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Pericardial neosinus creation for surgical treatment of right ventricular outflow tract: mid-term results

Sağ ventrikül çıkım yolunun cerrahi tedavisinde perikardiyal neosinüs oluşturulması: Orta dönem sonuçlarımız

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Background: This study aims to present the mid-term results of the right ventricular outflow tract reconstruction with creation of pulmonary neosinus using pericardial patching.

Methods: Thirty three patients who underwent neosinus creation with pericardial patching due to the right ventricular outflow tract stenosis in our clinic between January 2000 and December 2012 were retrospectively analyzed. The mean follow-up was 4.7 years (range, 1 to 10 years) postoperatively for 28 patients as assessed by echocardiographic findings.

Results: The mean duration of cardiopulmonary bypass and cross-clamp were 112.8±23 and 66.9±9.4 min, respectively. Postoperatively three patients required inotropic support in the intensive care unit. One patient who was operated for Fallot's tetralogy died due to pneumonia and sepsis following reintubation on postoperative day three. The remaining patients were discharged after an average duration of 8.1±1 days. No patients required reoperation during the follow-up. Twenty-five patients were in New York Heart Association (NYHA) Functional Classification class 1, while three were in NHYA class 2. Echocardiographic examination showed grade 2 pulmonary insufficiency in one patient and grade 1 in six patients with a mean gradient of 21±3 mmHg.

Conclusion: Our study findings suggest that creation of pulmonary neosinus with pericardial patching is a safe surgical technique with a lower perioperative mortality rate. The mid-term results of this technique are encouraging, which can be considered as an alternative treatment modality for the right ventricular outflow tract reconstruction.

Key words: Neosinus; pericardial patching; right ventricular outflow tract stenosis.

Amaç: Bu makalede sağ ventrikül çıkım yolu rekonstrüksiyonunda perikardiyal yama ile pulmoner neosinüs oluşturulmasına ilişkin orta dönem sonuçlar bildirildi.

Çalışma planı: Ocak 2000 - Aralık 2012 tarihleri arasında kliniğimizde sağ ventrikül çıkım yolu darlığı nedeni ile perikardiyal yama ile neosinüs oluşturulan 33 hasta retrospektif olarak incelendi. Cerrahi sonrasında ekokardiyografik bulgulara göre değerlendirilen 28 hastanın ortalama takip süresi 4.7 yıl (dağılım 1-10 yıl) idi.

Bulgular: Ortalama kadiyopulmoner baypas ve kros klemp süresi sırasıyla 112.8±23 ve 66.9±9.4 dk idi. Ameliyat sonrası dönemde yoğun bakım ünitesinde üç hastada inotropik destek gereksinimi oldu. Fallot tetrolojisi nedeni ile ameliyat edilen bir hasta ameliyat sonrası üçüncü günde pnömoni ve sepsis nedeni ile reentübasyonu takiben kaybedildi. Diğer hastalar ortalama 8.1±1 günde taburcu edildi. Takip sürecinde hiçbir hastada tekrar ameliyat gereksinimi olmadı. Fonksiyonel kapasiteleri New York Heart Association (NYHA) sınıflandırmasına göre 25 hastada sınıf 1 iken, üç hastada NHYA sınıf 2 idi. Ekokardiyografik incelemede bir hastada ikinci derecede, altı hastada birinci derecede pulmoner yetmezlik mevcut olup ortalama gradiyent 21±3 mmHg idi.

Sonuç: Çalışma bulgularımız, perikardiyal yama ile neosinüs oluşturulmasının düşük ameliyat sırası mortalite oranları ile güvenilir bir yöntem olduğunu göstermektedir. Bu tekniğin orta dönem sonuçları cesaretlendirici olup, sağ ventrikül çıkım yolu rekonstrüksiyonunda alternatif bir tedavi yöntemi olarak düşünülebilir.

Anahtar sözcükler: Neosinüs; perikardiyal yama; sağ ventrikül çıkım yolu darlığı.

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Residual pulmonary insufficiency following the surgical treatment of right ventricle outflow tract (RVOT) stenosis can result in the dilatation and dysfunction of the right ventricle. Reported techniques for the surgical treatment of this condition include valve replacement, valve conduit replacement, monoleaflet creation using the pericardium, xenografts, fascia lata, an autologous pulmonary artery wall, polytetrafluoroethylene (PTFE) grafts, and widening of the pulmonary artery and valve with pericardial patching.[1-7] In this study, our mid-term results regarding the creation of a pulmonary neosinus via the widening of the pulmonary valve using transannular pericardial patching are reported.

PATIENTS AND METHODS

A total of 33 male patients (mean age 20.85 years) who underwent the creation of a neosinus with pericardial patching due to RVOT stenosis between January 2000 and December 2012 were retrospectively evaluated. In 14 of the patients, RVOT stenosis was present as a component of tetralogy of Fallot (TOF), and six also had an atrial septal defect (Table 1). Pulmonary valve coaptation, the gradient at the level of the pulmonary valve, and pulmonary insufficiency were assessed echocardiographically during follow-up visits.

Surgical technique

Following general anesthesia and a midsternal incision, cardiopulmonary bypass (CPB) was commenced with aortic and double venous cannulation. Cardiac arrest was achieved with standard cardioplegia. After the placement of the aortic cross-clamp, the repair procedure was performed primarily through a right atriotomy for those patients with accompanying defects (atrial or ventricular septal defect). Then, the pulmonary artery was severed vertically 2 cm distal to the annulus, and the commissure and leaflets (particularly the anterior leaflet) of the pulmonary valve were evaluated with regard to their feasibility for reconstruction. A total of 45 patients were considered for this procedure, and it was performed on 33 via a small pulmonary annulus and commissural fusion. In addition, patients with pulmonary hypoplasia who needed a transannular patch underwent a pulmonary neosinus operation. In this procedure, the incision was extended to the anterior pulmonary sinus and RVOT. The anterior leaflet was then divided into two parts using an incision extending from the middle portion of the anterior leaflet to the free margin without damaging the commissure. However, a commissurotomy was performed where there was commissural fusion. Next, the hypertrophic fibrous bands and infundibular muscles of the RVOT were resected, and a pericardial patch was prepared with a Z value between 0 and 2. This was then sutured to the right and left side of the anterior leaflet using 4/0 polypropylene sutures, and valve reconstruction was accomplished to obtain pulmonary valve coaptation using the pericardial patch at the free margin of the anterior leaflet together with the two remaining rudimentary leaflets. The free margin of the pericardial patch was supported with 6/0 PTFE sutures in order to reduce the risk of early postoperative prolapsus. Following this, the remaining part of the patch attached to the anterior leaflet was closed via a pulmonary arteriotomy to widen the pulmonary artery. The RVOT stenosis was then repaired and widened using a second pericardial patch.[8,9] After the termination of CPB and assessment of the valve coaptation with control transesophageal echocardiography (TEE), the surgery was completed.

RESULTS

The CPB and cross-clamp times averaged 112.8±23 and 66.9±9.4 minutes, respectively, and all of the patients were extubated without complications. During the postoperative period, revision surgery was performed due to bleeding in one patient, and three patients required inotropic support for an average duration of five days. In addition, one patient who underwent reconstruction of the RVOT due to TOF

Table 1. Clinical profile of the patients

Variables	Preoperative (n=33)	Postoperative (n=28)
NYHA class		
Class 1	–	25
Class 2	9	3
Class 3	15	–
Class 4	9	–
Associated abnormalities	20	–
Atrial septal defect	6	–
Tetralogy of Fallot	14	–

NYHA: New York Heart Assosiation.

Table 2. Operative data (n=33)

Variables	n	%	Mean±SD
ACC time (minutes)			66.9±9.4
CPB time (minutes)			112.8±23
Re-exploration	1	5.6	
Early mortality	1	5.6	
Late mortality	0		
Hospital stay (days)			8.1±1

SD: Standard deviation; ACC: Aortic cross-clamp; CPB: Cardiopulmonary bypass.

Table 3. Echocardiographic findings of patients

Variables	Preoperative (n=33)		Postoperative (n=28)	
	n	Mean±SD	n	Mean±SD
Ejection fraction (%)		64±4		65±3
Pulmonary gradient (mmHg)		61±6		21±3
Pulmonary insufficiency				
None/trivial	16		21	
1+	12		6	
2+	5		1	
3+	–		–	
4+	–		–	

SD: Standard deviation.

died on postoperative day three due to sepsis caused by progressive pneumonia. The average time to discharge was 8.1±1 days for the remaining patients (Table 2). Following their discharge, the patients were followed up by telephone to check for symptoms, and the echocardiographic findings were evaluated in all of the patients except for the aforementioned four subjects. The average follow-up duration was 4.7 years (range 1-10 years), and none of the patients required a reoperation during the postoperative period. In terms of functional capacity, 25 patients were New York Heart Association (NYHA) functional class class 1, and three were NYHA class 2. Furthermore, 21 patients had no echocardiographic findings of pulmonary insufficiency, but one had grade 2 and six had grade 1 pulmonary insufficiency. The mean gradient at the pulmonary walve was 21±3 mmHg (Table 3).

DISCUSSION

Valvectomies and transannular patch repair for RVOT stenosis are associated with severe pulmonary valve insufficiency and right ventricular dilatation resulting in right ventricular insufficiency with diminished myocardial contractility and exercise intolerance. Although acute improvement in pulmonary oligemia and its proportional enlargement is an advantage of the transannular patch, the development of pulmonary insufficiency over the long term has led to its limited usage.[4] Several techniques have been used to decrease the risk of postoperative pulmonary insufficiency including valve replacement, valve conduit replacement, monoleaflet creation from the pericardium, xenografting, fascia lata, an autologous pulmonary artery wall, and the use of PTFE grafts.[1-7] Although valvular dysfunction after a period of three years has been reported for the PTFE monoleaflet valve technique, the pulmonary failure rates associated with it are lower than with transannular patches.[8,9]

Clinically significant pulmonary insufficiency has been reported to occur in 84% of the patients with RVOT stenosis who underwent the application of a transannular patch, whereas only 17% suffered from this complication when pulmonary valve augmentation with a pericardial patch was performed.[12] For patients whose RVOT stenosis is amenable to patch techniques (transannular or non-transannular), the durability is higher than with homografts. In addition, valve insufficiency or stenosis can develop in the early stages of homograft replacement.[6] Furthermore, Kaza et al.[1] found that the proportion of patients who did not require a reoperation was 88.9% in the non-transannular group compared with 63% in the transannular group.[1]

Although biological monoleaflets are able to prevent pulmonary insufficiency in the short term, they become non-functional in less than a year. This has led to the development of alternative techniques such as a pericardial patch, PTFE grafting with a thickness of 0.1 mm, allograft pulmonary valve tissue, and the creation of a monocusp in the RVOT.[4]

Porcine heterografts become calcified within three to five years while Dacron grafts show pseudointimal thickening, particularly when the diameter is small. In contrast, aortic and pulmonary allografts are associated with excellent short-term results for the reconstruction of RVOT stenoses, and pulmonary allografts are also more stable due to the preservation of pulmonary valve structure.[4] Porcine-valved Dacron conduit were used in the past for RVOT reconstruction, but allografts preserved with cryopreservation were introduced after the mid-1980's after advances in cryopreservation techniques.[4]

We found no significant differences in the survival rates between pulmonary or aortic allografts at 25 years.

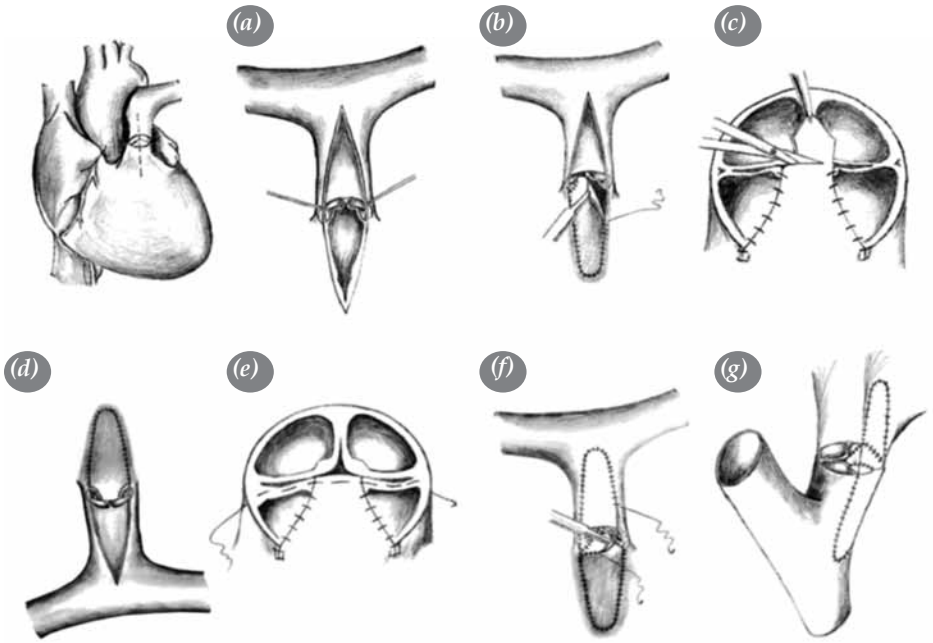

Figure 1. The line of the incision for the patch enlargement of the pulmonary annulus and pulmonary valve is shown with the transannular incision being made along the midcusp line of the anterior cusp. **(a)** The pulmonary arteriotomy was then extended through the pulmonary valve annulus and into the anterior cusp up to its free margin, and the anterior cusp was divided into two equal parts. **(b)** Both sides of the ventricular patch were sutured in place after reaching the pulmonary valve annulus, and then the suturing of the patch with the same diameter was continued through the right and left sides of the anterior leaflet. **(c, d)** The patch was sewn into place after reaching the free margin of the anterior cusp, and the remaining part beyond the free margin of the reconstructed neocusp was trimmed into a crescent shape, providing coaptation with the other cusps. **(e)** The polytetrafluoroethylene suture was sewn in a way so that it could pass in and out of the free margin of the reconstructed cusp. **(f)** The pulmonary arteriotomy was closed with a separated pericardial patch. The suture line was started distally, and it continued toward the level of the pulmonary annulus. **(g)** By suturing the pulmonary patch below the hinged area of the reconstructed anterior cusp, bulging of the patch was allowed which served as a neosinus.

According to Homann et al.[3] 30% of the allograft and 70% of the xenograft patients required a reoperation within 10 years. Furthermore, in the first five to six years after the procedure, no differences in durability were observed between the two groups. Since a reoperation is required due to growth, xenografts are preferred for newborns.[3] On the other hand, the limited availability of allografts is still a major issue. Trileaflet Contegra conduits with a natural sinus structure produced from heterologous bovine jugulary veins (Medtronic Inc., Minneapolis, MN, USA) have been reported to yield similar results at seven years;[10] therefore, this valve might be preferable, especially for infants and neonates, because of the lower regurgitation rates and freedom from significant gradients.[10]

When valvular homografts and xenografts are used, the conduit structure is usually disturbed in the majority of the cases due to the growth potential of the patient. Furthermore, augmentation of the pulmonary valve with autologous pericardial tissue for the treatment of pulmonary stenosis is associated with a reduced risk of pulmonary valve insufficiency postoperatively. This technique allows for the preservation of the natural function of the leaflets as well as the retension of the growth potential due to the use of native pericardial tissue.[11] Another option involves the use of the autologous pericardium for valvular reconstruction. This provides adequate tissue thickness and resistance, and the tissue compatibility is higher than with a bovine pericardium and synthetic patches.

The primary objective of the surgical treatment of RVOT stenosis is to create a functional pulmonary valve. A technique reported by Yılmaz et al.[8] in which the commissural structures are preserved and extended

into the anterior leaflet for this purpose has been associated with good valvular motility, coaptation, and positive results in the short term. In this technique in which the pulmonary annulus and leaflet are extended simultaneously using a pericardial patch, the native commissural structures are preserved and RVOT reconstruction is accomplished using autologous pericardial tissue. Moreover, the preservation of the commissural structures is also associated with the preservation of the physiological movement of the leaflets that have been reconstructed. Additionally, the infundibular functions are preserved due to less extensive surgical muscular resection and a smaller incision. The reconstructed leaflets then become a part of the right ventricle wall and move optimally during systole and diastole without causing obstruction.[8]

Creating a monoleaflet using a PTFE patch has been associated with normal valvular functions for the initial two to three years postoperatively without recurrent valvular gradient formation. However, in these patients, regurgitation developed in conjunction with RVOT stenosis.[4] The surgical technique that we used involved the expansion of the pericardial patch together with an increase in the size of the annulus, thus aiding the coaptation process. Thus far, no cases of significant pulmonary failure have been observed postoperatively. All of our study participants were adult patients with limited growth potential. Hence, the real value of our approach is more likely to be evident in a pediatric population. Although positive short-term results have been reported by Liu et al.[11] who used this same procedure on children, the long-term results need to be evaluated to judge what role that this procedure will have with this age group.

The monocusp technique has been associated with positive results for the first one to three years after the surgery, and the beneficial effects may even last up to 10 years in some cases. Although no RVOT gradient has been reported in these patients, pulmonary insufficiency upon the development of RVOT stenosis may occur. When a reoperation is required due to allograft dysfunction in the pulmonary valve, the PTFE monocusp technique may be preferred because it achieved better results compared with patients without a valve, and it does not result in recurrent obstruction.[4]

There is no difference between allografts and xenografts in terms of graft patency in the first postoperative five to six years; however, after 10 years, xenografts show signs of degeneration due to calcification and sclerosis[3] An early sign of a dysfunctional graft is tricuspid insufficiency.[3]

In addition to the patch used in the expansion of the pulmonary valve, the patch employed during the closure of the ventriculotomy can also affect long-term patency.[6] In our technique, the pericardial patch used for the pulmonary valve reconstruction has the same width as the pericardial patch used for the repair of the pulmonary annulus. Furthermore, the reconstructed leaflet is in the form of a native valve, with the level of the reconstructed valve being the same as that of the posterior leaflet or annulus. Expanding the pulmonary artery from the pulmonary annular level with a quadrangular pericardial patch helps achieve valve coaptation by creating a spacious neosinus,[8] and creating a new valsalva sinus via a second pericardial patch prevents regurgitation by helping ensure that coaptation occurs.

The main limitations of this study were the short follow-up duration, the small sample size, and a patient group comprised solely of young adults.

Conclusion

Excellent valve coaptation can been achieved with RVOT reconstruction in conjunction with the simultaneous expansion of the pulmonary leaflet and annulus using pericardial patching. In addition, we observed no cases of thrombosis or thromboembolic events during the postoperative follow-up period. The major difference between our technique and other monoleaflet techniques is that we are able to preserve the commissure, which we believe provides support for leaflet motility. Therefore, we posit that this technique is safe and can be used to achieve low perioperative mortality along with positive mid-term results.

Declaration of conflicting interests

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