumflex coronary artery coming from the right sinus constitutes approximately 6%.[5] This presentation was the most common seen in our study (frequency of 6.7%) requiring interposition of the right subclavian artery during translocation. The other 2 presentations of coronary anomalies described in our study are rare, comprising less than 1% of all cases of D-TGA.[5]

Several studies support an increased operative risk with abnormal coronary patterns during an ASO.[7-11] However, not all authors agree that coronary artery variants are a significant risk factor.[6,12] Such discrepancies may be related to surgical experience, the choice of technique used to do

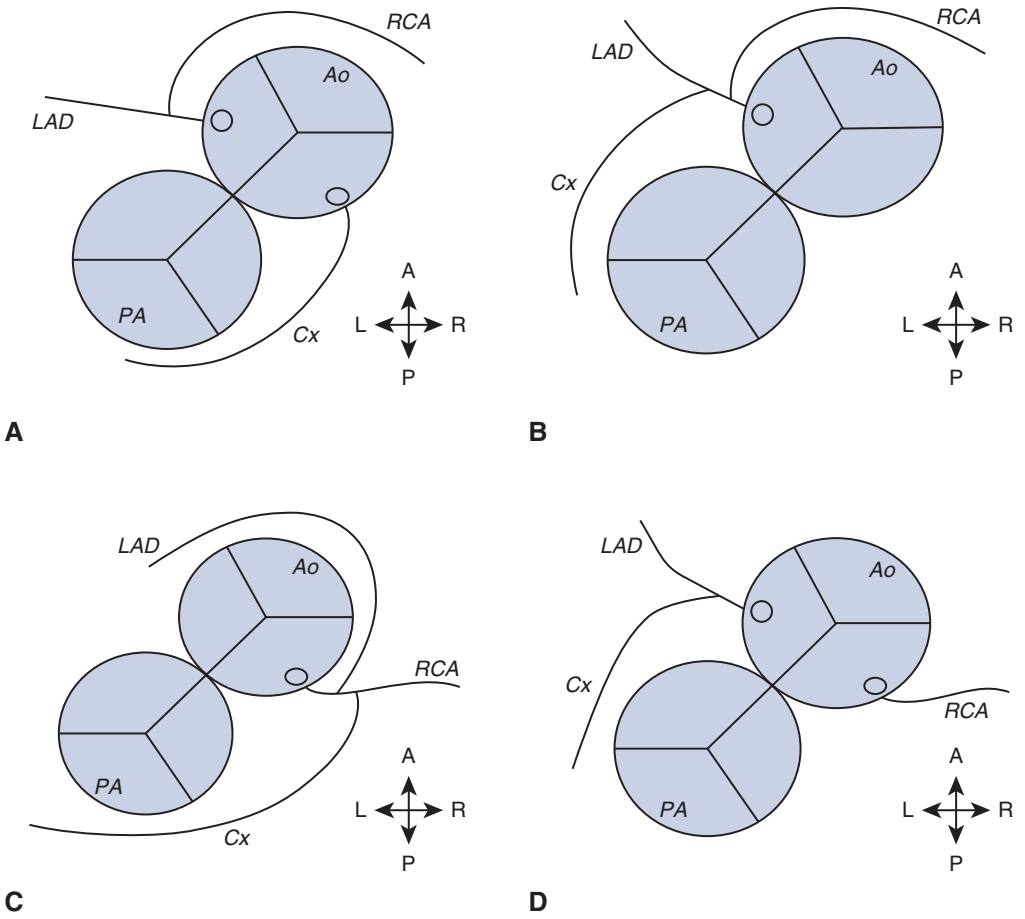


FIGURE 2. Coronary anatomy. A, LAD and RCA coming from the left sinus and Cx coming from the right sinus; B, single ostium arising from the left sinus; C, single ostium arising from the right sinus; and D, LAD and Cx coming from the left sinus and the RCA coming from the right sinus. *LAD*, Left anterior descending coronary artery; *RCA*, right coronary artery; *Ao*, aorta; *Cx*, circumflex coronary artery; *PA*, pulmonary artery.

the coronary translocations, or be related to an era effect.[5,6,13-15] Surgeon experience undoubtedly influences outcomes.[13,14] Our study, although small, demonstrates outcomes with the described coronary anomalies similar to children with normal coronaries patterns.

The technique described is applicable when a translocated coronary artery crosses anterior to the aorta, making it susceptible to extrinsic stretching or compression. The use of a subclavian artery graft allows for native growth and has minimal negative short-term consequences. The technique is not technically complex and does not depend on clear delineation of coronary anatomy preoperatively (Figure 3). Longer-term follow-up of these patients is required.

In summary, coronary anomalies in D-TGA can pose technical challenges for coronary translocation. The augmentation of coronary buttons using a segment of the right subclavian artery is a good option in selective cases. Postoperative outcomes of these children have been excellent.

TABLE 3. Postoperative data

ICU stay, d, mean (SD)/range	4 (2.05)/2-8
Hospital stay, d, mean (SD)/range	7 (2.45)/5-11
Mechanical ventilation, d, mean (SD)/range	2.5 (2.17)/0-6

ICU, Intensive care unit; *SD*, standard deviation.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

Figure 1 was created by Rafael Oliveira Coutinho Santos Soares. We thank him for his work.

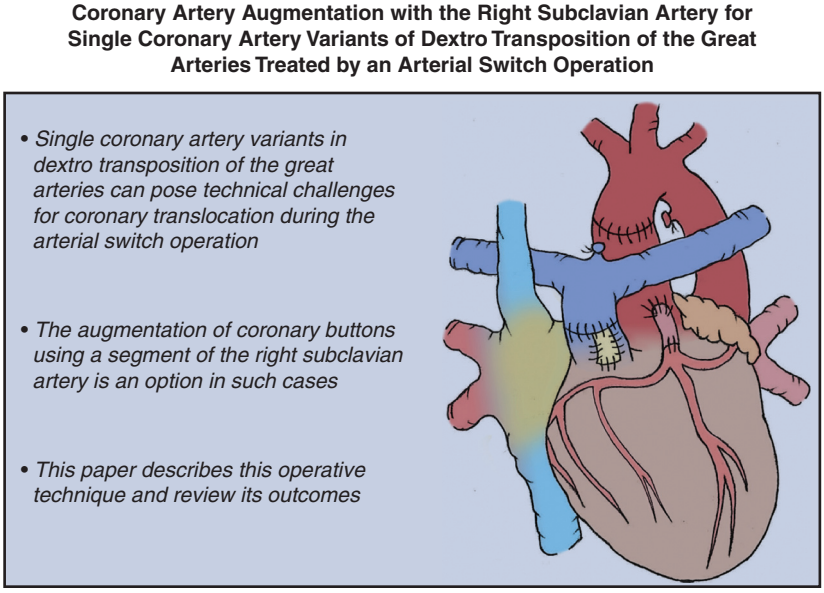


FIGURE 3. This image illustrates the final result after the arterial switch operation with coronary augmentation using the right subclavian artery as an interposition graft. This operation is a good option for the single coronary setting.

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Key Words: dextro transposition of the great arteries, arterial switch operation, single coronary artery, coronary translocation, subclavian artery graft, coronary augmentation