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Reverse Subclavian Flap Repair and Maintenance of Antegrade Blood Flow within the Left Subclavian Artery in Neonates with Aortic Coarctation and Distal Arch Hypoplasia

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ABSTRACT

Surgical palliation for aortic coarctation with aortic arch hypoplasia in neonates and infants has been used in the clinic as the most beneficial treatment for this disorder. This technique allows the correction of aortic coarctation by the use of "extended" anastomosis without cardiopulmonary bypass, which expands the hypoplastic distal aortic arch via the use of a reverse subclavian flap repair. This technique maintains antegrade blood flow within the left subclavian artery.

INTRODUCTION

Symptomatic aortic coarctation is associated with aortic arch hypoplasia in 5% to 9% of neonates. Surgical palliation of aortic coarctation with aortic arch hypoplasia is performed under deep hypothermia and cardiopulmonary bypass. However, recent studies have shown that application of this method causes significant structural and functional disorders of the central nervous system [Lim 2003]; therefore, there is a need to develop other methods of surgical correction without cardiopulmonary bypass. Underevaluation of the role of distal aortic arch hypoplasia when correcting aortic coarctation with aggressive methods of extended anastomosis can lead to a secondary surgery during follow-up in 35% to 40% of cases [Dodge-Khatami 2000]. Outcomes from hypoplastic distal aortic arch repair with flaps made of different materials cannot be considered favorable if a second surgery is needed in 40% of cases within 2 to 3 years. Therefore, we consider methods for expansion of the distal aortic arch via various aortoplasty techniques, because they exclude the application of foreign materials, maintain growth potential of the native aorta, and significantly decrease recoarctation rates 3.6% to 13.6% during follow-up. A previously described technique does not imply preservation of antegrade blood flow of the left subclavian artery blood [Kanter 2001].

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MATERIALS AND METHODS

We used this technique from 2009 through 2011 for treating 16 neonates (age range, 3-27 days) with preductal coarctation of the aorta and distal aortic arch hypoplasia. All patients were admitted to our clinic in poor condition and received prostaglandin infusions. Examinations and surgical interventions were performed within 24 hours of admission. According to the data we obtained from preoperative echocardiography and multislice spiral computed tomography examinations, the mean (±SD) transverse dimensions of the aorta were as follows: ascending aorta, 9.4 ± 1.1 mm; transverse segment (proximal segment), 5.4 ± 1.5 mm; distal segment, 3.7 ± 1.2 mm; aortic isthmus, 2.06 ± 0.81 mm; descending aorta, 9.1 ± 0.7 mm; arterial duct, 1 to 4 mm. The characteristics of the patients are summarized in Table 1. According to the echocardiography evaluations, the mean pressure gradient was 52.3 ± 10.5 mm Hg. Two patients with aortic coarctation and distal aortic arch hypoplasia also had significant hemodynamic defects of the interventricular septum, and one of these patients had a complete atrioventricular canal. Because of the patient's high pulmonary hypertension, surgical palliation of the coarctation was performed with banding of the pulmonary artery.

Surgical Technique

Surgical palliation for this disorder is performed via a left posterolateral thoracotomy through the third intercostal space. The aorta is mobilized extensively, including isolation of the aortic arch to the right brachiocephalic trunk, the left common carotid artery (LCCA), the left subclavian artery, the aortic isthmus, patent ductus arteriosus, the coarctation area, and the descending aorta. If necessary, 1 to 2 pairs of the intercostal arteries are ligated below the coarctation area. When correction of distal aortic arch hypoplasia (<50% of the ascending aorta diameter) and preductal coarctation includes a reverse subclavian flap repair, a proximal Satinsky clamp is placed between the right brachiocephalic trunk and the LCCA, followed by occlusion 1 cm above the opening. A distal Satinsky clamp is placed on the aorta to maintain a ductus-dependent circulation within the lower portions of the body. An additional clamp is placed on the left subclavian artery as high as possible. The left subclavian artery is dissected under an occlusion clamp, and the

Table 1. Patient Data*

Case No.	Age, d	Weight, kg	Sex	Ascending Aorta, mm	Proximal TA, mm	Distal TA, mm	Aortic Isthmus, mm	BCA, mm	P, mm Hg
1	15	1.8	M	6	5	4	1.8	4	81
2	11	2.9	M	10	6	4	1.8	5	61
3	20	3.2	M	11	4.8	3	3	4	56
4	3	2.2	F	6	5	3	2	5	41
5	14	2.3	F	12	5	4	3	3	58
6	11	3.2	F	15	7	5	2	4	61
7	12	2.8	M	9	5	4	2	4	42
8	9	3.1	F	8	6	3	1.8	3.8	50
9	20	2.7	M	9	4	3.6	3	4	32
10	24	2.8	F	8	5	4	2	4	63
11	15	4.0	F	10	6	4.5	2	4	48
12	10	2.9	M	8	4	3	1.5	4	50
13	12	3.1	M	10	7	3	1	4	60
14	27	2.8	F	6	4	2.8	1	4	30
15	21	2.9	M	9	6	4	2	3	48
16	18	3.2	M	11	6	5	2	4	56
	15.1 ± 8.1	2.9 ± 1.5	1.2:1	9.4 ± 1.1	5.4 ± 1.5	3.7 ± 1.2	2.06 ± 0.81	3.9 ± 0.8	52.3 ± 10.5

*Summary data are presented as the mean ± SD. Proximal TA indicates proximal segment aorta; Distal TA, distal segment aorta; BCA, brachiocephalic arteries; P, pressure gradient.

length of the left subclavian arterial segment should be at least 1.5 times the diameter of the subclavian artery for subsequent reimplantation of the left subclavian artery (Figure 1). Dissection of a proximal left subclavian artery stump is performed through the opening. The hypoplastic aortic arch segment up to the LCCA opening along the exterior aortic arch curvature is used to create a flap for reverse plasty (Figure 2). Defects in the aortic arch are repaired by using a left subclavian artery flap,

Table 2. Operative and Postoperative Data*

Case No.	Repair Type	"Skin-to-Skin" Time, min	Aortic Cross-Clamp Time, min	Ventilation Time in ICU, d	Length of ICU Stay, d	Length of Hospital Stay, d
1	SFA	58	29	1.5	3	16
2	SFA	59	27	2	5	18
3	SFA	56	28	1	2	18
4	SFA	58	30	3	6	17
5	SFA + banding	67	31	7	12	23
6	SFA	57	29	2	4	19
7	SFA + banding	65	28	7	10	25
8	SFA	54	26	1	2	18
9	SFA	53	25	2	4	19
10	SFA	56	29	3	5	18
11	SFA	54	31	1.5	4	20
12	SFA	58	30	2	7	23
13	SFA	55	28	3	6	19
14	SFA + banding	62	26	6.5	11	27
15	SFA	58	29	2	4	17
16	SFA	56	27	2	7	16
		58 ± 8.3	28.3 ± 1.2	2.9 ± 2.3	5.7 ± 6.8	19.5 ± 4.3

*Summary data are presented as the mean ± SD. ICU indicates intensive care unit; SFA, subclavian flap aortoplasty.

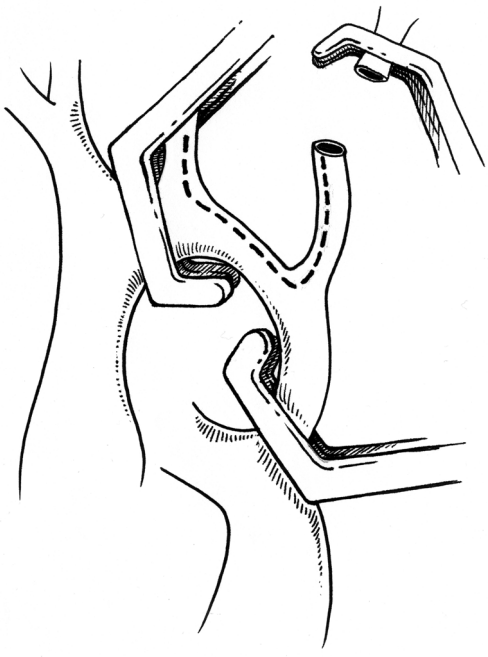

Figure 1. An additional clamp is placed on the left subclavian artery as high as possible. The left subclavian artery is dissected under an occlusion clamp, and the length of the left subclavian arterial segment should be at least 1.5 times the diameter of the subclavian artery for subsequent reimplantation of the left subclavian artery.

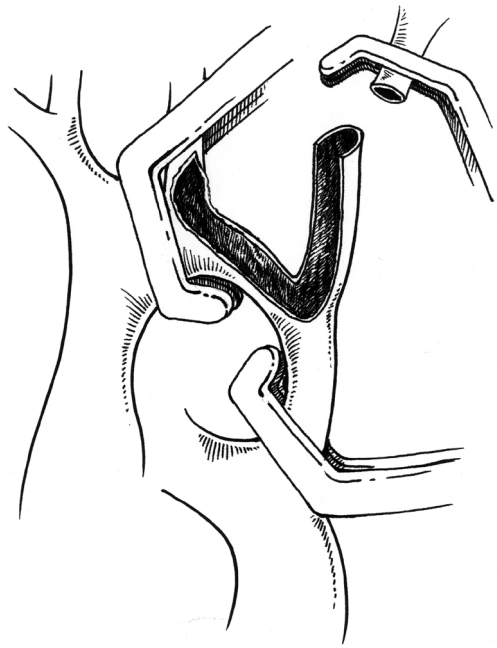

Figure 2. The hypoplastic aortic arch segment up to the left common carotid artery is opened along the exterior aortic arch curvature to create a flap for reverse plasty.

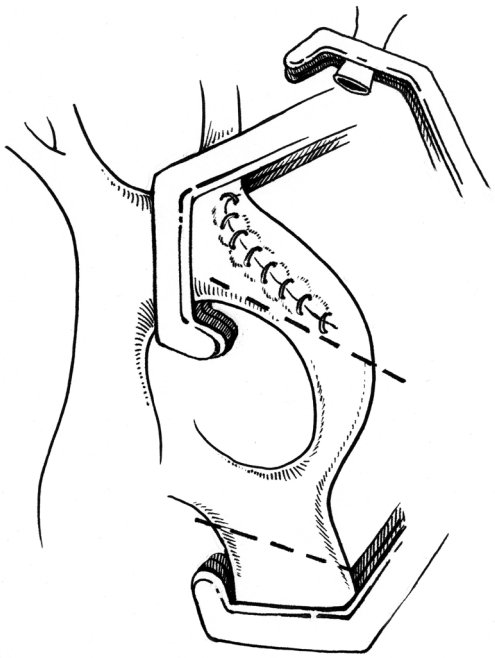

Figure 3. A Satinsky clamp is placed between the right brachiocephalic trunk and left common carotid artery. An additional Satinsky clamp is placed on the descending aorta below the coarctation and distally to the aortic coarctation segment in order to radically resect the coarctated segment with ductal tissues.

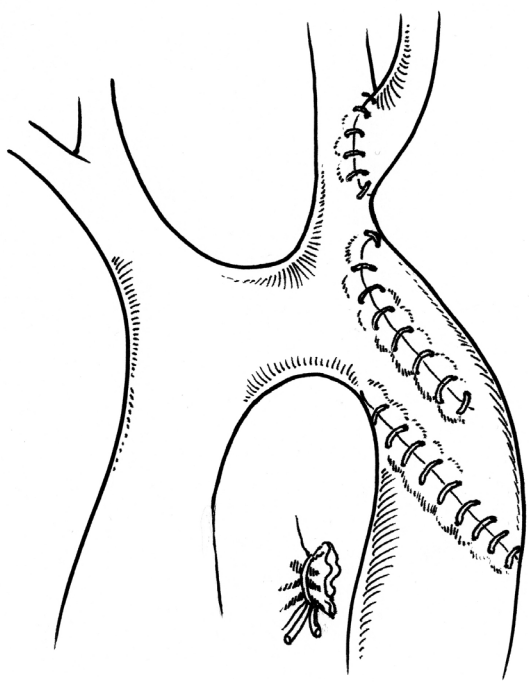

Figure 4. The final stage includes reimplantation of the distal left subclavian artery into the lateral portion of the left common carotid artery with 7-0 suture.

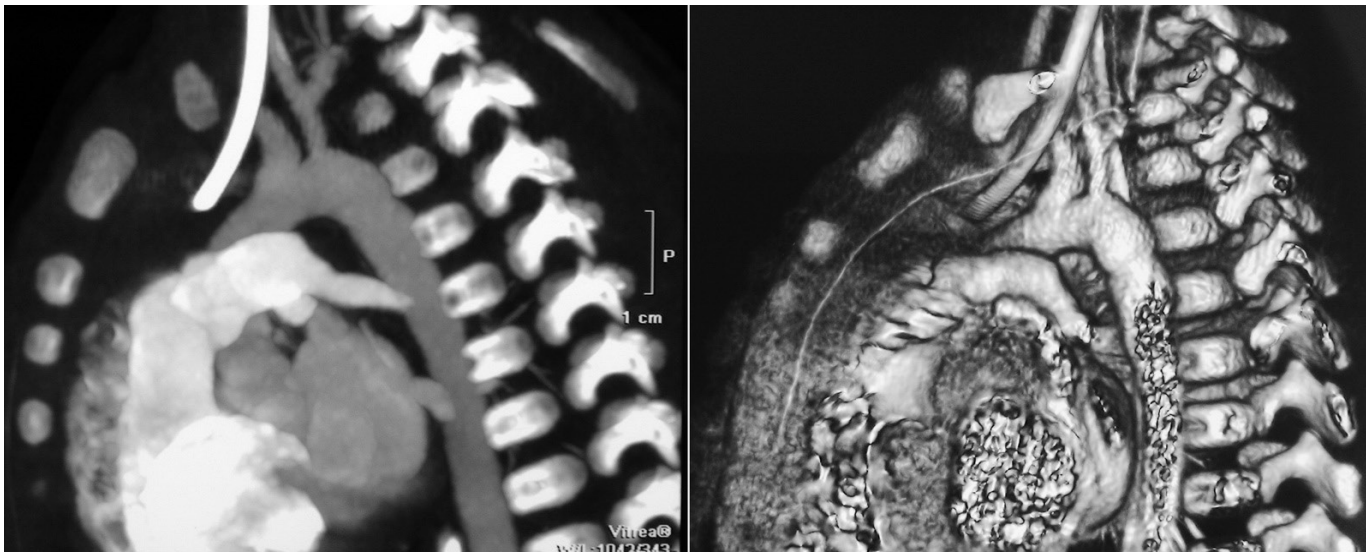

Figure 5. Absence of arch deformation and left subclavian artery patency were confirmed with multislice spiral computed tomography.

which is sutured to the defect margins by a continuous blanket monofilament suture from the top of the flap in the LCCA opening area, along with control of hemostasis. The second stage includes resection of aortic coarctation and development of an extended anastomosis. A Satinsky clamp is placed between the right brachiocephalic trunk and the LCCA. An additional Satinsky clamp is placed on the descending aorta below the coarctation and distally to the aortic coarctation segment in order to radically resect the coarctated segment with ductal tissues (Figure 3). In case of preductal coarctation, a ligature is placed around the open arterial duct. The coarctated segment is then excised with ductal tissues. To expand an anastomosis area, the surgeon dissects the aorta along the lower curvature at 2 to 3 mm before branches of a proximal Satinsky clamp. When necessary, the distal portion of the aorta is dissected along the exterior wall for application of an anastomosis. An end-to-end anastomosis is created via a continuous blanket suture with 6-0 to 7-0 suture material toward the area under the aortic arch

Table 2. Operative and Postoperative Data*

Case No.	Follow-up, mo	Distal TA, mm	Aortic Isthmus, mm	P, mm Hg	Arm/Leg Blood Pressure, mm Hg†	Left/Right Arm Blood Pressure, mm Hg†
1	5	6	7	10	96/60 / 100/60	96/60 / 96/60
2	6	6	8	11	90/60 / 90/60	90/60 / 90/60
3	10	8	9	9	103/68 / 98/60	103/68 / 103/68
4	12	8	10	12	90/60 / 98/60	90/60 / 90/58
5	3	6	7	11	96/58 / 96/60	96/58 / 98/60
6	18	9	10	9	105/56 / 103/60	105/56 / 105/60
7	6	6	8	8	85/60 / 86/60	85/60 / 85/60
8	9	7	8	11	100/58 / 100/58	100/58 / 100/60
9	15	8	9.8	11.8	98/60 / 100/60	98/60 / 98/60
10	12	8	10	10	105/60 / 105/60	105/60 / 105/60
11	6	7	8	13	95/60 / 95/60	95/60 / 95/60
12	8	6	7	14.1	100/63 / 100/60	100/63 / 103/65
13	12	7	9	11	110/65 / 105/60	110/65 / 110/65
14	2	6	7	9	98/60 / 98/60	98/60 / 98/60
15	26	9	11	10	110/65 / 110/65	110/65 / 110/60
16	19	9	10	11	106/70 / 103/70	106/70 / 103/70
		10.6 ± 12.3	7.2 ± 1.63	8.7 ± 1.06	10.6 ± 3.2	

*Summary data are presented as the mean ± SD. Distal TA indicates distal segment aorta; P, pressure gradient.

†Data are presented as systolic/diastolic pressures.

(extended anastomosis). The final stage includes reimplantation of the distal left subclavian artery into the lateral portion of the LCCA with 7-0 suture (Figure 4).

RESULTS

After restoration of blood flow, there was no pressure gradient (right pulmonary artery to femoral artery) in any of the patients. The mean total aortic clamping time was 28.3 ± 1.2 min. There was no perioperative and postoperative mortality and no incidence of paraplegia. There were no complications during follow-up: mean ventilation time, 2.9 ± 2.3 days; mean intensive care unit stay, 5.7 ± 6.8 days. There were no signs of recoarctation at discharge (Table 2). According to postoperative echocardiography and multislice spiral computed tomography examinations, the dimensions included the following: aorta in the anastomosis area, 8.7 ± 1.06 mm; distal aortic arch segment, 7.2 ± 1.63 mm. The mean pressure gradient in ultrasound examinations was 10.6 ± 3.2 mm Hg. The arterial pressures on both hands were equal. Absence of arch deformation and left subclavian artery patency were confirmed by multislice spiral computed tomography (Figure 5). During follow-up (2-26 months), there were no signs of recoarctation in the 16 patients (Table 3).

DISCUSSION

Different ways to expand the distal aortic arch segment with a left subclavian arterial flap have shown favorable long-term outcomes. According to recent data by Pandey et al, recoarctation of the aorta requiring a second surgery within a year following aortoplasty with a left subclavian arterial flap was instituted in 13.6% of patients who underwent their operations at an age younger than 4 weeks and in 3.6% of the older patients. A weak point of aortoplastic methods that use a left subclavian arterial flap (including a reverse one) is ligation of the distal left subclavian arterial segment. Their study showed a significant difference in recorded systemic pressures between the right and left upper limbs during follow-up (90 mm Hg versus 106 mm Hg; $P < .005$). Moreover, there were differences between the upper limbs in muscular development in 28.8% of patients who underwent aortoplasty with a left subclavian arterial flap. Disproportional lengths of the right and left upper limbs were observed in 24.4% of patients and occurred more frequently in patients who underwent their operations younger than 1 month of age [Pandey 2006]. The present modification of reverse plasty of the distal aortic arch segment, which uses a left subclavian arterial flap with simultaneous resection of the coarctation, extension of the anastomosis, and reconstruction of direct blood flow in the left subclavian artery, allows favorable outcomes in certain populations and is more effective than older techniques. Currently, a small number of patients have undergone operations with this technique in our clinic, with favorable preliminary results; however, further evaluation of long-term outcomes is required to adequately assess the efficacy of this therapy.

REFERENCES

Dodge-Khatami A, Backer CL, Mavroudis C. 2000. Risk factors for recoarctation and results of reoperation: a 40-year review. J Card Surg 15:369-77.

Kanter KR, Vincent RN, Fyfe DA. 2001. Reverse subclavian flap repair of hypoplastic transverse aorta in infancy. Ann Thorac Surg 71:1530-6.

Lim C, Kim WH, Kim SC, et al. 2003. Aortic arch reconstruction using regional perfusion without circulatory arrest. Eur J Cardiothorac Surg 23:149-55.

Pandey R, Jackson M, Ajab S, Gladman G, Pozzi M. 2006. Subclavian flap repair: review of 399 patients at median follow-up of fourteen years [abstract]. Ann Thorac Surg 81:14208.