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Surgical procedure and outcomes in patients undergoing surgical treatment for ascending aortic aneurysms

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ARTICLE INFORMATION

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The authors declare no competing interests

Acronyms
AAA: ascending aortic aneurysm
IABP: intra-aortic balloon pump
TCA: total circulatory arrest

ABSTRACT

Introduction: Ascending aortic aneurysms are lesions that should be surgically handled because of their life-threatening complications like rupture and dissection.
Objectives: To examine the early and midterm outcomes of surgical treatment in patients with ascending aortic aneurysm.
Method: We retrospectively examined the records of 78 patients who underwent surgical treatment due to ascending aortic aneurysm between August 2006 and July 2018 at Erzurum Regional Training and Research Hospital.
Results: The patients' average age was 51,7 ± 9,8 (ranged 24-77 years). There were 54 (69,2%) men and 24 (30,8%) women. Fifty-eight (74,3%) patients had Marfan's Syndrome. They also presented coronary artery disease (15,4%), mitral stenosis (3,8%), aortic regurgitation (11,5%), aortic stenosis (8,9%), and aortic coarctation (2,6%). The emergency surgical treatment was required in 41 (52,5%) patients. Only 55 (70,5%) patients had performed ascending aortic replacement. Bentall procedure (17,9%) and aortic valve replacement + ascending aortic graft replacement (11,5%) were performed. In 14 patients totally circulatory arrest was used. The operative mortality occurred in 3 (3,8%) patients with Bentall procedure and the early postoperative mortality occurred in 1 (1,3%) patient with aortic coarctation.
Conclusions: Patients with ascending aortic aneurysms should be closely monitored for the timing of surgery due to the risk of dissection and rupture. Although various surgical techniques can be applied according to the aortic valve status, especially in patients with Marfan's Syndrome, root replacement with composite graft, and Bentall modifications and button anastomosis of coronary arteries in composite graft applications should be the preferred surgical procedure.
Keywords: Ascending aorta, Aortic aneurysm, Marfan's Syndrome, Bentall procedure, Surgery

Tratamiento y resultados quirúrgicos en pacientes operados de aneurismas de aorta ascendente

RESUMEN

Introducción: Los aneurismas de aorta ascendente son lesiones que deben tratarse quirúrgicamente debido a sus complicaciones potencialmente mortales, como la ruptura y la disección.
Objetivo: Revisar los resultados a corto y mediano plazo del tratamiento quirúrgico en pacientes con aneurisma de aorta ascendente.
Método: Se revisaron retrospectivamente las historias clínicas de 78 pacientes que recibieron tratamiento quirúrgico debido a un aneurisma de aorta ascendente, entre agosto de 2006 y julio de 2018, en el hospital Erzurum Regional Training and Research Hospital.

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Resultados: La edad promedio de los pacientes fue de 51,7 ± 9,8 (rango 24-77 años). Hubo 54 (69,2%) hombres y 24 (30,8%) mujeres. Cincuenta y ocho pacientes (74,3%) tenían Síndrome de Marfan. También se encontraron enfermedad coronaria (15,4%), estenosis mitral (3,8%), insuficiencia (11,5%) y estenosis aórticas (8,9%) y coartación aórtica (2,6%). Se realizó tratamiento quirúrgico de emergencia en 41 pacientes (52,5%). Se realizó reemplazo de aorta ascendente en 55 pacientes (70,5%). Se empleó la técnica de Bentall (17,9%) y sustitución valvular aórtica más reemplazo de aorta ascendente con injerto (11,5%). En 14 pacientes se utilizó paro anóxico (parada circulatoria total). La mortalidad operatoria fue de 3,8% (3 pacientes) con la técnica de Bentall y la mortalidad postoperatoria temprana fue de 1,3% (1 paciente con coartación aórtica).

Conclusiones: Los pacientes con aneurisma de aorta ascendente deben tener un estrecho seguimiento para definir su momento quirúrgico, debido al riesgo de disección y rotura. Aunque se pueden aplicar varias técnicas quirúrgicas de acuerdo con el estado de la válvula aórtica, especialmente en pacientes con síndrome de Marfan, el procedimiento quirúrgico preferido debería ser el reemplazo de la raíz aórtica con injerto compuesto, con el uso de la técnica de Bentall modificada, con reimplantación de los ostium de las arterias coronarias en el injerto.

Palabras clave: Aorta ascendente, Aneurisma de la aorta, Síndrome de Marfan, Técnica de Bentall, Cirugía

INTRODUCTION

The ascending aorta shows the presence of aneurysmal dilatation growing up to 50% of its normal diameter. This dilatation may cause significant aortic valve insufficiency even if the aortic valve structure is normal. In addition, a dilated ascending aorta carries the risk of spontaneous dissection and rupture. The size of this risk depends on the diameter of the aorta and the underlying pathology associated with the aortic wall. Hypertension, congenital bicuspid aortic valve, Marfan's syndrome and atherosclerosis are major risk factors for ascending aortic aneurysm (AAA) and root expansions[1,2].

In patients with AAA, life expectancy has dramatically increased in the last 30 years. The application of the Bentall procedure and its various methods are the most important factors influencing this positive development. Today, various operative techniques for dilated aortic aneurysms are available. A wide spectrum of surgical techniques such as pulmonary autograft, composite root replacement applications and modifications, separate replacement of the lid and the ascending aorta, and valve preserving surgery have been presented[1-4]. In some eligible patients, external wrapping and aortoplasty are offered as alternative treatments[3]. This retrospective study examines the early and midterm outcomes of surgical interventions performed with the same team for patients with AAA or additional cardiac problems.

METHOD

Seventy-eight patients underwent surgical treatment, between August 2006 and July 2018, due to AAA and/or additional cardiac pathologies at Erzurum Regional Training and Research Hospital. Acute or chronic dissecting cases were not included in this retrospective investigation.

Information on aortic dilatation and comorbidities was obtained from preoperative aortic examination and imaging studies. The telecardiographic image of

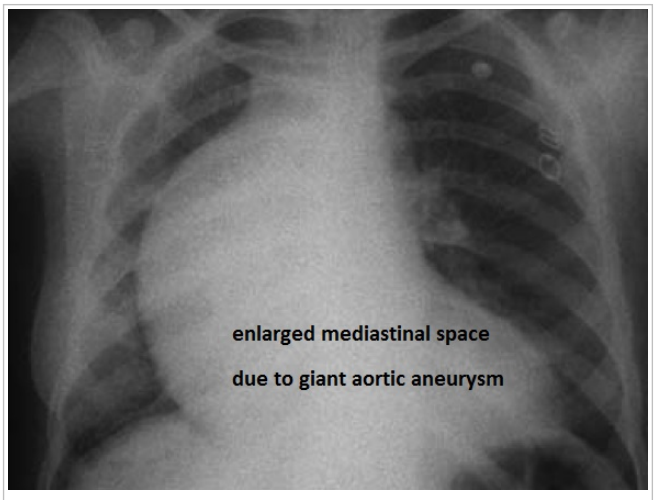

Figure 1. Chest X-ray showing a widened mediastinum due to a giant ascending aortic aneurysm.

a patient with giant ascending aortic aneurysm is shown in **figure 1**. Trans-thoracic echocardiography and contrast-enhanced computerized tomography were performed for all patients (**Figure 2**). Cardiac catheterization was performed in patients aged 50 years or older (45; 57.7%) who had coronary artery disease complaints. The diameter of the ascending aorta measured by preoperative tomography was 6-7 cm in 42 patients, 7-8 cm in 26 patients, and 8 or more cm in 10 patients. The diameter of the ascending aorta was 10.2 cm in the patient with the largest diameter. **Figure 3A** shows a preoperative AAA in one of our cases. They also presented coronary artery disease (15.4%), mitral stenosis (3.8%), aortic regurgitation (11.5%), aortic stenosis (8.9%), and aortic coarctation (2.6%). The emergency surgical treatment was required in 41 (52.5%) patients.

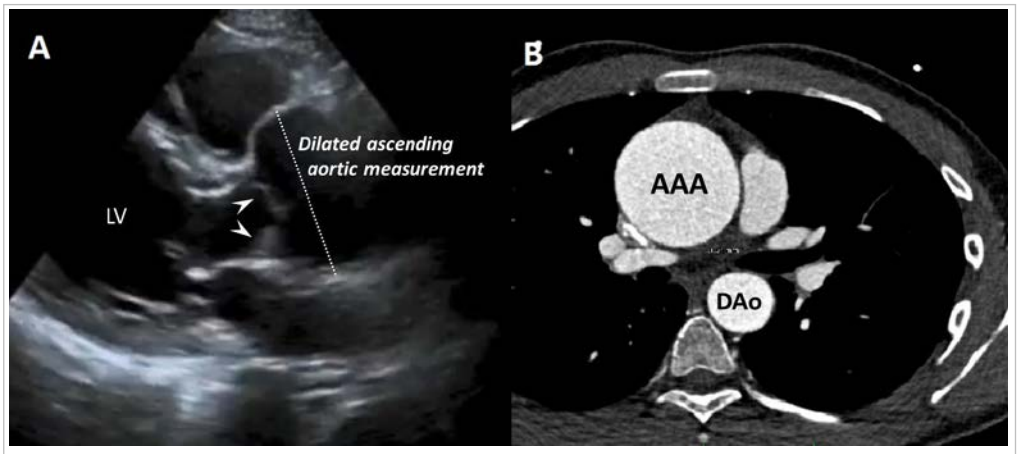

Figure 2. A. Echocardiographic image depicts ascending aortic aneurysm. Arrowheads point aortic valve cusps. LV, left ventricle. **B.** Contrast-enhanced computed tomography shows a 6 cm ascending aortic aneurysm (AAA). DAo, descending aorta.

Cardioplumonary bypass was used in all patients after median sternotomy. The localized aneurysms that did not extend to the aortic arch were operated with ascending aortic clamping (52 patients, 66.6%). In these cases, the femoral cannulation was performed in patients with sufficient space on the aorta

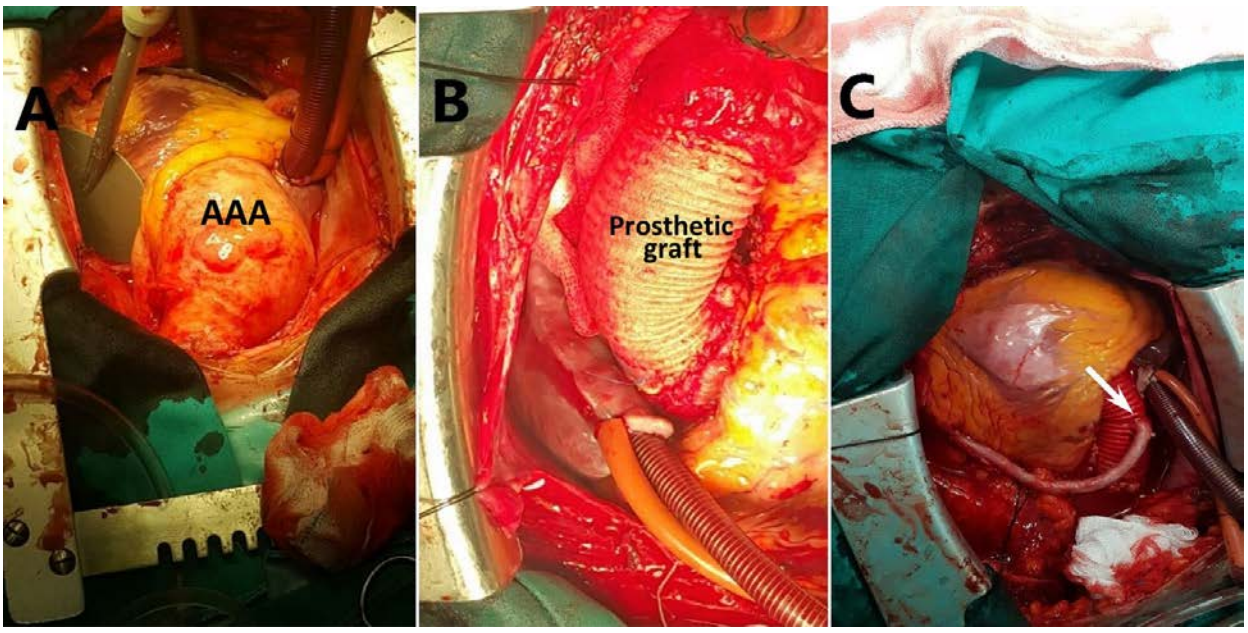

Figure 3. A. Ascending aortic aneurysm (AAA) is seen in a patient who was urgently operated. **B.** Ascending aortic graft replacement using a prosthetic synthetic graft in a patient who was operated on for ascending aortic aneurysm. **C.** Operation image of the patient who underwent ascending aortic replacement with prosthetic graft and one-vessel coronary artery bypass surgery. The arrow points the origin of vessel graft from the aortic prosthetic graft.

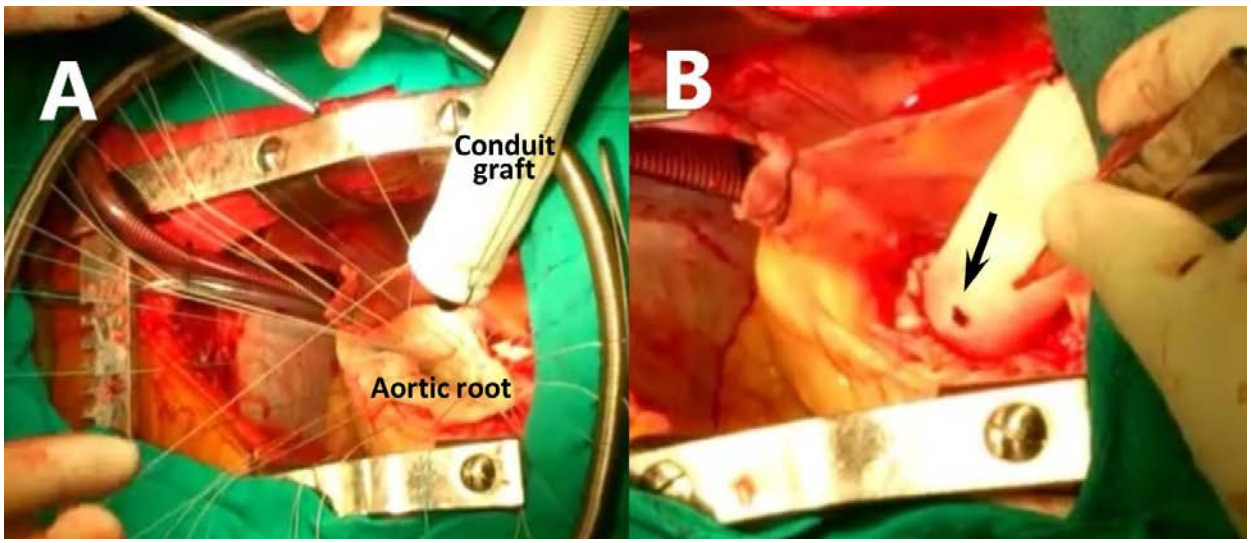

Figure 4. A. Per-operative image of suturing the conduit graft to the aortic root in a patient undergoing the Bentall procedure. **B.** The button anastomosis of coronary arteries (arrow) after suturing of a conduit graft in the same patient undergoing the Bentall procedure.

to place a cross clamp, and the surgical procedure was completed by clamping the ascending aorta prior to the aortic arch. In patients not eligible for distal ascending aortic cross-clamping, total circulatory arrest (TCA; 14 patients, 18%) or open technique (12 patients, 15.4%) were used. In open technique cases, axillary artery cannulation was used as arterial line. The innominate artery was clamped, the cardiopulmonary pump flow was reduced, and cerebral perfusion was achieved. TCA was generally used in cases operated before 2010; after this year, that process was abandoned. Retrograde cerebral perfusion was also performed with deep hypothermia (16°C) for brain protection in patients who underwent TCA. Decompression was achieved in the majority of cases using right upper pulmonary vein. In all patients, after aortic decompression at the pump, the ascending aorta was separated from the surrounding tissues and released. Myocardial cooling was performed in combination with intermittent antegrade and retrograde cold blood cardioplegia.

After the cardiopulmonary bypass in all patients, aortic opening was made by making a longitudinal incision in ascending aorta. First, the sino-tubular junction region and distal portion of the aneurysm were evaluated. Surgical intervention technique has been determined according to the conditions in these regions. **Figure 3B** shows an image of a case where ascending aortic replacement has been performed, and **figure 3C** shows the surgical image of a patient who underwent the same procedure besides coronary artery bypass surgery. During operation, proximal and distal anastomoses were reinforced with Teflon strip and supported with various adhesive materials (fibrin glue, cardiac gel). Dacron tube grafts (Sulzer Vascutek-PA4 9RR, Scodland, Intervascular and Hemashield Gold-Meadox Medical, Inc.) with mechanical bileaflet valves (mostly St. Jude Medical, USA) were used together in order to create composite grafts (**Figure 4A**).

Coronary arteries were implanted in a button-type ascending aortic graft in Bentall procedure (**Figure 4B**). In application of TCA, 15-30 μ/kg of Fentanyl with propofol and 0.15 μ/kg of pancuronium were used before the bypass. For cerebral protection, the head was wrapped with ice cushions. All patients in whom composite grafts were used, oral anticoagulation was started due to mechanical heart valves, and they were discharged after the desired dose was achieved.

RESULTS

Table 1 shows the characteristic information of the patients. Fifty-four cases (69.2%) were male and 24 (30.8%), female. Average age was 51.7 ± 9.8 (24-77 years old). The most common cause of AAA was annulo-aortic ectasia (58 cases with Marfan's Syndrome, 74.3%). Regarding additional cardiac problems, coronary artery disease was present in 12 cas-

es and also, hypertension was present in 69 (88.5%) patients. According to preoperative NYHA functional class, 70 patients (89.7%) were class I or II. In the majority of patients, the ejection fraction was between 40 and 60%.

Fifty-five patients (70.5%) had performed ascending aortic replacement alone. In addition, 18 of these patients also underwent aortic valve resuscitation. Bentall procedure (with additional pathologies and modified) was performed in the 14 patients, aortic valve replacement + ascending aortic graft replacement was made in 9 patients as separate replacement. Operative mortality occurred in 3 patients (3.8%) with Bentall procedure. These patients were emergency cases and were lost due to low cardiac output. The early postoperative mortality occurred in 1 patient (1.3%) with aortic coarctation. This patient underwent an extra-anatomic bypass + ascending aorta replacement (between ascending and descending aorta) for aortic coarctation, and postoperative was lost at 12 hours.

Table 1. Preoperative demographic findings of the patients (n=78).

Parameters	Nº	%
Average age (mean±SD)	51.7 ± 9.8 (24-77)	
Gender		
Male	54	69.2
Female	24	30.8
NYHA functional class		
Class I	44	56.4
Class II	26	33.3
Class III	5	6.5
Class IV	3	3.8
LV ejection fraction		
> 60%	62	79.5
40 - 60%	14	17.9
< 40%	2	2.6
Etiology		
Bicuspid aorta	13	16.6
Marfan's Syndrome	58	74.3
Atherosclerosis	5	6.5
Aortic coarctation	2	2.6
Surgery time		
Elective	37	47.5
Emergency	41	52.5
Accompanying pathologies		
Coronary artery disease	12	15.4
Mitral stenosis	3	3.8
Aortic regurgitation	9	11.5
Aortic stenosis	7	8.9
Aortic coarctation	2	2.6
Peripheral arterial disease	3	3.8
Hypertension	31	39.7
COPD	9	11.5

COPD: chronic obstructive pulmonary disease; LV: left ventricle; NYHA: New York Heart Association

The types of operation and postoperative information are shown in **table 2**. One of the 2 patients who developed renal complications was taken to the hemodialysis program and the other one improved with fluid replacement therapy. Two patients who underwent coronary artery bypass graft surgery + Bentall procedure developed low cardiac output syndrome, and intra-aortic balloon pump (IABP) was applied. Both patients improved following inotropic treatment and IABP. Four patients had postoperative bleeding between 2 and 12 hours postoperatively; that was why they were re-operated, and hemodynamic parameters were stabilized once anastomosis leaks were solved. Patients remained in intensive care unit for a mean of 2.5 days (range 2-6). Average discharge period was 7.2 days (range 9-22). Endocarditis, anticoagulant-related hemorrhage (intracerebral, gastrointestinal, epistaxis, or others), thromboembolic event or valve thrombosis were not detected. Patients were invited to monthly check-ups in the early period. After 6 months, echocardiographic and tomographic examinations were performed every 3 months, and reoperation was not required in early follow-up.

Late follow-up

Seventy-eight patients were followed from 3 months to 3.5 years (mean 2.6 years). Three patients were lost to follow-up because they moved to another city in Turkey. One patient died in a traffic accident and 2 patients lost their malignancy. Three patients could not be reached despite telephone and address records. More than 90% of patients were in the NHYA class I and II. Ten patients with Marfan's Syndrome had different aneurysmal changes in descending aorta; 3 of them underwent thoracic endovascular

aneurysm repair (TEVAR), while others had no indication of operation. Seven patients had aortic valve regurgitation, and in 3 patients –with previous ascending aortic replacement– Bentall procedure was performed at the end of the second year. Stent applications were performed in 12 patients due to coronary artery disease at different times.

Table 2. Operation types and postoperative findings.

Parameters	Nº	%
Bentall procedure (Cabrol)	2	2.6
Modified Bentall procedure with flanged technique	8	10.2
Supra-coronary ascending aorta replacement	43	55.1
Supra-coronary ascending aorta replacement + aortic re-suspension	12	15.4
Separate AVR + ascending aorta replacement	9	11.5
CABG + modified Bentall procedure with flanged technique	2	2.6
MVR + modified Bentall procedure with flanged technique	1	1.3
Modified Bentall procedure with flanged technique + ascending-descending aorta extra-anatomic bypass graft	1	1.3
CPB with femoral cannulation (cross clamping)	52	66.7
CPB with open technique	12	15.4
CPB with total circulatory arrest	14	17.9
Average of total circulatory arrest duration (minutes)	51 (32-80)	
Average cardiopulmonary bypass duration (minutes)	166 (130-202)	
Average cross clamping duration (minutes)	115 (85-188)	
Intra-aortic balloon pump	2	2.6
Reoperation for bleeding	4	5.2
Renal complications	2	2.6
Neurological complications	1	1.3
Exitus (operative mortality [low cardiac output])	1	1.3
Hospital mortality	1	1.3
Intensive care unit staying time (days)	2.5 (2-6)	
Hospital staying time (days)	7.2 (9-22)	
Postoperative NYHA		
Class I	47	60.2
Class II	29	37.2
Class III	1	1.3
Class IV	1	1.3

AVR, aortic valve replacement; CABG, coronary artery bypass graft; CPB, cardiopulmonary bypass; MVR, mitral valve replacement; NYHA, New York Heart Association.

DISCUSSION

Today's surgical techniques in ascending aorta aneurysms have brought good early and mid-term results. Surgery is preferred, in patients with AAA, depending on patient profile, age, underlying aortic pathology, the characteristics of distal aorta, sino-tubular junction and sinuses of Valsalva, anticoagulation risk, the experience of the surgeon, and aneurysm diameter[1-5]. Ascending aortic replacement with tubular graft, after the resection of the dilated ascending aorta, is usually performed in patients without dilatation or failure at the level of sino-tubular junction and aortic valve. Surgical interventions such as separate replacement or composite graft replacement are performed in patients with aortic valve regurgitation or sino-tubular junction dilatation. Marfan's syndrome and other hereditary connective tissue diseases are treated with composite graft replacement in those patients with aortic root problems. Bentall procedure and its modifications are usually preferred in such patients. The flanged technique[5] and modified Bentall procedure (which we prefer in our patients) play an important role in the continuation of the physiological function of the aortic root. The excellent long-term results of the flanged composite graft technique and the low complication rate of the prosthesis have been determined in some studies[5-7], which have led to excellent results with low morbidity and mortality in long term follow-up. We have not encountered any hemostasis and/or hemodynamic problems in our end stage patients after using flanged technique.

The diameter of the ascending aorta is important for surgical timing. Crawford *et al*[7] recommend sur-

gical treatment in patients with aortic external diameter of 5 cm. The Johns Hopkins group shows a 5.5 cm cut-off value for elective replacement of ascending aorta in patients with Marfan's Syndrome. On the other hand, Svensson *et al*[9] argued that if the diameter of the ascending aorta is 2-fold or greater than the normal aortic diameter, surgical intervention should be performed. Coady *et al*[1] have determined that the mean diameter at the time of rupture and dissection was 6 cm. The incidence of rupture or dissection in patients with AAA depends on certain parameters such as the quality of the aortic wall, underlying pathology and aortic diameter. A rupture or dissection could be detected in the Marfanoid aortic wall, which is a good example of a weakened aortic wall, even at small distances, especially in those with family history[10]. We preferred to perform elective surgery in 5.5-6.0 cm diameter and non-dissecting or rupturing ascending aortic patients.

Early clinical reports suggest that best results for aortic root replacement are provided with mechanical valves containing prosthetic conduits and reduce the likelihood of reoperation[11,12]. However, due to the increased experience of reoperations and the possibility to easily obtain bioprosthesis, biological prosthetic valves are more used nowadays[13,14]. Aortic homografts and recently used pulmonary autografts have been frequently used in patients with AAAs[14,15]. Since we do not have the possibility of finding and providing homografts, due to economic condition of the hospital and our region, in all patients requiring conduit a mechanical valve was implanted.

Sioris *et al*[16] compared patients with separate aortic valve replacement and Bentall procedure in those having AAAs with aortic root dilatation and consequently showed no difference between the two groups during follow-up periods. The clinical profile of our patients, who underwent Bentall procedure, was different from their patients, because most of ours were marfanoid, but there none with this characteristics among their patients. This fact increases the rate of Bentall procedures and impedes separate replacement in our series. Besides, Houel *et al*[17] noted that Bentall and separate replacement did not affect long-term outcomes. However, they reported that complications of aortic wall were more developed in patients with separate replacement.

Karck *et al*[18] compared valve preserving surgery with composite graft replacement in cases with Marfan's Syndrome. They stated that there was no early mortality in patients undergoing the David and Yacoup procedure[19]. The cumulative survival rate was 96% at 5 years. However, in 3 patients, commissural insufficiency was detected and reoperation was required. Gott *et al*[20] reported that they had undergone valve-sparing surgery and no valve regurgitation developed after 29 years of surgery.

Despite the excellent early and long-term outcomes of Bentall procedure, a significant proportion of patients may experience anticoagulant-related complications[21]. Due to this situation, it is of interest to apply biological valve or valve preserving surgery, especially in young patients with Marfan's syndrome. Surgeons, however, seem reluctant of aortic valve preservation due to long-term structural defect-related stabilization problems caused by fibrillin-1 deficiency in patients with Marfan's syndrome[22]. In general, valve preserving surgery can be performed in patients with ascending aorta and root aneurysm only if the aortic valve structure is normal[23]. We were able to perform valve preserving surgery only in 1 patient by performing aortic valve resuspension in addition to supra-coronary graft anastomosis.

Age and age expectancy are also important in these patients. Application of wrapping to the aorta can be performed in elderly and high-risk patients. Similarly, treatment with separate replacement can be performed in patients with limited life span[13].

Pathologies such as true or pseudoaneurysms of coronary artery or button anastomoses and early bleeding and kinks affect operative outcomes negatively[24]. To reduce such problems associated with reimplantation of the coronary arteries, the Cabrol procedure was applied[12], but this procedure was later found to cause more problems than the arterial button technique and was less frequently used. For this reason, it has been shown that the button technique that has been introduced to application gives better results in terms of late complications[25]. We preferred open-button technique for all of our patients who underwent root replacement. Early reoperation and mortality were not seen in our patients, but we believe that there is a periodic need to follow-up of patients in terms of late complications. In the postoperative period, β-blockers have been initiated prophylactically to reduce the progression of aortic dilatation and to prevent aortic complications, especially in patients with Marfan's Syndrome[4]. Echocardiographic and computed tomography assessment was performed in the early postoperative follow-up and up to 1 year.

In patients with AAA, aneurysmal resection and

end-to-end anastomosis technique have been used sporadically by some groups. Long-term results have been reported in selected patients as an alternative to graft interposition[2]. However, their long-term durability is controversial. Zher *et al*[26] reported that during the last 10 years, 8 patients underwent end-to-end anastomosis surgery and that they had been followed for an average of 11 months, and had no problems. With this technique, Vigano *et al*[27] reported that 45 patients had been operated and 1 patient had to undergo reoperation. In living patients, there was little or no re-dilatation and no pseudoaneurysm. Although this technique may be an alternative to aortic interposition grafting, it is not preferred in our patients because there is no possibility of practice in patients with Marfan's Syndrome.

CONCLUSIONS

Patients with ascending aortic aneurysms should be closely monitored for the timing of surgery due to the risk of dissection and rupture, and patients with operation indications should undergo surgery without delay. Although several surgical interventions techniques can be applied according to the aortic valve status, especially in patients with Marfan's Syndrome, root replacement with composite graft, and Bentall modifications with button anastomosis of coronary arteries in composite graft applications should be the preferred surgical procedure.

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