Outcomes of swing-back aortic arch repair in arterial switch and Norwood operations

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Abstract
The outcomes of the swing-back technique for aortic arch repair during the arterial switch and Norwood operations are not well reported. Between May 2004 and January 2011, we performed this technique during the arterial switch and Norwood operations in 2 and 4 patients, respectively. The median (range) patient age and body weight were 17 (12–147) days and 3.4 (2.2–6.1) kg, respectively. All patients survived the procedures. The median follow-up duration was 4 (1–8) years. One patient showed recoarctation in the early postoperative period, which was successfully repaired by a single-catheter intervention. The latest median pressure gradient across the neoaortic arch was 0 (0–6) mmHg. Neoaortic valve regurgitation was found to be minimal by echocardiography. During the follow-up period, the Fontan operation was performed in all the patients who underwent the Norwood operation. These results suggest that the swing-back technique yields satisfactory mid-term outcomes.

Keywords: Great vessel anomalies • Arterial switch operation • Norwood operation

INTRODUCTION
The swing-back technique is a known method of aortic arch repair to resolve the problems related to size disparities and relations of the great arteries in the arterial switch operation (ASO) and Norwood operation, respectively [1, 2]. However, reports of its outcomes are lacking. Here, we report our experience with the technique.

MATERIALS AND METHODS

Patients
Between May 2004 and January 2011, we performed ASO and the Norwood operation in 23 and 34 patients, respectively. Among them, we applied the swing-back technique in 2 (9%) and 4 patients (12%) concomitantly with the ASO and Norwood operation, respectively. Patient profiles were summarized in Table 1.

Surgical techniques
After a midline skin incision, cardiopulmonary bypass was instituted with arterial cannulas placed in both the brachiocephalic artery and the descending aorta and bicaval venous drainage. Moderate hypothermia was used and cardiac arrest was induced by a crystalloid solution. Details of the techniques in ASO and Norwood operations are shown in Fig. 1 from (A) to (E) and from (F) to (H), respectively.

RESULTS
All the patients survived the procedures. The median (range) follow-up period was 4 (1–8) years. Recoarctation was found at the distal end of the anastomosis between the bivalved artery and the neoaortic arch (pressure gradient, 18 mmHg) in 1 patient (Patient 5), who had the lowest body weight (2.2 kg) at the time of the operation. It was successfully enlarged by a single-catheter intervention 3 months later.

At the latest catheter examination (median, 3 years; range, 1–7 years), the median (range) pressure gradient across the neoaortic arch was 0 (0–6) mmHg. Neoaortic valve regurgitation was found to be minimal in all the patients by echocardiography at this time. Mild pulmonary artery stenosis (pressure gradient, 3–13 mmHg) was observed at the bifurcation in both the patients who underwent the ASO. The pulmonary arteries were hypoplastic and without localized stenosis in all the patients who underwent the Norwood operation. Patient 2 needed patch angioplasty and Patient 5 needed three reparative operations (bilateral modified Blalock-Taussig shunt operations followed by bilateral pulmonary patch angioplasty) before the Fontan operation. Although the pulmonary arterial growth varied among the patients, with a median (range) Nakata index value of 118 (69–162) mm²/m², there were no significant differences in sizes of the right and left pulmonary arteries [right, 5.9 (4.7–7.1) mm; left, 5.3 (3.6–7.3) mm].
median (range) pulmonary arterial pressure was 11 (6–14) mmHg. Fontan operations without fenestrations were completed in all the 4 patients by the age of 3 years. Bronchial compression was not observed in any patient by chest computed tomography performed 2 (1–5) years after the operation.

**DISCUSSION**

The swing-back technique offers the following potential advantages over other advanced techniques to resolve the problem of the size disparities [1, 3, 4] and relations [2, 5–7] of the great arteries: (i) it secures a large anastomosis by making the incision in the underside of the transverse ascending aorta as large as necessary to accommodate the large proximal neoaorta; (ii) the hypoplastic distal aortic arch is totally excluded from the arch reconstruction, ensuring a simple suture line, thus avoiding intraoperative bleeding and postoperative distal arch stenosis and the possible need for augmentation; (iii) anastomosing the ascending aorta to the descending aorta adds substantial length of tissue, thus enabling more radical excision of ductal tissue and the reconstruction without tension [1, 2]; and (iv) it can be

**Table 1: Patient profiles**

<table>
<thead>
<tr>
<th>No.</th>
<th>Age (days)</th>
<th>BW (kg)</th>
<th>Diagnosis</th>
<th>AAo (mm)</th>
<th>Main procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>3.6</td>
<td>D-TGA, VSD, Hypoplasia of distal aortic arch</td>
<td>6.4</td>
<td>ASO, VSD closure</td>
</tr>
<tr>
<td>2</td>
<td>14</td>
<td>3.0</td>
<td>[S,L,L], DILV, IAA (Type A), Restrictive BVF</td>
<td>9.1</td>
<td>Norwood with LV-PA conduit</td>
</tr>
<tr>
<td>3</td>
<td>147</td>
<td>6.1</td>
<td>(I,X,IN), CCH, DORV, CoA, s/p bPAB</td>
<td>7.8</td>
<td>Norwood with BVF</td>
</tr>
<tr>
<td>4</td>
<td>118</td>
<td>6.0</td>
<td>[S,L,L], DILV, IAA (Type A), Restrictive BVF, s/p bPAB</td>
<td>9.8</td>
<td>Norwood with BVF</td>
</tr>
<tr>
<td>5</td>
<td>18</td>
<td>2.2</td>
<td>(S,D,D), DORV, IAA (Type B), SAS, s/p bPAB</td>
<td>4.7</td>
<td>Norwood with RV-PA conduit</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>3.1</td>
<td>(S,D,D), DORV, TGA, Hypoplasia of distal aortic arch</td>
<td>7.0</td>
<td>ASO, VSD closure</td>
</tr>
</tbody>
</table>

Age: age at operation; BW: body weight; AAo: diameter of the ascending aorta; D-TGA: d-transposition of great arteries; VSD: ventricular septal defect; ASO: arterial switch operation; DILV: double-inlet left ventricle; IAA: interrupted aortic arch; Type A: Type A in Celoria and Patton classification; BVF: bulbo-ventricular foramen; LV: left ventricle; PA: pulmonary artery; CCH: concordant criss-cross heart; DORV: double-outlet right ventricle; CoA: coarctation of the aorta; bPAB: bilateral pulmonary artery banding; BDG: bidirectional Glenn anastomosis; SAS: subaortic stenosis; RV: right ventricle.

**Figure 1:** (A) Gross anatomy of transposition of the great arteries with aortic arch obstruction. (B) The ascending aorta and pulmonary trunk were transected, and the coronary arteries were transferred. The aortic isthmus was divided and the ductal tissue was removed. (C) The ascending aorta was turned towards and anastomosed to the descending aorta. A longitudinal incision was made on the underside of the neoaortic arch. (D) The neoaorta was anastomosed to the incision in an end-to-side fashion. A patch was used at the greater curvature of the anastomosis. (E) Final appearance. (F) Gross anatomy of double-inlet left ventricle with rudimentary bulbo-ventricular foramen and i-malposition of the great arteries. (G) The ascending aorta and pulmonary trunk were transected and anastomosed in a side-to-side fashion to create the neoaorta. Ductal tissue was removed. The ascending aorta was turned towards and anastomosed to the descending aorta. The neoaorta was anastomosed to the underside of the neoaortic arch. (H) Final appearance in a case with ventricle-to-pulmonary artery shunt.
applied to any type of relation of the great arteries, which is useful during the Norwood operation. However, it cannot be applied in patients with a diminutive ascending aorta in order to avoid recoarctation at the anastomotic site. Our experience indicates that the diameter of the ascending aorta should be >6 mm on echocardiography (Table 1); therefore, the technique cannot be applied in most patients with hypoplastic left heart syndrome.

The swing-back technique was originally performed without a patch during the ASO [1]. Similarly, we completed the technique without a patch in all the patients who underwent the Norwood operation. However, we used patches in the ASO; we believe that patch augmentation is advisable in the ASO in order to minimize the risks of tension and distortion of the neoaortic root in which the coronary arteries are transferred.

In conclusion, despite the limited sample size of this series, the swing-back technique for aortic arch repair seems to yield satisfactory mid-term outcomes.

Conflict of interest: none declared.

REFERENCES