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Treatment of aortic arch aneurysms: Open surgery or hybrid procedure?

Arkus aort anevrizmalarının tedavisi: Açık cerrahi mi hibrid işlem mi?

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ABSTRACT

Background: This study aims to compare the results of hybrid procedure and open surgery for the treatment of aortic arch aneurysms.

Methods: Twenty-six patients (21 males, 5 females; mean age 56.6±12.4 years; range, 20 to 83 years) who underwent total aortic arch replacement for aortic arch aneurysm between January 2004 and January 2010 were retrospectively analyzed. The patients were divided into two groups: open conventional surgery group (group 1, n=15) and hybrid procedure (total debranching of the aortic arch and simultaneous endovascular stent) group (group 2, n=11). Survival rates and need for reoperation were compared between the groups.

Results: The hybrid procedure was found to be more favorable in terms of postoperative revision, extubation period, and drainage amounts. However, there was no statistically significant difference in the survival rates, need for reoperation, and major adverse cardiovascular events between the groups.

Conclusion: Our study results suggest that conventional open surgery and hybrid procedure are similar in terms of survival and short-to-mid-term results in patients undergoing total aortic arch replacement for aortic arch aneurysm.

Keywords: Aortic arcus aneurysm; conventional open surgery; hybrid procedure.

ÖZ

Amaç: Bu çalışmada arkus aort anevrizmalarının tedavisinde hibrid işlem ve açık cerrahi sonuçları karşılaştırıldı.

Çalışma planı: Ocak 2004 - Ocak 2010 tarihleri arasında arkus aort anevrizması nedeniyle total arkus aort replasmanı yapılan 26 hasta (21 erkek, 5 kadın; ort. yaş 56.6±12.4 yıl; dağılım, 20-83 yıl) retrospektif olarak değerlendirildi. Hastalar açık konvansiyonel cerrahi grubu (grup 1, n=15) ve hibrid işlem (aynı seansta total arkus aort debranching ve endovasküler stent implantasyonu) grubu (grup 2, n=11) olarak iki gruba ayrıldı. Sağkalım oranları ve tekrar ameliyat gereksinimi gruplar arasında karşılaştırıldı.

Bulgular: Ameliyat sonrası revizyon, ekstübasyon süresi ve drenaj miktarları açısından hibrid işlem daha iyi bulundu. Ancak sağkalım oranları, tekrar ameliyat gereksinimi ve ciddi advers kardiyovasküler olaylar açısından gruplar arasında istatistiksel olarak anlamlı bir fark yoktu.

Sonuç: Çalışma sonuçlarımız arkus aort anevrizması nedeniyle total arkus aort replasmanı yapılan hastalarda sağkalım ve kısa ila orta dönem sonuçlar açısından açık konvansiyonel cerrahi ve hibrid işlemin benzer olduğunu göstermektedir.

Anahtar sözcükler: Arkus aort anevrizması; konvansiyonel açık cerrahi; hibrid işlem.

The conventional method for the treatment of aortic arch aneurysms is open surgery via graft interposition.[1] Although this method is commonly practiced, it is still associated with high surgical morbidity and mortality, particularly in the patients with several comorbidities.[1-8] New technologies have been developed to address these problems of open surgery, and surgeons currently tend to prefer alternative and less invasive treatment options.[1,2,6,8]

Currently, one of the leading alternatives is hybrid procedure, including the use of both open surgery and endovascular methods simultaneously. Despite being a less invasive treatment option for many aortic lesions, endovascular repair may not be possible in every case, mainly due to the necessity to obstruct orifices of one or more aortic arch branches to provide an adequate proximal or distal fixation site. This is because it may be necessary to close one or more aortic arch vessel orifices and the aneurysm and adequate proximal or distal fixation of the endograft can be ostracized. Consequently, there is a need for hybrid treatments for thoracic aortic aneurysm, involving of the aortic arch.

In the present study, we aimed to compare the results of open surgery and hybrid procedure in patients with aortic arch aneurysms.

PATIENTS AND METHODS

A total of 26 patients (21 males, 5 females; mean age 56.6±12.4 years; range, 20 to 83 years) who underwent surgery for aortic arch aneurysm between January 2004 and January 2010 were included in this study. Patients with acute aortic dissections were excluded. The study ptotocol was approved by the İzmir Katip Celebi University local ethics committee. The study was conducted in accordance with the principles of the Declaration Helsinki.

Postoperative follow-up data of the patients were taken from the hospital archive department and retrospectively analyzed using clinical variables. All patients underwent contrast-enhanced thoracoabdominal computed tomography (CT), echocardiography, and coronary angiography before operation. In addition, all patients underwent a comprehensive color Doppler ultrasonography, if elements of the supracoronary arch were involved.

The patients who underwent total aortic arch replacement using conventional open surgery were assigned to group 1 (n=15), while those who underwent total aortic arch debranching and endovascular stent implantation were assigned to group 2 (n=11). Both groups were compared on the basis of pre, intra-, and postoperative data and short-term and mid-term results were evaluated.

As described by Boehme et al.,[9] the diagnosis of systemic inflammatory response syndrome (SIRS) was made during the postoperative period. According to these criteria, at least two of the followings were required: body temperature >38.0ºC or <36.0ºC, heart rate >90/min, respiratory rate >20/min, and leucocyte count >12,000/μL or < 4,000/μL.

Conventional open surgical procedure

The operations were performed under general anesthesia. First, arterial cannulation was performed in all patients with an 8 mm Dacron graft attached to the right subclavian artery for anterograde cerebral perfusion (ACP). Following median sternotomy, right atrial venous cannulation was performed, followed by antegrade and continuous retrograde isothermic hyperpotassemic blood cardioplegia for myocardial protection. Nylon tapes were passed around the branches of aortic arch. Following cross-clamping, the patients were cooled down to 24 to 26ºC. Body circulatory arrest was achieved. The cerebral circulation was provided with ACP. All branches of the aortic arch were clamped during ACP. The pump flow was adjusted to maintain a right radial arterial pressure of 50 to 60 mmHg. First, a Dacron graft of suitable diameter was anastomosed to the descending aorta. Next, the cross-clamp was placed on the main graft, rewarming was started, and the main graft was anastomosed to the ascending aorta. The cross-clamp was removed and the branches of the aortic arch were anastomosed to the main graft.

Surgical procedure of hybrid intervention

In patients with an isolated aortic arch aneurysm, after median sternotomy and heparinization, the proximal end of a 14 mm Dacron graft was anastomosed to the proximal ascending aorta in an end-to-side fashion using a side-clamp without using cardiopulmonary bypass (CPB). The distal end of the graft was anastomosed to the brachiocephalic artery in an end-to-end fashion. The proximal end of a second 10 mm Dacron graft, which would be used for the deployment of antegrade endovascular graft, was anastomosed to the 14 mm Dacron graft in an end-to-side fashion. Other two 8 mm Dacron grafts were anastomosed to the 14 mm graft and the distal ends of these two grafts were anastomosed to the left carotid artery and left subclavian artery in an end-to-end fashion. A marker was positioned on the proximal anastomosis site of 14 mm Dacron graft to evaluate the level of the endograft.

For patients with an ascending aortic aneurysm in addition to an aortic arch aneurysm, CBP is a must for the replacement of ascending aorta.[1,2] Proximal anastomosis of the ascending aortic graft was performed using conventional technique after cross-clamping (aortic root replacement with composite graft can be considered for patients with aortic valve regurgitation, but aortic valve was normal in our patients). Distal attachment site was either distal

ascending aorta or proximal aortic arch. Positioning distal anatomosis of the graft to the aneurysmatic section seemed to cause postoperative problems, although these risks were excluded by positioning the proximal attachment site of the endograft on proximal level of distal anastomosis of the Dacron graft. After distal anastomosis, cross-clamping time was ended and arcus branch anastomosis was done under side-clamping. In this part, proximal end of 14 mm Dacron graft was anastomosed to the ascending aortic graft, but not to native ascending aorta as done for isolated aortic arch replacement.

Endovascular procedure of hybrid intervention

After surgical debranching, an antegrade endovascular graft was placed via the 10 mm Dacron graft previously anastomosed to the main root graft. Zone 0 was used in all patients. Proximal and distal landing zones of endograft were at least 2 cm in length. Control angiography was performed in hybrid operating room to check endoleaks, graft patency, and graft configuration. An iliac extender limb was placed in a patient with type 1B endoleak. Operation was terminated after control angiography. The hybrid procedure technique was previously described by Yilik et al.[1]

Statistical analysis

Statistical analysis was performed using IBM SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean, standard deviation, median lowest, highest, frequency and ratio values. The Fisher's exact test was used for intragroup comparisons of the categorical data, while the Mann-Whitney U test was used for the intragroup comparisons of the continuous variables. Survival analysis was performed using the Kaplan-Meier plot and log-rank test. A p value of <0.05 was considered statistically significant.

RESULTS

In terms of preoperative variables, the only difference was the rate of previous operations. The rate of previous operations was significantly higher in group 2 than group 1 (p<0.05) (Table 1). In terms of the perioperative data, there was a significantly higher rate of ascending aortic replacement in group 1 than group 2 (p<0.05) (Table 2). Ascending aortic replacement was performed in all patients undergoing open surgery with aortic root replacement in four patients. Of these patients, two underwent a previous cardiovascular operation (aortic valve replacement and femoropopliteal bypass, respectively).

Table 1. Preoperative data

	Group 1 (n=15)			Group 2 (n=11)			
	n	%	Mean±SD	n	%	Mean±SD	p
Age (year)			55.4±13.9			65.4±6.2	0.054
Gender							
Female	3	20		2	18.2		1.000
Hypertension	9	60		10	90.9		0.178
Chronic obstructive pulmonary disease	5	33.3		6	54.5		0.426
Diabetes mellitus	4	26.7		5	45.5		0.419
Peripheral arterial disease	2	13.3		1	9.1		1.000
Chronic renal failure	1	6.7		2	18.2		0.556
Smoking	11	73.3		8	72.7		1.000
Previous surgery	2	13.3					0.038
Coronary artery bypass + AVR	1	6					
Femoropopliteal bypass	1	6					
Supracoronary aortic replacement				4	36.3		
Coronary artery bypass				1	9		
TEVAR				1	9		
Preoperative ejection fraction			52.3±6.8			56.4±8.1	0.132
Body Mass Index			24.9±3.4			32.3±9.4	0.052
EuroSCORE			7.2±2.3			7.4±2.1	0.560
Aneurysm diameter (mm)			65.5±11.7			67.5±6.9	0.621

SD: Standard deviation; AVR: Aortic valve replacement; TEVAR: Thoracic endovascular aortic replacement; EuroSCORE: European System for Cardiac Operative Risk Evaluation.

Table 2. Operative data

	Group 1 (n=15)			Group 2 (n=11)			
	n	%	Mean±SD	n	%	Mean±SD	p
Emergency surgery	2	13.3		0			0.492
Concomitant procedures-ascending aortic replacement	15	100		3	27.3		0.000
Concomitant procedures-aortic root replacement	4	26.7		0			0.113
Other concomitant procedures	4	26.7		0			0.113
Aortic valve replacement	2	13.3		0			
Coronary artery bypass	2	13.3		0			
Duration of operation (min)			337.3±77.2			360.2±95.5	0.517

SD: Standard deviation.

Eight of the patients in the hybrid group had an isolated aortic arch aneurysm, two had a concomitant ascending aortic aneurysm and aortic arch aneurysm, and one had an ascending aortic aneurysm with an aortic arch aneurysm and descending aortic aneurysm (i.e., mega aorta syndrome). In the same group, six patients underwent a previous cardiac operation (supracoronary aortic replacement due to type 1 aortic dissection in four patients -none of them had false lumen resistance-, a coronary bypass in one, and thoracic endovascular aortic replacement [TEVAR] due to a descending aortic aneurysm in one).

One patient with an isolated aortic arch aneurysm also had prostate cancer and an abdominal aortic aneurysm. This patient underwent simultaneous aortic arch debranching and endovascular aortic replacement (EVAR). However, the operative data in this study were not assessed statistically as the amount of data was limited (e.g., data from the CPB and cross-clamping periods in the hybrid events with CPB, as well as the open surgery group).

The median interval of CPB in group 1 was 112 (range, 78 to 105) min, and that of cross-clamping

Table 3. Postoperative data

	Group 1 (n=15)			Group 2 (n=11)			
	n	%	Mean±SD	n	%	Mean±SD	p
Postoperative revision	7	46.7		0			0.010
Postoperative SIRS	11	73.3		6	54.5		0.419
Postoperative renal failure	3	20		0			0.238
Postoperative cardiac failure	3	21.4		0			0.230
Thirty day postoperative neurologic events	0			0			-
Postoperative drainage (mL)			1203.3±544.0			695.5±348.9	0.019
Postoperative blood products used (IU)			5±2.9			4.8±1.6	0.937
Postoperative ventilation time (h)			17.6±8.8			11.3±2.7	0.017
Length of ICU stay (days)			5.9±4.7			3.8±1.5	0.447
Thirty day survival	12	80		11	100		0.238
One year survival	11	73.3		11	100		0.113
Five year survival	9	60		8	72.7		0.683
One year cardiac reoperation	-			-			-
Five year cardiac reoperation	2	13.3		2	18.2		1.000
Long-term neurologic events	3	20		0			0.238
Major adverse cardiovascular event.	5	33.3		4	36.4		1.000
Duration of follow (months)			54.9±39.3			80.4±21.2	0.102

SD: Standard deviation; SIRS: Systemic inflammatory response syndrome; ICU: Intensive care unit.

was 60 (range, 38 to 138) min. In three patients who underwent CPB in group 2, the median CPB interval was 60 (range, 45 to 170) min, while the median cross-clamp interval was 37 (range, 28 to 110) min. In addition, the mean diameter of the endografts used in the hybrid group was 43±2 (range, 40 to 45) cm, and their mean length was 18.6±3.2 (range, 15 to 25) cm. The control angiographies of the patients who underwent hybrid surgery revealed type 1B endoleak in one patient (9%).

No statistically significant difference was found between the groups in terms of the postoperative variables including SIRS, chronic renal failure, heart failure, rate of neurological events, blood transfusion, duration of intensive care unit (ICU) stay, and 30-day survival ($p>0.05$). However, postoperative revision was significantly higher, the extubation period was significantly longer, and the amount of drainage was significantly higher in group 1, compared to group 2

($p<0.05$) (Table 3). In group 1, three patients died from low cardiac output in the early postoperative period, while no deaths occurred in the early postoperative period in group 2.

Comparison of the groups in terms of long-term follow-up revealed that the rates of one-year survival, five-year survival, freedom from reoperation for one year, freedom from reoperation for five years, long-term neurological events, and major adverse cardiovascular events (MACEs) were similar (Figure 1). In the open surgery group, one patient died in the postoperative ninth month due to hemorrhagic infarcts, one patient died in the postoperative 26th month due to an intracerebral hematoma which developed in the ICU following surgery of a proximal pseudoaneurysm, and one patient died in the postoperative 42nd month due to multiple organ dysfunction. In the hybrid group, no patient died during the first postoperative year;
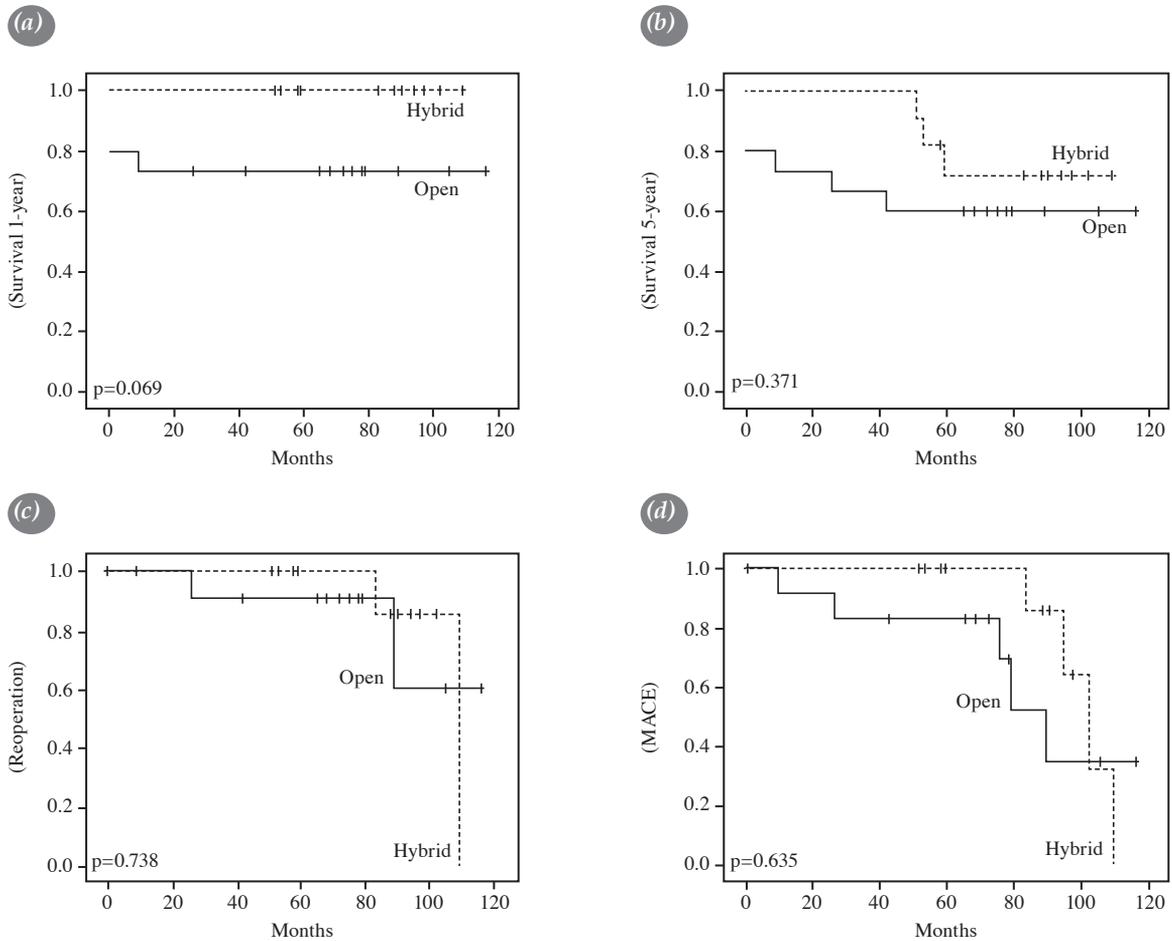

Figure 1. Kaplan-Meier Curve **(a)** One-year survival, **(b)** five-year survival, **(c)** five-year freedom from cardiac reoperation, **(d)** Freedom from MACE (Major Adverse Cardiovascular Event).

however, two patients died in the postoperative 51st and 59th months, respectively, due to multiple organ dysfunction. In the postoperative 53rd month, one patient who underwent a re-EVAR procedure to treat an aortoenteric fistula died from major bleeding. In both groups, there was no need for re-cardiac surgery during the first postoperative year. In the open surgery group, two patients required reoperation. In the first patient, supracoronary ascending aortic replacement and total aortic arch replacement were performed due to a pseudoaneurysm arising from the proximal anastomosis in the postoperative 26th month. The second patient was reoperated in the postoperative 89th month due to aortic valve failure (the aortic root was not treated during the first operation). In the hybrid group, due to an aneurysmal development in the proximal attachment site in the postoperative 62nd month, re-TEVAR was required in one patient (the ascending aorta was not treated during the first operation). Reoperation was also necessary in another patient due to aortic valve failure caused by an aneurysm in the proximal adherence zone in the postoperative 75th month. In the hybrid group, EVAR was performed in one patient in whom an abdominal aortic aneurysm developed during long-term follow-up. One patient developed a temporary ischemic attack and, with the exception of the two patients who died in the surgery group, none of the patients developed a neurological event in the hybrid group.

The mean follow-up was 54.9±39.3 months in group 1 and 80.4±21.6 months in group 2, indicating a shorter follow-up period for group 1. The follow-up period for three patients who were lost to follow-up within the first 30 days was calculated as 0.

DISCUSSION

Technical and clinical challenges rising from the anatomical structures of aneurysms of the aortic arch have led to alternative treatment options to conventional open surgery.[1,10-15] Of these options, the leading choice is endovascular intervention, which is used more commonly currently, thanks to the advances in technology and increasing experience. However, as the proximal attachment site of the endovascular grafts coincide with the aortic arch or more proximal areas, one or more aortic arch branches may be covered by the endovascular graft. To overcome this problem, hybrid procedure has been developed that includes surgical reconstruction of aortic arch elements and endovascular repair of aneurysms.[1] As it is used more commonly today, the results of these hybrid

procedures have started to appear in publications. To the best of our knowledge, there are a few studies comparing open surgery with the hybrid technique in the literature.[12-18] Yet, examination of these limited studies revealed no homogeneity among patient groups. Most of the studies included patients with aortic dissections.[12-15] Furthermore, some studies compared open surgery and hybrid procedures and showed that the rates of dissection etiology between the groups were different.[12,17] In such studies, dissection patients must be removed from studies or the groups should be equalized in this respect. Outcome results of the dissection patients are worse and this situation may affect the study results. Another problem related to homogeneity among patient groups in these studies is that EuroSCORE (European System for Cardiac Operative Risk Evaluation) values are higher in the hybrid groups due to the abundant comorbidity factors and age.[12,14-17] Notably, the hybrid procedure is used in higher-risk patients, as it is less invasive than open surgery. However, this may result in loss of homogeneity between the patients undergoing the two techniques, which may affect the results. Unlike previous studies, in our study, we only included patients with aneurysms and excluded those with dissections. Moreover, both groups consisted of similar patients in terms of all other variables, including EuroSCOREs and excluded those who underwent a previous operation. Of note, it should be kept in mind that the number of prior operations is higher in hybrid procedure group.

The hybrid procedure for the treatment of aortic arch aneurysms is considered less invasive than open surgery with a shorter stay in the ICU, a shorter extubation period, and less bleeding.[14] Recently, there have been studies with preoperative data that support this opinion, reporting that there is no difference between these two methods. Iba et al.[16] found that the length of stay in both the ICU and the hospital were shorter in patients who underwent a hybrid procedure than those who underwent open surgery for aortic arch aneurysms without dissection. However, in the aforementioned study, no difference was reported between the groups in terms of the weaning period. In other studies, no difference was reported between two methods in terms of ICU stay or weaning period; this did not support the hypothesis that the hybrid procedure would show improvements in these variables owing to its less invasive nature.[12,13,15] Interestingly, in a study by Tokuda et al.[15] including 192 patients, open surgery had better results in terms of these same variables, and no difference during the perioperative period was reported between two techniques. Only a few studies reported that the hybrid procedure was superior to open surgery in terms of the

need for re-surgery and blood transfusion.[13] In our study, we found that the hybrid procedure was superior to open surgery in terms of the amount of drainage, reoperation due to bleeding, and weaning period. However, we found no significant difference in the need for blood transfusion, duration of ICU stay, or early postoperative complications between the two groups.

Although data are available on the mid-to-long-term results of open surgery and endovascular methods for abdominal and descending aortic aneurysms, such data on the hybrid procedure and open surgery performed for aortic arch aneurysms have only recently been reported, since the hybrid procedure is a relatively new method. In one of the earliest reports, Milewski et al.[12] reported no difference between the two techniques in terms of early and late mortality rates. In the aforementioned study, there was a difference in the mortality rate between patients above the age of 75 versus those under the age of 75 in the open surgery group. In the study by De Rango et al.,[17] a hybrid procedure was used in older patients and those with several comorbidities, and no difference was found between open surgery and the hybrid procedure in terms of perioperative death and four-year survival rates. In the study of Cazavet et al.[18] including 46 patients, open surgery and hybrid procedure were compared in patients with aortic arch aneurysms, and no difference between the two techniques was found in terms of the one, three, five, and seven-year survival rates. However, the authors reported that open surgery was superior to the hybrid procedure in terms of the re-intervention rates. Kang et al.,[14] Tokuda et al.,[15] and Iba et al.[16] also reported similar results in their studies. In four studies and a meta-analysis including 378 patients, there was no difference between the two methods in terms of early and late mortality rates; however, the rate of events causing permanent neurological damage was lower in the open surgery compared to the hybrid procedure group.[19] Regarding all of these studies, it should be kept in mind that the hybrid procedure was used mainly in older patients and in those with several comorbidities and, thus, high EuroSCOREs. Accordingly, even if there is a situation related to survival favoring the use of a hybrid procedure, this may be eliminated due to the group of higher-risk patients. In our study, we found that the two techniques were similar in terms of the incidence of MACEs, survival rates, and the need for reoperation; given that both groups were homogeneous in terms of comorbidities, we believe that this is a valuable finding.

To identify the zone where the endovascular graft should be placed during the hybrid procedure, standard proximal landing zone classifications were used.[3] Accordingly, there are differences in aortic arch reconstruction, depending on the proximal landing zone. The incidence of temporary or permanent neurologic damage is usually higher than those of conventional TEVAR practices in hybrid procedures, while this rate varies from 0 to 20% among studies (in the case of Zone 1 and Zone 2 settlement in particular).[1,20,21] Neurological damage is higher in these cases due to emerging embolism with higher degrees of aortic arch debranching, which are used for guidewire and endograft manipulations.[22]

As the proximal parts of the brachiocephalic arteries were ligated in patients undergoing total arch debranching with graft placement in Zone 0, there was a mild risk during the endovascular procedure.[1] Another benefit of using Zone 0 as the proximal landing zone is that the risk of type 1A endoleak, particularly that seen in Zone 1, is reduced according to several studies.[23,24] In our study, Zone 0 was used in all patients, and neither an early neurological event nor a type 1A endoleak was observed in any of the patients.

In the present study, we performed all hybrid practices in the operating room at a single session. Performing the hybrid procedures during the same session eliminated drawbacks, such as a long operation period, higher volumes of blood loss, and the need for contrast agents.[20,22] Furthermore, we believe that performing the procedure in a single session of anesthesia has a psychologically protective effect on the patient; it also allows us to perform surgical intervention for any complication that may occur during the endovascular procedure.

The limitations of our study included its small sample size and retrospective design. However, as mentioned above, our study is different from others, as all the patients included had aneurysms; furthermore, the patients in both groups were similar to each other in terms of all preoperative variables, particularly the EuroSCOREs.

In conclusion, the short-term and long-term results of conventional open surgery and the hybrid procedure for aortic arch aneurysms are rather promising and both methods can be performed feasibly by reliable and experienced teams. However, there is a need for at least 10-year follow-up results to compare these two methods more precisely.

Declaration of conflicting interests

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