Aort Kök Anevrizmalarında Yeni Sinüs Oluşturularak Kapak Koruma

VALVE SPARING SURGERY USING CREATION OF A NEOSINUS FOR AORTIC ROOT ANEURYSMS

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Özet

Amaç: Asandan aort anevrizmalarında uygulanacak aort kapak resüspansiyon tekniğinde sinus Valsalva'lar rezeke edilir. Bu ek girişim yaprakçık hareketlerini ve uzun dönem durabilitesini olumsuz etkileyebilir. Aort kapak yaprakçıklarının açılım ve kapanma karakteristikleri David ve neosinüs yaratılan modifikasyonlarında reimplantasyon sonrası karşılaştırdık.
Materyal ve Metod: Eylül 1995 – Mayıs 2002 tarihleri arasında 25 hastaya David tekniği (Grup A) ve 24 hastaya modifiye neosinüs tekniği (Grup B) ile aort kök rekonstrüksiyonu uygulandı. Her iki grupta aort kapak muhafaza edilerek aort kökünün sentetik greft ile replasmanı sonrası suspense edildi ve koroner ostiumlar reimplante edildi. Transtorasik ve transözefageal çalışmalar intraoperatif, taburcu edilmeden önce ve 1 yıl sonra yapılarak üç grup karşılaştırıldı. Üçüncü bir grup kontrol grubu olarak (Grup C) ele alındı ve aort girişimi yapılmayan 25 hasta bu gruba dahil edildi.
Bulgular: Peroperatif mortalite 2 hastada (miyokard enfarktüsü ve mezentur embolisi) görüldü. İki hastada strok gelişti. Yirmialtı hasta 12 ay takip edildi ve bunların 22 tanesi fonksiyonel kapasite I, iki tanesi II ve iki tanesi III. sınıfta idi. Üç hasta postoperatif dönemde kaybedildi. Altı hastada minimal, 4 hastada hafif ve bir hastada orta derecede aort yetmezliği saptandı. Tromboembolik olay görülmedi. Ortalama transvalvuler gradiyent 3.5 ± 2.2 mmHg idi. Kapak açılım velositesi Grup A'da 61.3 ± 20.1 cm/sn, Grup B'de 46.3 ± 8 cm/sn ve Grup C'de 29.2 ± 9.8 cm/sn idi (Grup A ile B arasındaki $p = 0.003$, Grup A ile C arasındaki $p < 0.001$, Grup B ile C arasındaki $p < 0.001$). Kapanma velositesi Grup A'da 57.5 ± 23 cm/sn, Grup B'de 43.8 ± 7 cm/sn ve Grup C'de 23.6 ± 7 cm/sn idi (Grup A ile B arasında $p = 0.012$, Grup A ile C arasındaki $p < 0.001$, Grup B ile C arasındaki $p < 0.001$). Grup A'daki 7 hastada nativ aort yaprakçıkları sistolde prostetik aort duvarına çarpıyordu.
Sonuç: Nativ aort kapağının prostetik greft içerisine reimplantasyonu, anormal açılım ve kapanma hızlarına neden olur. Konvansiyonel tekniğine nazaran sinus bombesi yaratılması daha fizyolojik kapak dinamiklerine neden olur. Orta dönem klinik gözlemler her iki tip yöntemde olumlu sonuçlar verse de, kapak durabilitesini devam ettirecek daha fizyolojik yaprakçık dinamiklerinin hangi teknikte olacağı konusunda uzun dönem takip sonuçlarına ihtiyaç vardır.

Anahtar kelimeler: Aort kök anevrizması, kapak koruma, aort kök rekonstrüksiyonu

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Summary

Background: Aortic valve resuspension for ascending aortic aneurysm repair is associated with removal of the sinus of Valsalva. This may cause changes in leaflet motion and thus impact on long term durability. We studied the opening and closing characteristics of the aortic valve leaflets after reimplantation by the technique described by T. David and a modification to create a "neosinus" compared to an age matched control group.
Methods: Between September 1995 and May 2002, 25 patients underwent aortic root reconstruction as described by Tirone David (Group A). In 24 patients the technique was modified by shaping a "neosinus" (Group B). In both groups the native valve was preserved and suspended inside a tubular prosthesis with reimplantation of the coronary arteries. Transthoracic and transesophageal studies on aortic valve dynamics were performed intraoperatively, before hospital discharge and one year after surgery in all patients and compared to a separate group of 25 matched control individuals (Group C).
Results: There was two perioperative deaths due to myocardial infarction and mesenterial emboli. Two patients suffered a stroke. Twentysix patients were followed up 12 months postoperatively. Twentytwo out of 26 patients were in NYHA functional class I, 2 patients in class II and the remaining 2 in class III. Three patients died in the postoperative period. Six patients had trivial AR, 4 had mild and 1 had moderate regurgitation. There were no thromboembolic events during follow up. The mean transvalvular gradient was 3.5 ± 2.2 mmHg. Valve opening velocity was 61.3 ± 20.1 cm/s in Group A, 46.3 ± 8 cm/s in Group B, and 29.2 ± 9.8 cm/s in Group C (Group A vs. B $p = 0.003$, A vs. Group C $p < 0.001$, B vs. C $p < 0.001$). Closing velocity was accelerated to 57.5 ± 23 cm/s in Group A and 43.8 ± 7 cm/s in Group B compared to 23.6 ± 7 cm/s in Group C (A vs B $p = 0.012$, A vs C $p < 0.001$, B vs C $p = 0.002$). In 7 patients of Group A the leaflets touched the prosthetic wall during systole.
Conclusions: Reimplantation of the natural aortic valve in a prosthetic graft causes abnormally high opening and closing speeds with possibly increased stress. We could prove more physiologic valve dynamics after creation of a sinus bulge compared to the conventional reimplantation technique. Midterm clinical observation however showed favourable valve competence for both types of repair. Long term follow up is necessary to prove whether more physiologic leaflet dynamics lead to improved durability.

Keywords: Aortic root aneurysm, valve sparing operation, aortic root reconstruction

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Introduction

Patients with ascending aortic aneurysms frequently develop aortic regurgitation secondary to dilatation of the sinotubular junction and to some degree due to annular dilatation [1-6]. Composite replacement of the aortic valve and the proximal aorta has become a standard procedure with an operative mortality rate of 5% or less in patients with aneurysm of the ascending aorta and secondary incompetent aortic valves [4-6]. This approach is associated with the drawbacks of prosthetic heart valves. Aneurysms of the sinotubular junction are frequently associated with severe aortic valve incompetence although the leaflet structure is preserved. In 1992, David [7] described a method of reconstruction of the aortic valve in these patients. The three sinuses of Valsalva and the ascending aorta were excised, and the aortic valve was resuspended inside a tubular Dacron graft. Sarsam and Yacoub [8] have suggested replacement of the ascending aorta and a remodeling of the sinuses of Valsalva with graft material. By effectively reshaping the aortic root with decreasing the diameter of the sinotubular junction and aortic annulus, coaptation of the aortic valve leaflets is restored. These aortic valve-sparing operations are alternative procedures to the composite replacement of the aorta in patients with aortic root aneurysm and macroscopically normal aortic valve cusps [9]. However, one of the major concerns to these operations is the altered closing dynamic and stress posed on the leaflets as well as possible leaflet abrasion. The new aortic root is noncompliant and lacks an anatomic sinus bulge. Surrounding graft material stops systolic expansion of the annulus that normally stretches leaflet edges and thus prevents them to touch the aortic wall [10,11]. Closing dynamics may be changed by the lack of blood vortices in the sinuses. Although leaflet abrasion is not yet reported clinically we observed leaflets touching the rogh graft material echocardiographically and thus modified the technique by creating a neo-sinus. This paper presents our clinical experience in patients operated on with the classic David technique and our modification. Echocardiographic findings were compared to the dynamics of an age matched control group.

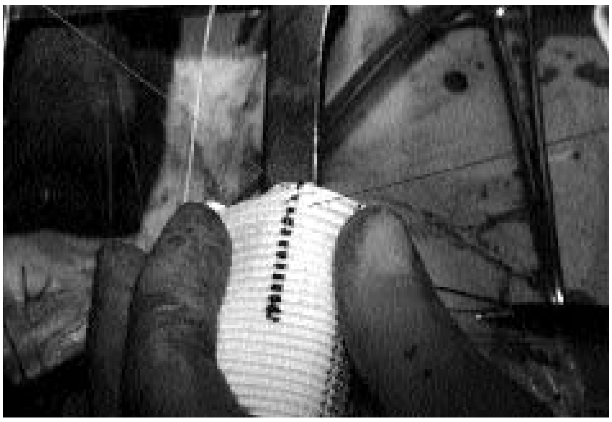
Material and Methods

From September 1995 to March 2002, 49 patients (32 male, 14 female) with aortic root aneurysm and aortic insufficiency underwent replacement of the ascending aorta and reconstruction of the aortic root with preservation of the native aortic valve (AV). The underlying diagnosis was chronic aneurysm in 39 and acute aortic dissection Stanford type A in 10 cases. The mean age of patients was 58.4 ± 14.2 years (range 10 to 78 years). All patients had a preoperative echocardiographic study, which graded the aortic regurgitation (AR) from 0 (none or trivial) to 4 (severe). The mean grade of AR was 3.2. In 4 patients the AR was additionally caused by a secondary leaflet prolaps. Three patients had Marfan`s syndrome. During the initial period, the David I technique (Group A; n = 25) was performed; subsequently, the modified “neosinus” technique (Group B; n = 24) was used. The inclusion criteria for both groups were identical and consisted of the absence of gross organic changes in the valve cusps, regardless of the size of the aneurysm, the duration of the aortic insufficiency, ventricular function, or age.

The control group (Group C) consisted of 25 matched patients (age, gender) with coronary artery disease in whom no abnormalities of the aortic valve, aortic root, or left ventricle were detected by medical history, standard clinical examination, and echocardiography. Table 1 summarizes the clinical profile of the patients. Echo data were gathered from preoperative transthoracic and intraoperative transesophageal examinations and mainly transthoracic discharge and one year follow up studies.

Echocardiography

Adequate function of the aortic valve was controlled intraoperatively with transesophageal echocardiography after discontinuation of cardiopulmonary bypass. All patients underwent a transthoracic echocardiographic study before discharge and at 12 months follow up with the patient in supine position (Vingmed System Five, GE Medical Systems, Wisconsin/USA). Examination included 2-dimensional, M-mode, continuous wave, pulsed doppler and color doppler analyses. All measurements were averaged from 3 cardiac cycles and performed by only 2 sonographers. The opening and closing times were measured in the following way: Leaflet movement of the aortic valve was evaluated by M-mode echocardiography. The obtained data were transferred to an external computer and digitally analyzed (Echo Pac Software, Vingmed System Five, GE Medical Systems, Wisconsin/USA).



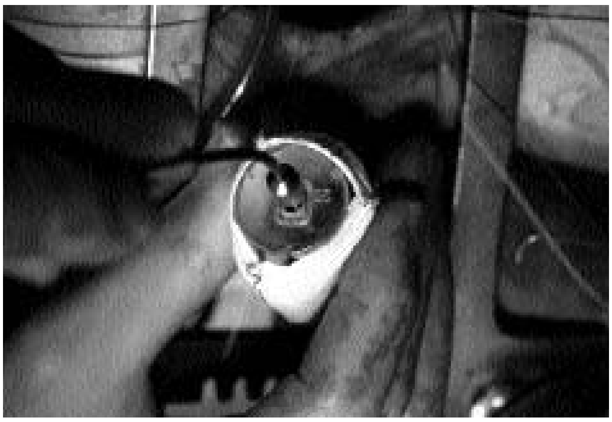


Figure 1 a-b. Creation of the “neosinus” by plicating the base of the graft with Z-sutures.

Clinical data were obtained yearly by questionnaire or telephone call. Patients were followed up one year after surgery in our outpatient department. Complications were evaluated according to the guidelines for reporting [12].

Operative technique

The chest was opened by median sternotomy in 46, by upper partial sternotomy in 1 case and for treatment of extensive aortic disease by bilateral transsternal thoracotomy in 2 cases. Cardiopulmonary bypass was established by cannulating the proximal aortic arch (n = 35) the right subclavian artery (n = 10) or the femoral artery (n = 4) for arterial return and the right atrium for venous drainage. Core temperature was lowered to 32°C or to 18°C for circulatory arrest in patients with associated arch disease or dissections respectively. Myocardial protection was achieved with cold blood cardioplegia. The decision to preserve the native AV was made intraoperatively after inspection of the valve leaflets. With increasing experience obvious prolapse of one or two leaflets did not exclude patients from the procedure. Table 2 shows the operative data.

The sinuses of Valsalva were excised, leaving approximately 4 to 5 mm of aortic wall adjacent to the insertion line of the leaflets. In acute dissection, the wall layers of the aortic root were reconstructed at this point with gelatine-resorcin-formol surgical glue (Colle chirurgicale, Cardial, St Etienne, France) or by sutures. In 6 patients cusp prolapse was reconstructed by triangular resection of the excess cusp tissue and continuous suture (5/0 Cardionyl™, Pèters Lab., Bobigny-Cedex, France). Graft sizing changed with experience and after personal communication with T. David. First we used the formula leaflet height times 1.5 plus 2 millimeters, changed then to the formula twice leaflet height. Finally in patients with a normal and nondilated annulus the graft was matched to the annular diameter adding the aortic wall thickness. In cases where the creation of a "neosinus" was planned additional 5 mm are added for excess diameter.

The graft was slightly beveled to account for the ventricular muscle extension into the commissure between the right and left coronary sinus [9]. Transmural mattress sutures were placed just below the leaflet insertion to the aortic wall. These sutures were then passed through the graft and tied. The valve was resuspended with pledgeted prolene sutures above the commissures and a running mattress suture along the aortic wall remnant.

Three neosinus were shaped by plicating the base of the graft with figure of 8 sutures taking bites 5 mm apart in hight and circumference (n = 24). This reduces the diameter of the base, provides a more physiologic triangular shape and creates a sinus bulge by hight reduction at the line of the commissures. (Figure 1a and b). This also places the aortic wall remnants of the sinuses more naturally in an outward direction at the base of the "neosinus" and accommodates for the compensatory elongation of the cusp edges observed after chronic aneurysmal dilatation.

The coronary ostia were reimplanted into the graft. If necessary, partial or total arch replacement was performed during hypothermic circulatory arrest, with retrograde cerebral perfusion or low flow antegrade cerebral perfusion. In these cases a second segment of vascular graft was used and later anastomosed to the root reconstruction graft.

Statistical Methods

Analysis of variance was used to compare continuous data among the 3 groups. Nonparametric data were compared by means of the chi-square test. A multiple-way analysis of variance for repeated measures was used to compare preoperative and postoperative ventricular diameter and volume. Post hoc comparisons were made with the Scheffè F test (ANOVA). Data are indicated as mean ± SD. All statistical analysis was performed with StatView (version 5.0) for Windows software (SAS Institute, Inc, Cary, NC).

Table 1. Patients demographics and perioperative data.

Preoperative patient demographics	
Age (years)	58 ± 21 (13-74)
Sex ratio (M:F)	7:25
Average body surface area (m^2)	1.73 ± 0.17
Aneurysm of the ascending aorta	38 (76%)
Leafletprolapse	6 (12%)
Marfan Syndrome	3 (6%)
Dissection of the ascending aorta	11 (22%)
Coronary artery disease	9 (18%)
Atrial Septal Defect	1 (2%)
NYHA preoperative	3.1 ± 0.5
Ejection fraction (%, [levocardiography])	53 ± 14 (35-72)
Aortic regurgitation (grade)	3.1 ± 0.4

NYHA = New York Heart Assosiation

Table 2. Perioperative data.

Perioperative data	
Operating time (min)	299 ± 72
Cardiopulmonary bypass time (min)	187 ± 48
Cross clamp time (min)	141 ± 21
Operative techniques	
Reconstruction of the leaflet prolapse	6 (12%)
Minimally invasive technique	1 (2%)
Partial aortic arch replacement	11 (22%)
Craction of the neosinus	24 (49%)
Concomitant procedures	10 (20%)
CABG	9 (18%)
Closure of atrial septal defect	1 (2%)
Complications	
Death	1 (2%)
Reexploration for bleeding	2 (4%)
Stroke	2 (4%)
Myocardial infarction and low output syndrome	2 (4%)
Sternal infection	1 (2%)
Mean respirator time (hours)	12.2 ± 6.3
Postoperative hospital stay (day)	14.7 ± 10.7

CABG = coronary artery bypass grafting

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Table 3. Echocardiographic data.

Echocardiographic data	Preoperative	Postoperative (n = 36)	12 months (n = 26)	5 years (n = 6)
Aortic valve area (planimetry, cm^2)	-	2.7 ± 0.4	2.55 ± 0.5	2.5 ± 0.4
Pmax (mmHg)	-	7.5 ± 4	9.8 ± 5.1	8.6 ± 4.3
Pmean (mmHg)	-	3.4 ± 2.1	3.5 ± 2.2	3.5 ± 2.4
Aortic regurgitation	3.1 ± 0.4	0.4 ± 0.5	0.2 ± 0.5	0.2 ± 0.6
LVESD (mm)	49.9 ± 8.4	47.9 ± 9.2	46.4 ± 7.4	45.3 ± 5.9
Ejection fraction (%)	58.6 ± 13.8	63.0 ± 10.3	64.1 ± 9.1	65.4 ± 6.8

LVESD = left ventricle end systolic diameter

Table 4. Analysis for leaflet opening and closure characteristics of the aortic valve in M-Mode technique.

				P		
	Group A (n = 25)	Group B (n = 24)	Group C (n = 25)	A vs C	B vs C	A vs B
VOT (msec)	22 ± 6	31 ± 4	46 ± 10	< 0.001	< 0.001	ns
VOV (cm/sec)	61.3 ± 20.1	46.3 ± 7	29.2 ± 9	< 0.001	< 0.001	ns
VCT (msec)	23 ± 10	32 ± 6	47 ± 4	< 0.001	< 0.001	ns
VCV (cm/sec)	57.5 ± 22.7	43.8 ± 7	23.6 ± 8	< 0.001	< 0.001	ns
Systolic contact	7	0	0	-	-	-

Group A = Tirone David technique; Group B = neosinus technique; Group C = healthy individuals in whom no abnormalities of the aortic valve were detected by clinical examination; VCT = valve closure time; VCV = valve closure volecity, and systolic contact of aortic cusp and prosthesis; VOT = valve opening time; VOV = valve opening volecity

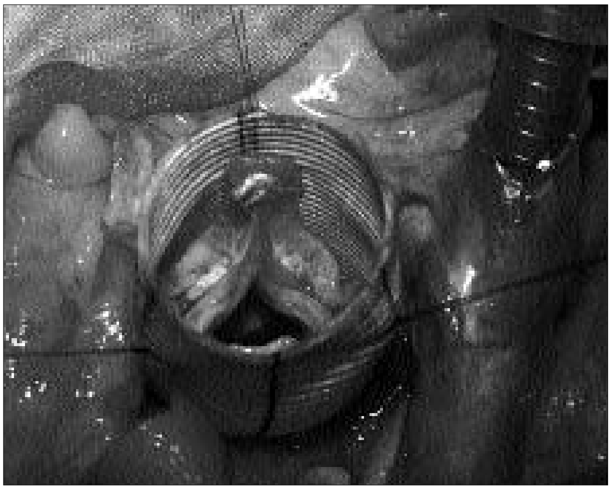

Figure 2. Resuspension of the aortic valve and reimplantation of the coronary arteries.

Results

There was two (4.1%) perioperative death due to myocardial infarction and mesenterial emboli. Postoperative complications were 4 (8.7%) reexplorations for bleeding, 1 additional myocardial infarction with low output syndrome, 2 (4.3%) strokes with permanent neurologic deficit and 1 sternal infection (Table 2).

Thirtyeight of operative survivors (n = 47) were followed from 4 to 18 months, with a mean of 11. Late mortality was 8.8%. There were 3 sudden deaths and 1 non-cardiovascular (bronchial cancer). During follow up no thrombembolic events or strokes were observed; one patient required early reoperation due to rupture of the right coronary leaflet and received a mechanical valve with further uneventful recovery. Another patient developed severe aortic insufficiency due to perforation of the left coronary leaflet 4 years after surgery, which could be reconstructed. One patient with Marfan`s syndrome developed mitral endocarditis 9 months postoperatively. One year after surgery 25 of followed patients are in NYHA functional class I, 2 patients in class II and the remaining 1 in class III.

Echocardiography

Postoperatively complete competence of the AV was observed in 36 patients. Six patients had trivial AR, 4 had mild and 1 had moderate regurgitation. The mean transvalvular gradient was 3.4 ± 2.1 mmHg. Tweentyeight patients underwent transthoracic echocardiography at 1 year follow up. There was a significant reduction in left ventricular end systolic diameter (LVESD) during the postoperative follow up in both groups (postoperative vs one year follow up LVESD $p < 0.001$) Systolig gradients were negligible and valve competence was stable during the follow up (Table 3).

Classic reimplantation (Group A) led to an increased opening velocity of 61.3 ± 20 cm/sec compared to normal controls 29.2 ± 9.8 cm/sec (Group A vs Group C, $p < 0.001$). After creation of a neosinus (Group B) opening speed was more physiologic with 46.3 ± 8 cm/sec (Table 4). In Group A aortic valves also closed at a higher velocity (57.5 ± 22.7 cm/sec) than in the control group (23.6 ± 6.8 cm/sec) and showed shorter opening Group A: 22 ± 6 msec vs Group C: 46 ± 10 msec ($p < 0.001$) and closing times (Group A: 23 ± 10 msec vs Group C: 47 ± 14 sec, $p < 0.001$). The minimum distance between cusps and the prosthetic wall Table 4 was largest (11.6 mm) in Group C and least in Group A (3.7 mm). Neosinus creation shifted leaflet motion towards more physiologic values (Table 4). In 7 patients of Group A the cusps of the resuspended valve touched the graft during systolic opening, this was not observed in any Group B patient. The fraction of total closing displacement observed during the slow closing movement (Table 3) was less in group A (only 7.3%from maximal opening) than in Group B (12.6%) and C (21.1%).

Diameters of the sinus valsalva region were significantly different with 27.5 ± 2.3 mm in Group A, 29.5 ± 1.3 mm in Group B, and 31.7 ± 4.1 mm in Group C (A vs B $p = 0.05$, B vs C $p = 0.02$, Figure 2).

Discussion

A normal valve motion during the cardiac cycle is regulated by the anatomic configuration, the cyclic modifications of the aortic root and the dependant fluid dynamics . The valve starts to open even before forward blood flow is ejected due to a slight increase of the aortic diameter at the level of the commissures [12]. As soon as forward flow opens the leaflets further and reaches the sinus ridge, it curls down into the sinuses of Valsalva, acting as a cushion for the leaflets and preventing them from contact with the aortic wall [10]. Caused of the eddy currents within the sinuses, the cusps start to close slowly before forward flow has ended. When blood flow reverses in diastole, remaining cusp excursion is small and valve closure will be smooth with minimal stress and closing volume. Furthermore, cyclic expansion of the sinuses contributes to a reduction of the systolic and diastolic stress on the valve leaflets. Angulation at the hinge points is limited by the stretch and triangular shape change of the aortic annulus [18-21].

The aortic valve cusps are often normal for age, and reduction of the sinotubular junction with an appropriate tubular Dacron graft is all that is needed to restore valve competence. David and Feindel [7] have pointed out that, in extensive root dilatation, not only the sinuses of Valsalva are dilated but also the fibrous portions of the root inferior to the valve insertion line (ie, fibrous trigone and membranous septum). To correct the root also at this level, they have proposed mobilisation of the root, anchoring a Dacron graft to the aortoventricular junction, and reimplantation of the aortic valve within the vascular graft [7,9,14]. In the remodeling type of valve sparing procedure described by Yacoub [8,13,17], a standard Dacron tube is trimmed into the mirror image of the crown shape of the aortic annulus and replaces the diseased sinus wall. This recreates a space behind the leaflets, but sinuses and sinotubular ridge cannot expand circumferentially in a physiologic manner.

These current techniques of valve sparing aortic root reconstruction lead to a change in aortic root anatomy and dynamic function. In the David procedure, a Dacron tube graft is placed over the entire aortic root structure. This technique maintains valve competence by downsizing the sinotubular junction and sinuses, allowing the aortic cusps to centrally coapt. Disadvantage of this technique is that the cusps may touch and abrade against the dacron tube graft when the valve opens. In addition, there are no sinuses of Valsalva and no systolic elastic expansion of the aortic root, a fact that results in significantly abnormal stress exerted on the cusps during opening and closing [23]. The Yacoub technique uses a graft to replace the aneurysmatic sinuses but does not stabilize the annulus. Exact geometric matching is not easy and the long suture lines to deseased aortic wall remnants make hemostasis definitely more problematic than in the safe reimplantation technique. Remodeling results theoretically in a more normal cusp motion and avoids contact of the cusps with the Dacron graft. However, elasticity is not physiologic and sinus sizes are not anatomic , which may result again in significant cusp stress during opening and closing [22,23]. As the annulus is not supported in this technique, there is a possibility of late annular dilatation and consecutive progressive aortic insufficiency [17].

Cochran and associates [24] proposed a modification of tube graft reimplantation to produce pseudosinuses. In their technique, the slightly scalloped tube graft was sewn in a subannular position. It does not create a tear shaped, natural sinus but keeps the Dacron away from the leaflets. This technique has been shown experimentally to result in significantly less stress and strain on the cusps compared with the Yacoub or David approaches [24].

Van Son et al. described another technical modification, in which aortic root is reconstructed with preservation of the native AV and sinuses [11]. Follow up is necessary to evaluate long term results. Grande-Allen and colleagues demonstrated by finite element modeling, that the valve sparing with sinus space formation resulted in close to normal cusp stress load [23]. Others developed a specially shaped dacron graft to reestablish a sinus bulge and report near normal cusp dynamics after repair [25].

Our study defines the dynamics of valve opening and closing after valve sparing operations in the technique described as T. David I and a modified “neosinus” technique, compared with a matched cohort of patients. The “neosinus” technique has been primarily developed to avoid cusp abrasion and to accommodate for the cusp edge elongation in chronic aneurysms as the conventional technique may overcorrect the valve. The modified method recreates more closely the anatomic and physiologic conditions of the natural aortic root and aortic valve .

After the reimplantation procedure valve cusp movement is unphysiologically accelerated increasing stress at least at rapid valve closure. On the other hand by the modified neosinus technique some of the physiologic features of the aortic root and leaflets were better preserved. First, sinuses were bigger and more round shaped. This was confirmed mainly by the larger area beyond the leaflet for Group B. Second, as a consequence of a better shape and function of the sinuses, slow closing displacement of the cusps was significantly more evident and motion more similar to normal as in Group A patients. The modified neosinus technique resulted in a better valve opening area and slightly lower gradients. By obtaining a more physiologic valve motion, the stress on the leaflets is decreased. Furthermore, in seven classic Tirone David patients the cusps touched during valve opening, a phenomenon, that was not observed in any of the neosinus cases. Prevention of the contact of the aortic valve leaflets with the rough surface of the Dacron graft may result in cusp abrasion. These findings may have implications on the durability of the repair. Our findings on cusp dynamics are in consistence with the observations of Leyh and colleagues [22] who reported a more physiologic valve motion for the remodelling than for the reimplantation type of repair. Stress reduction by sinus formation was also calculated in finite element analyses [23].

Clinically patients are well after both reimplantation types of repair. Ventricular function improved, exercise tolerance was good in most cases and there was only one valve related late event caused by a secondary valve incompetence after repair for acute type A dissection. No patients suffered a thromboembolic event or an anticoagulation related hemorrhage.

It is still too early to determine the long term fate of the native AV after modified neosinus technique comparing classic David operation, but we anticipate good long term function at least in those instances in which perfect valve geometry was achieved and either trivial or no aortic incompetence is seen within the first 2 years. Midterm results for the classic technique show a very moderate rate of late failure indicating that stresses are still within the strength of leaflet tissue [26].

In conclusion, preservation of the aortic valve in cases of ascending aortic aneurysms and valve incompetence is an excellent alternative to root replacement with valved conduits. Valve function is near normal and valve related complication rate is low. However cusp motion is significantly accelerated compared to normal but can be rendered more physiologic by the creation of e new "pseudosinus" bulge in the graft wall. Better anatomic fit and stress reduction by this technical modification may further improve the good midterm results of aortic valve repair by reimplantation.

References

1. Halloran BG, Davis VA, McManus BM, Lynch TG, Baxter BT. Localization of aortic disease is associated with intrinsic differences in aortic structure. J Surg Res 1995;59:17-22.
2. Roman MJ, Rosen SE, Kramer-Fox R, Devereux RB. Prognostic significance of the pattern of aortic root dilatation in the Marfan syndrome. J Am Coll Cardiol 1993;22:1470-6.
3. Becker AE. Surgical and pathological anatomy of the aortic valve and root. Operative Techniques Card Thorac Surg 1996;1:3-14.
4. Bentall H, DeBono A. A technique for complete replacement of the ascending aorta. Thorax 1968;23:338-9.
5. Borst HG, Laas J. Surgical treatment of thoracic aortic aneurysms. Adv Cardiac Surg 1993;4:47-87.
6. Bachet J, Termingnon JL, Goutot B, et al. Aortic root replacement with a composite graft: Factors influencing immediate and long-term results. Eur J Cardiothorac Surg 1996;10:207-13.
7. David TE, Feindel CM. An aortic valve-sparing operation for patients with aortic incompetence and aneurysm of the ascending aorta. J Thorac Cardiovasc Surg 1992;103:617-22.
8. Sarsam MA, Yacoub M. Remodeling of the aortic valve annulus. J Thorac Cardiovasc Surg 1993;105:435-8.
9. David TE. Remodeling the aortic root and preservation of the native aortic valve. Op Tech Cardiac Thorac Surg 1996;1:44-56.
10. Van Son JAM, Battellini R, Mierzwa M, Walther T, Autschbach R, Mohr FW. Aortic root reconstruction with preservation of native aortic valve and sinuses in aortic root dilatation with aortic regurgitation. J Thorac Cardiovasc Surg 1999;117:1151-6.
11. Perry GJ, Helmcke F, Nanda NC, Byard C, Soto BL. Evaluation of aortic insufficiency by Doppler color flow mapping. J Am Coll Cardiol 1987;9:4:952-9.
12. Roman MJ, Devereux RB, Kramer-Fox R, O'Loughlin J. Two dimensional echocardiographic aortic root dimensions in normal children and adults. Am J Cardiol 1989;64:507-12.
13. Reid K. The anatomy of the sinus of Valsalva. Thorax 1970;25:79-85.
14. Brewer RJ, Deck JD, Capat ID, Nolan SP. The dynamic aortic root: It's role in aortic valve function. J Thorac Cardiovasc Surg 1976;72:413-7.
15. Thubrikar MJ, Bosher LP, Nolan SP. The mechanism of opening of the aortic valve. J Thorac Cardiovasc Surg 1979;77:863-70.
16. Thubrikar MJ, Heckman JL, Nolan SP. High speed cine-radiographic study of aortic valve leaflet motion. J Heart Valve Dis 1993;26:653-61.
17. Bellhouse BJ, Bellhouse FH. Mechanism of closure of the aortic valve. Nature 1968;217:86-7.
18. Thubrikar MJ, Nolan SP, Aoud J, Deck JD. Stress sharing between the sinus and leaflets of canine aortic valves. Ann Thorac Surg 1986;42:434-40.
19. Schäfers HJ, Borst HG. Valve-sparing operation in aortic root ectasis. Operative Techniques Card Thorac Surg 1996;1:38-43.
20. Schäfers HJ, Fries R, Langer F, Nikoloudakis N, Graeter T, Grundmann U. Valve-preserving replacement of the ascending aorta: Remodeling versus reimplantation. J Thorac Cardiovasc Surg 1998;116:990-6.
21. Yacoub MH, Gehle P, Chandrasekaran V, Birks EJ, Child A, Radley-Smith R. Late results of a valve preserving operation in patients with aneurysms of the ascending aorta and root. J Thorac Cardiovasc Surg 1998;115:1080-90.
22. Grande-Allen KJ, Cochran RP, Reinhall PG, Kunzelman KS. Re-creation of sinuses is important for sparing the aortic valve: A finite element study. J Thorac Cardiovasc Surg 2000;119:753-63.
23. Leyh RG, Schmidtke C, Sievers HH, Yacoub MH. Opening and closing characteristics of the aortic valve after different types of valve-preserving surgery. Circulation 1999;100:2153-60.
24. Cochran RP, Kunzelman KS, Eddy AC, Hofer BO, Verrier ED. Modified conduit preparation creates a pseudosinus in an aortic valve–sparing procedure for aneurysm of the descending aorta. J Thorac Cardiovasc Surg 1995;109:1049-58.
25. De Paulis R, De Matteis GM, Nardi P, et al. One-year appraisal of a new aortic root conduit with sinuses of Valsalva. J Thorac Cardiovasc Surg 2002;123:33-9.
26. David T. Aortic valve sparing operations. Ann Thorac Surg 2002;73:1029-30.