



Surgical treatment with wrapping of the moderately-dilated ascending aorta

Orta derece dilate çıkan aortun wrapping ile cerrahi tedavisi

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ABSTRACT

Background: The aim of this study is to present early and mid results associated with the treatment of dilatation of the ascending aorta using the wrapping technique.

Methods: A total of 54 patients (16 males, 38 females; mean age 56.9±12.7 years; range 21 to 77 years) who were subjected to the wrapping technique due to dilatation of the ascending aorta between January 2010 and February 2017 were retrospectively analyzed. The Dacron grafts were used in all patients. Wrapping was performed in all patients in combination with the other cardiac surgical procedures. Wrapping was performed with aortoplasty in 32 patients and as an isolated procedure in 22 patients. Preoperative clinical findings, concomitant cardiac procedures, intraoperative parameters, postoperative early and long-term outcomes were evaluated. The ascending aorta and descending aorta diameters, ejection fraction, left ventricle end-diastolic and end-systolic diameters were measured using a computed tomography scan and/or transthoracic echocardiography after surgery, and was compared with the preoperative values.

Results: The median follow-up was 3.8 (range, 1 to 7) years. No intraoperative complication associated with the wrapping procedure was reported in any of the patients. One patient died during the early postoperative period. Relapse-free intra-arterial fibrinolysis was used to correct postoperative cerebral infarct in one patient without any sequelae. Revision surgery was required in two patients due to bleeding and in another two patients due to sternal dehiscence. A postoperative decrease in the aortic diameter and an increase in the ejection fraction were found to be statistically significant. Findings such as sinus of Valsalva and distal aortic dilation, rupture, pseudoaneurysm, and graft mobilization were not observed during follow-up.

Conclusion: Our study results show that the wrapping techniques may be safely performed in patients with moderate dilatation of the aorta who do not require replacement of the ascending aorta.

Keywords: Aneurysm; aorta; wrapping.

ÖZ

Amaç: Bu çalışmada çıkan aort dilatasyonunun wrapping tekniği ile tedavisinin erken ve orta dönem sonuçları sunuldu.

Çalışma planı: Ocak 2010 - Şubat 2017 tarihleri arasında çıkan aort dilatasyonu nedeniyle wrapping tekniği uygulanan toplam 54 hasta (16 erkek, 38 kadın; ort. yaş: 56.9±12.7 yıl; dağılım 21-77 yıl) retrospektif olarak incelendi. Tüm hastalarda Dacron greftler kullanıldı. Wrapping, tüm hastalarda diğer kardiyak cerrahi işlemler ile birlikte uygulandı. Wrapping 32 hastada aortoplasti ile birlikte, 22 hastada ise izole olarak yapıldı. Ameliyat öncesi klinik bulgular, eşlik eden kardiyak sorunlar, ameliyat sırası parametreler, ameliyat sonrası erken ve uzun dönem sonuçları değerlendirildi. Çıkan aort ve inen aort çapları, ejeksiyon fraksiyonu, sol ventrikül diyastol sonu ve sistol sonu çapları, cerrahi sonrası bilgisayarlı tomografi veya transtorasik ekokardiyografi kullanılarak ölçüldü ve ameliyat sonrası değerler ile karşılaştırıldı.

Bulgular: Ortalama takip süresi 3.8 (dağılım 1-7) yıl idi. Hastaların hiçbirinde wrapping işlemi ile ilişkili ameliyat sırası komplikasyon gözlenmedi. Bir hasta ameliyat sonrası erken dönemde kaybedildi. Bir hastada ise, ameliyat sonrası serebral infarkt, relapsız intraarteriyel fibrinolitik ile sekelsiz olarak düzeltildi. İki hastada kanama nedeni ile diğer iki hastada ise sternal dehisens nedeniyle revizyon gerekti. Ameliyat sonrası aort çaplarında küçülme ve ejeksiyon fraksiyonunda artış istatistiksel olarak anlamlı idi. Takip sırasında sinüs Valsalva ve distal aort dilatasyonu, rüptür, pseudoanevrizma ve greft mobilizasyonu gibi bulgulara rastlanmadı.

Sonuç: Çalışma sonuçlarımız, çıkan aort replasmanı gerektirmeyen orta derece aort dilatasyonu olan hastalarda wrapping tekniğinin güvenli bir şekilde uygulanabileceğini göstermektedir.

Anahtar sözcükler: Anevrizma; aort; wrapping.

Received: June 14, 2017 Accepted: September 02, 2017

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Cite this article as:

Kaya U, Çolak A, Ceviz M, Becit N, Koçak H. Surgical treatment with wrapping of the moderately-dilated ascending aorta. Turk Gogus Kalp Dama 2018;26(2):192-199.

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Treatment of the cases of moderately dilated ascending aorta remains a matter of controversy. Although it is often accepted that, in large aneurysms, replacement with excision and vascular prosthesis is the preferred approach, the standard for treating a moderate aortic dilatation (40 to 55 mm) is unclear.^[1] Aortic wrapping is a surgical technique that can be used for the management of dilated ascending aorta. The technique can be performed in various forms as with aortoplasty (concomitant aortoplasty) or as an isolated procedure (wrapping without aortoplasty), using different materials such as Dacron, polypropylene, and polyester. Most studies report the results of wrapping with concomitant aortoplasty, where the excessive aortic wall is either resected or plicated, followed by a reinforcement using an external material.^[2,3] Isolated wrapping (without aortoplasty) is a procedure which is mainly utilized in patients with a moderately dilated aorta (a diameter of 40 to 55 mm) undergoing other cardiac surgery operations.^[4]

In this study, we present the results of the use of the wrapping technique with and without concomitant aortoplasty.

PATIENTS AND METHODS

An approval of the local ethics committee was obtained for this study. The study was conducted in accordance with the principles of the Declaration of Helsinki.

In this study, a total of 54 patients (16 males, 38 females; mean age 56.9 ± 12.7 years; range 21 to 77 years) who were subjected to the wrapping technique due to dilatation of the ascending aorta at Cardiovascular Surgery Clinic of Ataturk University, Faculty of Medicine, between January 2010 and February 2017 were retrospectively analyzed. All patients underwent wrapping procedure with a Dacron graft from the ventricular-aortic junction to the beginning of the innominate artery due to dilatation of the ascending aorta. The procedure was performed in the patients with moderate dilatation (38 to 50 mm) without aortic wall calcification and dissection. Predicted dimensions (PD) at the level of the sinuses was calculated by the use of the regression formula: mean sinus dimension (cm) = $0.97 + (1.12 \times \text{body surface area [m}^2\text{]})$. The aortic ratio (measured diameter/predicted diameter) was considered to be an indication for wrapping which is <1.5 for the age under 40 and <1.65 for the age over 40 years.^[5] When the patient's normal aortic diameter obtained by this formula was 30 mm, a 32 mm diameter dacron graft was used, taking into consideration that a 2 mm diameter narrowing during suturation of graft may

occur. Thus, the aortic diameter was reduced to the planned diameter after the procedure.

Patients with Marfan syndrome or other known genetically determined connective tissue disorders, with focal areas of thinning, dissection, and patients with an Ergin score above 1.5/1.65 were excluded from our study.

The mean preoperative aortic diameter was 44.3 ± 3.7 (range, 38 to 50) mm. The patient with the lowest preoperative aortic diameter of 38 mm was a patient scheduled to undergo CABG with a body surface area of 1.6 m². According to body surface area, the patient's abdominal aorta was about 35% dilated. For this reason, concomitant wrapping was also applied. The mean preoperative aortic diameter at the level of the sinus of valsalva was 41 ± 1.6 (range, 38 to 42) mm. The aortic dilatation rate (measured diameter/predicted diameter) at the level sinus of valsalva calculated by this formula was <1.5 , so wrapping was applied to these patients. Detailed patients characteristics are presented in Table 1. Twelve of the patients were operated with upper partial sternotomy and 42 with conventional median sternotomy. All patients who underwent upper partial sternotomy were in the group subjected to aortic valve surgery or subaortic membrane resection. The primary cardiac surgical procedures are shown in Table 2. Thirty-two patients (59.3%) with aortic dilatation who were required aortic valve surgery were treated with wrapping together with aortic wall resection, while 22 patients (40.7%) who were operated for another cardiac pathology without aortic valve pathology were performed wrapping without aortoplasty.

Preoperative aortic diameters were evaluated using transthoracic echocardiography (TTE) and/or computed tomography (CT). The median follow-up was 3.8 ± 1.9 (range, 1 to 7) years. During the follow-up period, the ascending aorta was assessed using both CT and TTE (Figure 1). Follow-up data were obtained by retrospective review of medical records or by direct

Guidelines for Surgery^[5]

Adult age, 40 years BSA 2 m ²	Diameter	Ratio
Marfan (+ family history)	>4.3	1.3
Chronic dissections	>4.3	1.3
Degenerative without AI	>4.8	1.5
Degenerative with AI	>4.8	1.5
Bicuspid valve with dysfunction	>4.5	1.4
Other cardiac surgery	>4.8	1.5
Surgeons' experience	$+0.5$	0.15

BSA: Body surface area; AI: Aortic insufficiency.

telephone interviews or office visits. Follow-up was completed in 88.8% (n=48) of the patients. One patient died on Day 22 and records of five patients were unable to be reached.

Operative technique

The patients were subjected to partial sternotomy or conventional median sternotomy. After opening the pericardium, the aorta was freed from the pulmonary artery and surrounding tissues, from the sinotubular junction to the innominate artery. The cardiopulmonary bypass (CPB) was established with arterial cannulation of the ascending aorta near the brachiocephalic trunk and unicaval or bicaval venous cannulation from the right atrium according to the type of primary surgery. For myocardial protection, intermittent antegrade or retrograde warm or directly in the coronary ostia warm blood cardioplegia was used with moderate systemic hypothermia (28°C).

The aortic clamp was removed after completing the concomitant surgical operation. During warming-up of the patient, systolic blood pressure was maintained at 60 to 80 mmHg to prevent aortic wall laceration

and graft mobilization, accompanied by CPB. A longitudinal cross-section of the Dacron graft was wrapped in the dilated segment of the ascending aorta, and continuous suturing with prolene suture was made through the tunica adventitia of the aorta. After performing proximal anastomosis in patients who underwent coronary artery bypass grafting (CABG), the Dacron graft was shaped according to the position of the artery or venous graft, and wrapped around the proximal anastomoses. The proximal and distal ends of the Dacron graft and surrounding of the proximal anastomosis of patients who underwent CABG were fixed with a few 5-0 prolene sutures to the adventitia of the aorta to prevent movement of the graft and the risk of the graft blockage (Figure 2). After the process, the flow of grafts was checked by measuring with transit-time flow measurement (TTFM) which is used routinely in our clinic. In the patients undergoing resection aortoplasty, aortic longitudinal opening was made by calculating the length of the tissue to be excised under CT during the postoperative period ($\chi=\pi(D1-D2)$), where D1 is the maximal aneurysm diameter and D2 is the aortic diameter at the level of

Table 1. Demographic and comorbid factors of the patients (n=54)

Preoperative data	n	%	Mean±SD
Age (year)			56.9±12.7
Gender			
Male	16	29.6	
Female	38	70.4	
Hypertension	35	64.9	
Diabetes mellitus	18	33.3	
Chronic obstructive pulmonary disease	11	20.4	
Coronary artery disease	22	40.7	
Aortic valve disease	28	51.8	
Mitral valve disease	5	9.5	
Left ventricular hypertrophy	26	48.1	
Congenital heart disease	3	5.5	
Tobacco use	23	42.5	
Diameter of the ascending aorta (mm)			44.3±3.7
Diameter of the sinus of Valsalva (mm)			41±1.6
Diameter of the descending aorta (mm)			24.8±3.3
Preoperative LVEF (%)			
Left ventricle size (mm)			
Left ventricle end-diastolic diameter			50.5±8.9
Left ventricle end-systolic diameter			34.2±10.2
Diagnostic method			
Catheter angiography	40	74.1	
Computed tomography	28	51.9	
Transthoracic echocardiography	54	100	
Transesophageal echocardiography	20	37	

SD: Standard deviation; LVEF: Left ventricular ejection fraction.

Table 2. Concomitant cardiac procedures in patients undergoing wrapping procedure

Concomitant cardiac surgery procedures	n	%
AVR	23	42.6
AVR + CABG	2	3.7
CABG	18	33.3
MVR	1	1.6
MVR + CABG	1	1.6
AVR + MVR	3	5.6
TV repair + CABG	1	1.6
Subaortic membrane resection	3	5.6
CABG + Subaortic membrane resection + AVR	1	1.6
LA thrombus resection	1	1.6

AVR: Aortic valve replacement; CABG: Coronary artery bypass grafting; MVR: Mitral valve replacement; TV: Tricuspid valve; AV: Aortic valve; LA: Left atrium.

the origin of the innominate artery).^[6] For example, if the planned final aortic diameter was from 40 mm to 34 mm, the aortic wall $(3.14 \times (40-34) = 18.8$ mm, which was approximated 2 cm) about 2 cm wide was elliptically resected together with the suture line and the aorta closed. After aortic valve surgery, the aortic wall was removed by resection and closed using continuous propylene sutures. The wrapping procedure was finalized by encircling the aortic wall externally using the Dacron graft (Figure 3). The operation was terminated after completion of the standard procedures. The aortic lumen diameter was reduced to about 30 mm considering the aortic wall thickness.

Statistical analysis

Statistical analysis was performed using the SPSS for Windows version 13.0 software (SPSS Inc., Chicago, IL, USA). Descriptive data were expressed in mean \pm standard deviation or number and percentage.

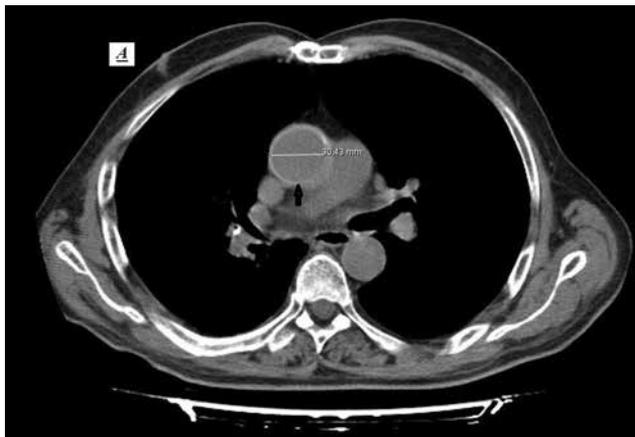


Figure 1. Postoperative computed tomography scan demonstrates of wrapping.

Comparisons of the aortic diameters were analyzed by repeatedly measured analysis of variance, and the difference between preoperative and postoperative data for nominal data was analyzed using the Mann-Whitney U test. A *p* value of <0.05 was considered statistically significant.

RESULTS

There were no intraoperative complications in any of the patients and there were no problems associated with applying the aortic wrap. The intra- and postoperative data are presented in Table 3. One patient (1.9%)

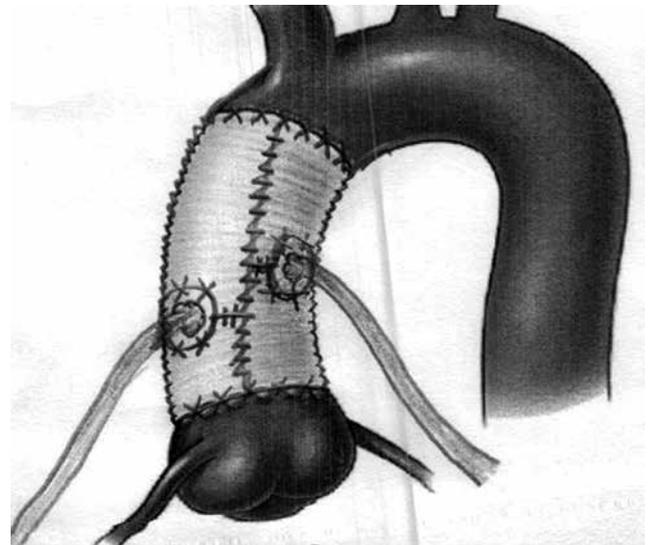


Figure 2. A schematic presentation of wrapping of the dilated ascending aorta. The proximal and distal ends of the Dacron graft and surrounding of the proximal anastomosis were fixed with sutures.

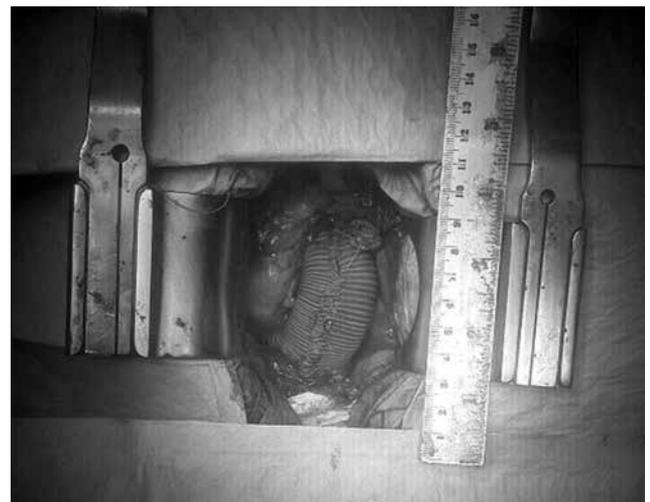


Figure 3. Intraoperative view of wrapping.

Table 3. Intraoperative parameters and postoperative early and long-term outcomes

	n	%	Mean±SD
Median sternotomy	42	77.8	
Upper partial ministernotomy	12	22.2	
Concomitant aortoplasty	32	59.2	
Isolated wrapping without aortoplasty	22	40.7	
Cross-clamp time (min)			52.2±9.2
Cardiopulmonary bypass time (min)			90±24.6
Total procedure time (h)			4.8±0.4
The mean numbers of proximal anastomoses			2±0.7
Re-exploration for bleeding	2	3.7	
Amount of chest tube drainage (mL)			190.2±90.9
Postoperative atrial fibrillation	15	27.8	
Stroke	1	1.9	
Acute renal failure	4	7.4	
Revision for sternal infection	2	3.7	
Ventilation time (h)			6.4±2.8
Stay in intensive care unit (days)			2.63±0.8
Hospital stay (days)			10.9±4
Hospital mortality	1	1.9	

SD: Standard deviation.

died during the postoperative period. This case was a 65-year-old female patient who underwent double valve replacement and developed acute renal failure. She died on Day 22. Another patient developed early postoperative cerebral infarct which was corrected with relapse-free intra-arterial fibrinolysis. Revision surgery was required in two patients during the early stages due to bleeding. Median sternotomy was performed in one of these patients, while the other patient underwent right anterior mini-thoracotomy to drain the hematoma. Revision surgery was also required in two patients after 20 days and after four months, due to sternal dehiscence and wound infection, respectively. Omentoplasty was performed in these two patients during revision to prevent any graft infection. No graft infection was observed in any of the patients. One patient underwent reoperation due to aortic valve dysfunction in the postoperative fourth year. Of the

patients who underwent surgery, 53 were discharged without any problems. A postoperative decrease in the aortic diameter and an increase in the ejection fraction were found to be statistically significant (33.4 ± 4.9 ; $p=0.001$, 53.7 ± 7.5 ; $p=0.007$, respectively). Although the left ventricular diastolic and systolic diameters decreased during postoperative follow-up, the results were not found to be statistically significant. Findings such as sinus of Valsalva and distal aortic dilation, dissection, rupture, and graft mobilization were not observed during the follow-up period. Peri- and postoperative characteristics of the patients are shown in Tables 3 and 4. There was no significant enlargement of the aortic diameter at the level of the sinus of Valsalva (41 ± 1.6 preoperatively to 41.4 ± 2.7 postoperatively; $p=0.26$) and the descending aorta (24.8 ± 3.3 preoperatively to 25 ± 1.6 postoperatively; $p=0.33$) in the study group during the follow-up period.

Table 4. Comparison of preoperative and postoperative data

	Preoperative	Postoperative	<i>p</i>
	Mean±SD	Mean±SD	
Diameter of the ascending aorta (mm)	44.3±3.7	33±4.9	0.001
Diameter of the sinus of Valsalva (mm)	41±1.6	41.4±2.7	0.26
Diameter of the descending aorta (mm)	24.8±3.3	25±1.6	0.33
Left ventricular ejection fraction (%)	50±7.3	53.7±7.5	0.007
Left ventricle end-diastolic diameter	50.5±8.9	46±7.1	0.11
Left ventricle end-systolic diameter	34.2±10.2	31±7.3	0.79

SD: Standard deviation.

However, there was a significantly lower diameter of the ascending aorta during the follow-up period (44.3 ± 3.7 preoperatively to 33 ± 4.9 postoperatively; $p=0.001$).

DISCUSSION

The threshold value for ascending aortic replacement is accepted as 55 mm in patients without Marfan syndrome and other comorbidities, such as bicuspid aortic valve.^[7] However, until date, no consensus has been reached as to whether moderately dilated ascending aorta should be managed by replacement or through follow-up. Rylski *et al.*^[8] reported in their study that aortic dissection might develop even at diameters less than 55 mm. As a result, early surgical intervention is considered reasonable for the management of moderate aortic dilatation in patients who would be particularly exposed to other cardiac surgical operations.

Supracoronary graft interposition and ascending aortic replacement have been shown to cause longer cross-clamping and CPB interval compared to isolated aortic replacement. Furthermore, the risk of bleeding from suture lines is higher, compared to standard aortotomy. Less invasive techniques may be appropriate for the management of patients with moderate aortic dilatation. External wrapping does not prolong the cross clamp duration and may cause less blood loss, compared to aortic replacement.^[9-11] This technique is a safe and easily applicable technique for severely dilated (>60 mm) and non-calcified aorta cases. Our results show that aortic wrapping is a technique which can be applied to patients either accompanied with or without CPB. However, connecting the patients to the extracorporeal circulation allows for easier and safe control, and the procedure is performed at low pressure, preventing the aortic wall from injury and any possible bleeding.

Many studies have reported good mid- and long-term results of isolated ascending aortic wrapping (wrapping without aortoplasty) and wrapping with reduction aortoplasty.^[6,9,12] Concomitant aortoplasty may be associated with a higher rate of hospital mortality, early and late stage mortality and morbidity rates. This can be explained by the longer surgical operation time and the additional suture line, compared to patients who underwent the isolated wrapping procedure. In addition, aortic wall thickening which occurs when the aortic diameter is reduced by vascular prosthesis is not observed during aortic reduction aortoplasty, due to removal of the aortic wall. Aortoplasty and wrapping do not probably offer

additional advantages over isolated wrapping for moderately dilated aorta cases (40 to 50 mm). However, this combined technique may be useful when associated with an aorta of a larger diameter since this aortic wall would prevent deformation. Deformation may occur after isolated wrapping when the wall diameter is reduced extensively.^[1,2] We performed reduction aortoplasty together with aortotomy, whenever there was a necessity for aortotomy.

The results of aortoplasty, whether with or without wrapping, are still controversial, and 44% of surgeons suggest that aortoplasty (with or without wrapping) should be performed in patients with aortic dilatation. In their analyses, Robicsek *et al.*^[13] reported that concomitant aortoplasty demonstrated better redilatation and dissection rates, compared to isolated aortoplasty. Thus, based on the data from studies concerning reduction aortoplasty without concomitant external wrapping, it seems reasonable to perform additional wrapping to lower the risk of further redilatation.^[13,14]

According to the results of meta-analysis for the wrapping technique, early mortality rate in patients who underwent this surgical operation was 0.4%.^[1] Two large-scale studies evaluating the results of the wrapping technique demonstrated that there was no aorta-related early and late stage mortality.^[9,15] Furthermore, recently published biomedical analyses reported that external wrapping reduced the risk of stress, pressure, and aortic dissection on the wall of the aorta.^[16]

The incidence of aortic complications after wrapping is reported to be low.^[1] However, a few cases associated with complications have been published. These are usually associated with wrapping graft substitution or aortic root redilatation.^[17,18] According to the experience of the surgeons who routinely use this technique, the aorta needs to be proximally and distally fixed to prevent dislocation of the vascular prostheses used for wrapping.^[15] Our experience also shows that it is possible to prevent such complications, when the suture line is being stitched by passing the sutures through the aortic adventitial tissue, attaching the proximal and distal aorta grafts with individual sutures, and attaching the grafts around the holes for proximal anastomosis with prolene sutures in CABG patients. Moderately-dilated aortic roots (45 to 55 mm) may not remain intact during the wrapping procedure. Replacement of wrapping should be performed to prevent the development of aortic root aneurysms.^[4] We did not perform the wrapping procedure in patients with aortic root diameters of more than 45 mm.

Another problem associated with wrapping is the development of wall degeneration. Aortic wall erosion is a rare complication under wrapping and has been reported in a few cases.^[19] The reason for this complication is not well understood. Neri et al.^[20] described histopathological modifications of aortic tissue in the region covered by wrapping. The authors demonstrated that interruption of vasa vasorum might be associated with chronic foreign body reaction and aortic wall compression and tissue metabolism between opposing forces (external banding and aortic pressure). Also, similar to Bauer et al.,^[21] they found that the lesions of the aortic wall were in the posterior aspect of the ascending aorta, that is its concavity, where the wrinkles are likely to develop.

The wrapping technique has been reported with various modifications (with or without aortoplasty) and various types of grafts (Dacron, thin Dacron, polypropylene, polyester).^[15,22] Cohen et al.^[15] reported excellent long-term results of ascending aortic repairs using Dacron mesh over a 20-year period and with a 102-disease series. In this series, proximal aortic degeneration was detected in only two cases during long-term follow-ups. However, it has been reported in various studies that the use of polypropylene (Prolene; Ethicon) or polyester (Mersilene; Ethicon) mesh may be superior to Dacron grafts as they are both non-absorbable, they have a certain degree of elasticity which cannot be achieved with Dacron grafts, and they are in perfect conformity with the aortic wall.^[12-22]

External wrapping may cause the development of rarefaction in the wall of the aorta.^[20] However, there is still no evidence to support the clinical significance of this condition. Furthermore, studies have shown that this outer layer placed on the aorta does not increase stress on the aortic wall.^[16] It is suggested that the aorta may be less susceptible to dissection, even if it is thinner.

After reducing the aortic diameter, the pericardial space surrounding the remaining aorta is filled with pericardial fluid and hematoma. In some cases, this hematoma within the pericardium may resemble intramural hematoma. However, an intramural hematoma cannot be located outside the corset made of the vascular prosthesis. Therefore, this aortic complication may also be excluded, when the internal diameter of the periaortic hematoma is larger than the diameter of the vascular prosthesis used for wrapping.^[23] In our patients, this image was also detected at various diameters around the grafts.

Aortic wall plication is one of the complication which can be observed particularly when wrapping is performed on large aortas (>50 mm). However, there is no definite data to show that the plicated aortic wall following wrapping is more prone to degeneration and dissection.

In conclusion, our study results indicate that external wrapping of the ascending aorta has good short and long-term results. In the present study, none of the patients died or suffered from aortic complications during follow-up. Therefore, wrapping surgical operations in the moderately-dilated aneurysmal ascending aortas, which do not require replacement of the ascending aorta, may be performed in combination with coronary artery bypass grafting and/or valve surgery, and may ensure an adequate long period without the development of dilatation by limiting the degree of aortic dilatation. Nevertheless, there are some limitations to this surgical method, such as the fact that it should not be applied, when the aortic wall is degenerated (i.e., severe calcification, ulceration, dissection). This procedure is applicable only to selected patients with aortic dilatation without dissection and connective tissue diseases.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

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