Aneurysms of the innominate artery: Surgical treatment of 27 patients

Edouard Kieffer, MD, Laurent Chiche, MD, Fabien Koskas, MD, and Amine Bahnini, MD, Paris, France

Purpose: Aneurysms of the innominate artery (AIA) are widely considered to be a rare entity. We describe our experience with AIA in the last three decades.

Methods: From October 1973 to October 2000, we operated on 27 patients with an AIA. The underlying cause of aneurysm was Takayasu’s disease in 7 patients, degenerative disease in 6 patients, syphilis in 5 patients, chronic dissection in 3 patients, trauma in 2 patients, infection in 2 patients, a postoperative complication in 1 patient, and Marfan syndrome in 1 patient. AIA was associated with an aortic aneurysm in 17 patients. Fourteen patients had no symptoms. The remaining patients had symptoms, with thromboembolic complications in 7 patients, pain without rupture in 3 patients, and a ruptured aneurysm in 3 patients. In two patients at high risk for surgery who had a small AIA with embolic complications, a cervical approach was used as a means of performing distal exclusion and crossover bypass. In the remaining 25 patients, a midline sternotomy was used. One patient with a ruptured AIA exsanguinated during sternotomy. Ten patients underwent a prosthetic replacement of the ascending aorta and/or aortic arch with a separate prosthetic branch to the innominate artery (IA). Thirteen patients underwent ascending aorta-to-IA prosthetic bypass in association with lateral suture (8 patients) or prosthetic patching (5 patients) of the aorta. One patient with an infected aneurysm was treated by means of resection of the aneurysm, proximal ligation of the IA, and transposition of the right into the left common carotid artery. Cardiopulmonary bypass with deep hypothermic circulatory arrest was used in 10 patients.

Results: Three perioperative deaths occurred (2 of 4 in association with emergency treatment and 1 of 23 with elective treatment). Respiratory complications requiring prolonged artificial ventilation developed in five patients. Two patients had transient worsening of preoperative neurologic deficits. Late results, with a mean follow-up of 85 months, were good.

Conclusion: The etiology and presentation of AIA are variable. Surgical management with current cardiovascular techniques achieves excellent results. (J Vasc Surg 2001;34:222-8.)

Aneurysms of the innominate artery (AIAs) are purportedly rare. In the last three decades, we operated on 27 patients with an AIA. This retrospective study highlights the diversity of the etiologies underlying these lesions and the major progress made in surgical management in the last 25 years.

PATIENTS AND METHODS

From October 1973 to October 2000, we operated on 27 patients with an AIA. There were 18 men and nine women with a mean age of 52.4 ± 19.2 years (range, 19-77 years). The underlying cause was Takayasu’s disease in 7 cases, degenerative disease in 6 cases, syphilis in 5 cases, chronic dissection in 3 cases, trauma in 2 cases, infection in 2 cases, proximal false aneurysm of an aortoinnominate bypass graft in 1 case, and Marfan syndrome in 1 case. On the basis of the extent of aneurysmal involvement, we divided the patients in this series into three categories: group A, no involvement of the origin of the innominate artery (IA; n = 1); group B, involvement of the origin of the IA but not of the aorta (n = 16); and group C, involvement of both the IA and aorta (n = 10; Fig 1).

In 17 patients, the AIA was associated with 19 aortic aneurysms located in the ascending aorta, transverse aortic arch, or both in 10 patients, the descending thoracic aorta in 4 patients, and the abdominal aorta in 5 patients. In seven patients, including four patients with Takayasu’s disease, the AIA was associated with occlusive disease in the supraaortic trunks. Four patients had a concurrent aneurysm involving another supra-aortic trunk: the left subclavian artery in 2 patients, the left common carotid artery in 1 patient, and the right subclavian artery in 1 patient. Three patients had a common trunk for the IA and left common carotid artery.

In 14 patients with no symptoms, an AIA was discovered during a diagnostic workup for an aortic aneurysm (8 patients) or for occlusive arterial disease or aneurysm in another supra-aortic trunk (6 patients). Symptoms were observed in 13 patients. One or more cerebral emboli occurred in seven patients, including three patients with persistent neurologic deficits. Two of these patients had superior vena cava syndrome and dysphonia. Three patients had thoracic pain with no rupture. Three patients, including the two with infected aneurysms, had a mediastinal rupture with constant pain, dyspnea, dysphonia, and superior vena cava syndrome. One of these patients also had a persistent neurologic deficit after cerebral
embolization. Arteriography (Figs 2, A, 3, A, and 3, B) was performed before surgical treatment in all patients except 1 patient who required emergency treatment after rupture with severe respiratory insufficiency. All patients treated after 1982 underwent computed tomography (CT) scanning to accurately evaluate the relationship between the aneurysm and sternum (Figs 2, C and 3, C).

Surgical treatment was carried out under emergency conditions in 4 patients, including 3 patients with a ruptured aneurysm and 1 patient with a brain and upper-extremity embolism. The other 23 procedures were elective. In two patients with a small embolic aneurysm, poor general condition mandated the use of the cervical approach. AIA repair consisted of exclusion of the right common carotid artery and subclavian artery by means of distal ligation of the IA and revascularization by means of crossover bypass grafting from the left subclavian artery.1

The remaining 25 patients were treated by means of sternotomy. One patient treated under emergency conditions for ruptured AIA died of exsanguination during sternotomy. A total of 10 procedures were carried out under cardiopulmonary bypass with anterograde cerebral perfusion in three patients. Femorofemoral cardiopulmonary bypass was performed to allow deep hypothermic circulatory arrest before sternotomy in two patients who had a ruptured infected aneurysm and syphilitic aneurysm shown by means of a CT scan to be adherent to the sternum. In the eight other patients, cardiopulmonary bypass was installed between a single atrio caval cannula and femoral artery cannula after sternotomy. In eight of the 10 cases performed under cardiopulmonary bypass, AIA repair was associated with the repair of an aneurysm of the ascending aorta or transverse aortic arch. In four of these cases, an elephant trunk prosthesis was placed in the descending thoracic aorta to facilitate second-stage treatment of aneurysms of the descending thoracic aorta or thoracoabdominal aorta. Fourteen patients were treated without cardiopulmonary bypass or cerebral protection. Two of these 14 patients underwent exclusion bypass grafting of the aortic arch with an ascending aorta-to-abdominal aorta bypass graft.

In the 24 patients treated by means of sternotomy, the treatment of the AIA consisted either of aneurysmorrhaphy or resection. Arterial continuity was always reestablished with the placement of a prosthetic bypass graft from either the native ascending aorta (13 patients) or aortic prosthesis (10 patients; Fig 4). The distal bypass graft anastomosis was performed to the IA in 14 patients, to the right subclavian artery in 2 patients with extensive right carotid occlusion complicating Takayasu’s disease, to the right common carotid artery in 1 patient with axillosubclavian artery occlusion complicating Takayasu’s disease, and to the right common carotid and subclavian arteries in a sequential (Fig 2, D) or bifurcated (Fig 3, D) fashion in 6 patients. Extra-anatomic reconstruction with transposition of the right common carotid artery into the left common carotid artery and ligation of the right subclavian artery was performed in one patient with an infected aneurysm. In the 14 cases without aortic replacement, the origin of the IA was treated by means of ligation in 1 patient, by means of lateral suture in 8 patients, and by means of patch angioplasty in 5 patients. In four of the five patients treated by means of patch angioplasty, cross-clamping of the aorta was performed without cardiopulmonary bypass, according to the technique described by Crawford et al2 (Fig 5).

Concurrent lesions were treated during the same procedure in 16 patients. Associated procedures included treatment of occlusive disease in the supra-aortic trunks in 7 patients, repair of aneurysms involving other supra-aortic trunks in 4 patients, repair of abdominal aortic aneurysms in 2 patients, aortic valve replacement in 1 patient, the Bentall procedure in 1 patient, and coronary artery bypass grafting in 1 patient. In three patients, the existence of a common trunk for the IA and left common carotid artery required reimplantation of a healthy left common carotid artery.

RESULTS

Three patients (11%) died perioperatively, including one patient who died of exsanguination during sternotomy and two patients who died of multiple organ failure on postoperative days 17 and 21. The postoperative deaths involved patients who were 73 and 74 years old and had extensive aneurysms involving the IA and aorta (group C). In one case, the aneurysm was caused by atherosclerosis and had ruptured. In the other case, the aneurysm was caused by chronic dissection and was intact. No deaths occurred in the 15 patients with intact group B aneurysms. Perioperative mortality was 50% (2 of 4) for patients treated under emergency conditions and 4.3% (1 of 23) for patients treated electively. In addition to the two
patients who died of multiple organ failure, five patients (22%) required artificial ventilation for more than 5 days. The condition of two of the four patients with neurologic deficits worsened transiently after vascular repair. Both of these patients had Takayasu’s disease with concurrent occlusive lesions in other supra-aortic trunks. Postoperative dysphonia developed in 3 patients; it resolved in 2 cases and was permanent in 1 case. Mediastinitis that was successfully treated by means of omentoplasty, closure of the sternum, and drain placement developed in one patient. Postoperative arteriography was performed in 21 patients; early graft patency was shown in all patients.

Three foreign patients with Takayasu’s arteritis were lost to follow-up at 1, 16, and 21 months. The mean follow-up period was 85 months (range, 3-194 months). Seven patients (33%) died during follow-up of cancer (3 patients), cardiac causes (2 patients), accident (1 patient), and an unknown cause (1 patient). Late graft patency was assessed during the year 2000 in 14 patients by means of duplex scanning. All grafts were found to be patent. There were no cases of late infection or recurrent AIA.

**DISCUSSION**

The characteristics of AIA have changed in the last five decades. In the 1950s, most AIA were massive, syphilitic lesions associated with compressive syndromes, and alternatives for surgical treatment were limited.3-5 Technical progress has changed both the etiological and therapeutic
outlook for AIAs. With the latest imaging technologies, the discovery of small asymptomatic AIAs has become increasingly common, especially during workups for the diagnosis of thoracic aortic aneurysms. Similarly current surgical science offers a range of techniques for treatment.

The etiology of AIAs has diversified greatly. The proportion of syphilitic AIAs has decreased, but they have not disappeared.5–8 We had five such cases in our experience. The prevalence of AIAs caused by degenerative disease has increased,9–12 and these lesions are frequently concurrent with an abdominal aortic aneurysm. Special attention has been focused on chronic type-A aortic dissection with involvement of the IA. There is also an increasing proportion of injury-related aneurysms involving disinsertion or rupture of the IA after blunt trauma.13,14 Because of our referral practice, our number of AIAs caused by Takayasu’s disease was high despite the low incidence of that disease, even in the Far East.15–17 Another interesting etiological finding is the high incidence of AIAs associated with thoracic aortic aneurysm.

The most common manifestation of AIAs that are large, ruptured, or both is compressive syndrome, including dyspnea, dysphonia, or superior vena cava syndrome. Embolization is possible from small aneurysms associated with mural thrombosis.13,18 Neurologic symptoms may be permanent, as in four of our patients. Diagnosis of asymptomatic lesions is...
increasingly common, either incidentally on plain thoracic films in the form of a mass in the upper region of the anterior mediastinum\textsuperscript{19} or during assessment for occlusive disease of supra-aortic trunks or thoracic aortic aneurysm. Definitive diagnosis of AIA requires arteriography or CT scanning. Phlebography can be used as a means of obtaining greater detail in cases involving venous compression (Fig 2, B).

Operative indications include ruptured and symptomatic aneurysms. Asymptomatic aneurysms should be operated on, irrespective of size, when they are associated with aortic arch aneurysms. In our opinion, patients with isolated asymptomatic aneurysms who are at good surgical risk should undergo surgery when the aneurysms are saccular or when their maximum transverse diameter is more than 3 cm.

Surgical treatment for AIA has made great strides in the last two decades. As Cormier stated as early as 1957\textsuperscript{20} midline sternotomy is the exposure technique of choice. However, sternotomy may be contraindicated after rupture or in cases involving syphilitic aneurysm with erosion of the sternum. A possible solution in these cases is to install a femorofemoral cardiopulmonary bypass, lower core temperature, and induce deep hypothermic circulatory arrest before opening the chest. In this way, the sternum can be opened without exsanguination.\textsuperscript{6,21} If cross-clamping at the origin of the IA or side-clamping on the aorta near the IA is possible, circulatory arrest lasts only a few minutes, and then cardiopulmonary bypass and rewarming can be started. For patients with transverse aortic arch involvement, prolonged circulatory arrest is necessary to allow reconstruction of the transverse aortic arch. In these cases, cerebral perfusion, optimally through a polyester (Dacron) tube anastomosed to the distal IA, is warranted. When cardiopulmonary bypass is unavailable, an alternative technique is the two-step approach starting with cervicotomy and anterolateral thoracotomy through the third intercostal space to isolate the lesion before performing upper-half sternotomy to join the two incisions and obtain sufficient exposure for repair.\textsuperscript{20}

Treatment of the AIA itself depends on the extent of involvement. Group A aneurysms (no involvement of the origin of the IA) are easy to treat but rare. After distal
revascularization by means of bypass grafting from the ascending aorta, the AIA can be excluded by means of ligation at the origin.

Group B aneurysms (involvement of the origin of the IA) are the most common. Treatment requires aortic clamping. Side-clamping may be possible if lateral suture of the aorta is sufficient. Cross-clamping is required in many cases, including for patch angioplasty. In four patients in this series, we used the technique described by Crawford et al.2 This technique consists of first revascularizing the supra-aortic trunks from the ascending aorta, then performing patch angioplasty after aortic cross-clamping with anti-hypertensive treatment. If the left common carotid and subclavian arteries are patent, only minimal cerebral protection, such as the moderate administration of heparin (1 mg/kg) and the stabilization of arterial pressure, is required. If the aneurysmal process includes the left common carotid artery, especially in patients with a common trunk for the IA and left common carotid artery, the best technique consists of sequential revascularization from the ascending aorta to left common carotid artery and IA. If the left common carotid and subclavian artery are occluded, a passive shunt (eg, a small 7 mm Gitt shunt22 or preferably a Javid shunt) can be placed between the ascending aorta and right common carotid. However, a simpler technique is sequential bypass grafting from the ascending aorta to the right subclavian artery and right common carotid artery. Measurement of distal pressure in the right common carotid artery can be a useful means of choosing between these two techniques.

Treatment of group C aneurysms (involvement of the origin of the IA and aorta) requires cardiopulmonary bypass for aortic replacement. In this series, we used deep hypothermia at 18°C to 20°C for cerebral protection. This technique allows sufficient time to perform end-to-end distal anastomosis of the aortic prosthesis to the transverse aortic arch and side-to-side anastomosis of an aortic button, including the healthy ostia of the left common carotid and left subclavian arteries. Revascularization of the IA can be achieved with a prosthetic graft from the aortic prosthesis after completing these anastomoses, restarting cardiopulmonary bypass, and perfusing the brain by the left carotid and subclavian arteries. When placement of separate prosthetic grafts are required for treatment of concurrent lesions in the left common carotid and subclavian arteries, cerebral perfusion can be completed by first anastomosing a Dacron tube to the distal end of the IA, as was done in three patients in this series.

Another important part of cerebral protection in all cases is the prevention of cerebral emboli. Sophisticated mechanical methods are not always reliable for this.10,21,23 Excessive handling of the aneurysm before distal clamping must be avoided.

Infected aneurysms pose special problems. They can be treated by means of extra-anatomic bypass grafting, as in one of our patients in whom the diagnosis was made preoperatively. However, in situ bypass grafting is feasible with a vein graft,24,25 arterial allograft,26 or even an antibiotic-treated prosthesis,27 as in our second case in which the diagnosis was made postoperatively on the basis of routine bacteriologic findings.

Our data show that excellent results can be achieved by means of the surgical treatment of AIA with the latest cardiovascular surgery techniques. The mortality rate for elective procedures in this series was 4.3% (1 of 23).

REFERENCES


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