Surgical treatment for Kommerell's diverticulum

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Objective: Kommerell's diverticulum, which is a rare condition, is a congenital abnormality of the aortic arch. The strategy of surgical treatment for Kommerell's diverticulum has not been established.

Methods: Between 1994 and 2004, 6 patients underwent surgery for Kommerell's diverticulum at our institute. Diagnoses included right aortic arch with aberrant left subclavian artery in 4 patients and left aortic arch with aberrant right subclavian artery in 2 patients. Indications for surgery were dilatation of Kommerell's aneurysm (n = 4) and dysphagia (n = 2). One patient underwent total arch replacement through the median sternotomy plus right thoracotomy. Five patients underwent replacement of the descending aorta and reconstruction in situ (n = 4) or ligation (n = 1) of the stenotic aberrant subclavian artery through the right (n = 3) or left (n = 2) thoracotomy.

Results: There were no patient deaths or patients who required rehospitalization. Mediastinitis occurred in 1 patient. This patient required mediastinal drainage and an omentopexy. Two patients who had dysphagia became asymptomatic. Postoperative angiographies in all patients were satisfactory. The patient whose aberrant subclavian artery was ligated had no ischemic symptom of the arm. At the midterm outcomes (mean follow-up length was 55.6 ± 42.2 months, ranging 10-114 months), all patients resumed normal activities without any complications.

Conclusions: Kommerell's diverticulum can be repaired safely with graft replacement concomitant with in situ reconstruction of the aberrant subclavian artery through thoracotomy.

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Kommerell's diverticulum is a rare condition that occurs in association with a left aortic arch (LAA) with aberrant right subclavian artery (ARSA) (0.5%-2.0% of the population),¹ or a right aortic arch (RAA) with aberrant left subclavian artery (ALSA) (0.05%-0.1%).² Fewer than 50 cases have been reported in the literature. Originally, Burckhard F. Kommerell reported an aortic diverticulum in a patient who had LAA and ARSA in 1936.³ In the literature, the right subclavian artery arose as the last branch of the aortic arch and coursed from the proximal descending aorta to the right arm, passing behind the esophagus. The aneurysmal diverticulum of the descending aorta at the origin of ARSA is called Kommerell's diverticulum, which consists of both an aneurysm of the thoracic aorta and an aneurysmal orifice of an aberrant subclavian artery. Anatomically, in a patient with RAA and ALSA, the left common carotid artery arises from the anterior of the ascending aorta, followed by the right common carotid artery, the right subclavian artery, and the ALSA that arises from Kommerell's diverticulum (Figure 1).

The various surgical techniques have been applied, such as total arch replacement,⁴ replacement of the descending aorta with aberrant subclavian artery-carotid artery transposition,⁵ open stent grafting with the extra-anatomic by-

Abbreviations and Acronyms

ALSA = aberrant left subclavian artery
 ARSA = aberrant right subclavian artery
 LAA = left aortic arch
 RAA = right aortic arch

pass,⁶ ligation of the aberrant subclavian artery, and reconstruction of the descending aorta.⁷ However, a specific strategy for surgical treatment of Kommerell's diverticulum has not been established.

Patients and Methods

Between 1994 and 2004, 6 patients underwent surgery for Kommerell's diverticulum. The patient characteristics are listed in Table 1. Two patients had dysphagia, and 1 patient had chest discomfort. The others were asymptomatic. Diagnoses included RAA with ALSA in 4 patients (Figure 2, A) and LAA with ARSA in 2 patients (Figure 2, B). The mean diameter of Kommerell's diverticulum was 53.3 ± 4.1 mm. Patient 5 had a blood pressure difference between the upper limbs (right 140/68 mm Hg, left 120/60 mm Hg). His angiogram revealed a stenosis of ALSA. However, the patient was asymptomatic. In patient 4 the diagnosis was made incidentally during the usual health checkup. In patient 6 the diagnosis was made during coronary angiography for the angina pectoris. Indications for surgery

were dilatation of Kommerell's aneurysm ($n = 4$) and dysphagia ($n = 2$).

The operations in patients 2 to 6 were performed with a posterolateral thoracotomy through the fourth intercostal space with removal of the fifth rib (patients with RAA: right thoracotomy $n = 3$; patients with LAA: left thoracotomy $n = 2$). Cardiopulmonary bypass was established with return into the femoral artery ($n = 3$) or the descending aorta ($n = 2$) and drainage of the right atrium ($n = 2$), femoral vein ($n = 1$), bicaval ($n = 1$), and right atrium with the pulmonary arterial trunk ($n = 1$). In 2 cases (patients 3 and 5), the proximal aorta was clamped between the right carotid and the right subclavian arteries, and a distal clamp was placed on the descending aorta using partial cardiopulmonary bypass with mild hypothermia (32°C). In 3 cases (patients 2, 4, and 6) with atherosclerotic aortic arch, open proximal anastomosis was performed with deep hypothermia (16°C) and circulatory arrest (DHCA). After the aneurysms were opened, blood backflow from the aberrant subclavian artery, located in the bottom of Kommerell's diverticulum, was blocked with a 5F arterial occlusion catheter (Figure 3, B). First, reconstruction of the aberrant subclavian artery was performed. A 10-mm collagen-impregnated Dacron graft was anastomosed to the ostium of the aberrant subclavian artery by continuous sutures of 5-0 polypropylene. Second, proximal aortic anastomosis was performed with a 22- to 26-mm Dacron graft with 4-0 polypropylene sutures. In cases in which DHCA was used, antegrade cerebral and coronary reperfusion was restarted through the graft. Third, the previous 10-mm graft was anastomosed to the main graft of the descending aorta (Figure 3, C).

Figure 1. Digital subtraction angiograms of right aortic arch (RAA) and aberrant left subclavian artery (ALSA). **A**, Early phase. **B**, Late phase. ALSA arising from the Kommerell's diverticulum is demonstrated. **LC**, Left carotid artery; **RC**, right carotid artery; **RS**, right subclavian artery; **ALSA**, aberrant left subclavian artery; **KM**, Kommerell's diverticulum; **Asc.Ao**, ascending aorta; **Des.Ao**, descending aorta.

TABLE 1. Characteristics of patients

Patient No.	Age (y)	Gender	Symptoms	BP differences between upper limbs	Aneurysmal size (mm)	Diagnosis
1	63	M	Chest discomfort	No	50	RAA ALSA
2	68	F	Dysphagia	No	55	LAA ARSA
3	69	M	Dysphagia	No	55	RAA ALSA
4	67	F	None	No	60	RAA ALSA
5	63	M	None	Yes	50	RAA ALSA
6	66	M	None	No	50	LAA ARSA

BP, Blood pressure; RAA, right aortic arch; ALSA, aberrant left subclavian artery; LAA, left aortic arch; ARSA, aberrant right subclavian artery.

Figure 2. Contrast-enhanced computed tomography. Kommerell's diverticulum (arrow 1) was seen. A, Case of RAA and ALSA. The esophagus (arrow 2) was displaced anteriorly. B, Left aortic arch (LAA) and aberrant right subclavian artery (ARSA).

Figure 3. A, Surgical view of the RAA with the ALSA through the right thoracotomy. B, A 10-mm graft was anastomosed to the ostium of the aberrant subclavian artery blocking blood backflow using a 5F arterial occlusion catheter. C, The 10-mm graft was anastomosed to the main graft of the descending aorta after proximal anastomosis of the main graft. D, Completed drawing; LC, left carotid artery; RC, right carotid artery; RS, right subclavian artery; ALSA, aberrant left subclavian artery; KM, Kommerell's diverticulum.

Figure 4. Postoperative contrast-enhanced computed tomography of the RAA and ALSA. The 10-mm in situ graft (arrow) for the reconstruction of left subclavian artery was recognized without compression of the esophagus.

Finally, distal anastomosis was performed (Figure 3, D). In patient 5, the stenosed orifice of the ALSA was closed from the inside of Kommerell's diverticulum, after test-clamp of the ALSA. Patient 1 underwent total arch replacement with the median sternotomy and the additional right anterolateral thoracotomy with DHCA and selective cerebral perfusion. The concomitant procedure was a coronary artery bypass in patient 6.

Results

There were no rehospitalizations or deaths. Patient 1 had mediastinitis and required a mediastinal drainage and an omentopexy. Eventually, he was discharged 75 days after the operation and was free of symptoms. The postoperative course was uneventful in all patients except patient 1.

Two patients who had dysphagia became asymptomatic. A postoperative computed tomography confirmed no compression of the esophagus or the airway by in situ subclavian artery graft (Figure 4). A patient whose aberrant subclavian artery was ligated had no ischemic symptom in his arm. Postoperative blood pressure of the upper limbs was 135/65 mm Hg in the right and 116/60 mm Hg in the left, which was the same as before the operation.

The circulatory arrest times of the patients who were operated on with DHCA and retrograde cerebral perfusion through the thoracotomy were 40 minutes in patient 2, 41 minutes in patient 4, and 38 minutes in patient 6 (mean 39.7 minutes).

Postoperative angiograms of all patients revealed intact repairs of all aortic arch branches. In patient 5, ALSA (which was ligated at the bifurcation of Kommerell's diverticulum) was enhanced by the collateral pathway without a steal phenomenon of left vertebral artery.

In the midterm follow-up (mean 55.6 ± 42.2 months, range 10-114 months), all patients were asymptomatic and were able to resume a normal lifestyle.

Discussion

Kommerell's diverticulum is a rare condition. Sixty percent of patients who have an aberrant subclavian artery have Kommerell's diverticulum.⁸ ARSA is the most common aortic arch anomaly. ALSA is the most common vascular anomaly in people with RAA.⁹ However, the proportion of the population who have ARSA or ALSA is not large.

The cause of an aberrant subclavian artery can be traced to abnormal regression of the fourth primitive aortic arch during embryologic development. The left fourth arch persists as the aortic arch and the right fourth arch develop into the right subclavian artery and the innominate artery. ARSA is caused by abnormal development of the right fourth arch and the vestigial remnants of the right dorsal primitive aorta. If right-and-left inverted development occurs, anomaly of RAA and ALSA occurs.¹⁰

In all patients, aberrant subclavian arteries course behind the esophagus upward to the contralateral arm. Generally, aberrant subclavian artery often goes through the retroesophageal space (80%), but also passes between the esophagus and the trachea (15%) or anterior to the trachea (5%). In 5%, they cross anterior to the trachea.¹¹

Dilatation of Kommerell's diverticulum results in compression of the surrounding structures, such as dysphagia, dyspnea, stridor, wheezing, cough, recurrent pneumonia, obstructive emphysema, or chest pain.¹² In our study, 2 patients had dysphagia, and 1 patient had chest discomfort. During adulthood, 5% of patients with an aberrant subclavian artery have symptoms because of the development of atherosclerosis.¹³ Most patients with Kommerell's diverticulum are asymptomatic; however, the most severe issue in the course of aneurysms is their marked propensity toward acute rupture. In a review of 32 patients, Austin and Wolfe¹⁴ reported that 19% of patients presented with rupture, and all of them died.

Surgical indications have not been established because of the rareness of the condition. Our primary indications were that the diameter of Kommerell's diverticulum was more than 50 mm in patients who had symptoms associated with Kommerell's diverticulum. Core components are the resection of Kommerell's diverticulum and the reconstruction of the aberrant subclavian artery. Currently, we perform replacement of the descending aorta and the in situ reconstruction of the aberrant subclavian artery through a right or left thoracotomy on the side where the aortic arch is located. In the literature, the majority of procedures were 2-staged operations divided

into the descending aorta and the aberrant subclavian artery through separate approaches.^{5,14-16} However, the potential disadvantages of the 2-staged repair were obvious. Surgical mortality used to be as high as 16.6% except for rupture.¹⁴

Posterolateral thoracotomy provides excellent exposure of the ascending aorta through to the descending aorta, which allows reconstruction of aneurysms including Kommerell's diverticulum and an aberrant subclavian artery repair. In the first patient, median sternotomy was applied; however, additional right anterolateral thoracotomy was required to obtain normal exposure. In patients with RAA and ALSA, exposure of the posteromedial side of the aortic arch and the proximal descending aorta was particularly difficult through the median sternotomy.

In regard to reconstruction of the aberrant subclavian artery, our policy was in situ repair. Ligation and division of the subclavian artery as reported by Gross¹⁷ in 1946 had been an option. However, complications of subclavian artery division have been reported, such as ischemia of the upper limbs and subclavian steal syndrome. In a report of 14 patients, Esposito and colleagues¹⁵ reported that significant ischemic complications such as coldness, rest pain, and fingertip necrosis were found in 64% of patients treated without restoration of blood flow to the arm. In the present study, the ALSA was ligated in 1 patient because the ALSA was stenosed at the orifice, and the intraoperative blood pressure difference between the right and left arms remained unchanged after the ALSA was occluded. Eventually, there was no postoperative ischemic symptom.

The orifice of the aberrant subclavian artery was usually located deep at the bottom of Kommerell's diverticulum. Controlling blood backflow from the aberrant subclavian artery was important to obtain a bloodless field. The arterial occlusion catheter was useful.

Conclusion

Kommerell's diverticulum can be repaired through thoracotomy with the in situ reconstruction of an aberrant subclavian artery.

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