Original Article / Özgün Makale

Early surgical outcome of pulmonary valve replacement in patients with previous right ventricle outflow tract reconstruction

Sağ ventrikül çıkım yolu rekonstrüksiyonu yapılmış olan hastalarda erken dönem pulmoner kapak replasmanı cerrahi sonuçları

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ABSTRACT

Background: In this study, we present our early surgical outcomes of pulmonary valve replacement in patients who underwent right ventricle outflow tract reconstruction.

Methods: Seventy-six patients (34 males, 42 females; mean age 11.4±5.8 years; range 7 to 18 years) underwent pulmonary valve replacement for pulmonary insufficiency following right ventricle outflow tract reconstruction between January 2009 and September 2016. Surgical indications were symptoms including exercise intolerance or arrhythmias which are attributed to the right ventricular volume overload or dysfunction with or without branch pulmonary artery stenosis in 54 symptomatic patients with chronic pulmonary insufficiency. Surgical indication was made according to magnetic resonance imaging in 22 asymptomatic patients.

Results: The mean follow-up was 60±19 (range 17 to 108) months. There was no early and late mortality. The mean right ventricular ejection fraction value in symptomatic patients increased in the postoperative period, although it did not reach statistical significance. There was a decline in the right ventricular area index, right ventricular volume index, and tricuspid annulus measurements, compared to preoperative values. Compared to the symptomatic patients, the increase in the right ventricular ejection fraction and the decline in the right ventricular area index, right ventricular volume index, and tricuspid annulus was less prominent in asymptomatic patients, indicating no statistically significant difference.

Conclusion: Pulmonary valve replacement can be performed with low morbidity and mortality rates. To relief the right ventricle function, the operation should be performed before the irreversible changes in the right ventricular volumes and functions occur.

Keywords: Congenital heart disease; pulmonary valve insufficiency; pulmonary valve replacement

ÖZ

Amaç: Bu çalışmada sağ ventrikül çıkım yolu rekonstrüksiyonu yapılan hastalarda erken dönem pulmoner kapak replasmanı cerrahi sonuçlarımız sunuldu.

Çalışma planı: Ocak 2009 - Eylül 2016 tarihleri arasında sağ ventrikül çıkım yolu rekonstrüksiyonu sonrasında pulmoner yetmezlik nedeniyle 76 hastaya (34 erkek, 42 kadın; ort. yaş 11.4±5.8 yıl; dağılım 7-18 yıl) pulmoner kapak replasmanı yapıldı. Kronik pulmoner yetmezlikli 54 semptomatik hastada cerrahi endikasyon semptomların sağ ventrikül volüm yüklenmesi ile ilişkili egzersiz intoleransı veya aritmi veya pulmoner arter dallarında darlık ile birlikte veya tek başına fonksiyon bozukluğu gibi semptomlar idi. Asemptomatik 22 hastada cerrahi endikasyon, manyetik rezonans görüntülemeye göre belirlendi.

Bulgular: Ortalama takip süresi 60±19 (dağılım 17-108) ay idi. Erken ve geç dönem mortalite gözlenmedi. Ameliyat sonrası dönemde semptomatik hastalarda ortalama sağ ventrikül ejeksiyon fraksiyonu değerinde artış gözlendi; ancak bu istatistiksel olarak anlamlı değildi. Sağ ventrikül alan indeksi, sağ ventrikül hacim indeksi ve triküspid annulus ölçümlerinde ameliyat öncesi değerlere kıyasla azalma tespit edildi. Semptomatik hastalara kıyasla, sağ ventrikül ejeksiyon fraksiyonundaki artış ve sağ ventrikül alan indeksi, sağ ventrikül hacim indeksi ve triküspid annulus değerlerindeki düşüş asemptomatik hastalarda daha az belirgin olmakla birlikte, istatistiksel olarak anlamlı bir fark görülmedi.

Sonuç: Pulmoner kapak replasmanı düşük mortalite ve morbidite oranları ile yapılabilmektedir. Sağ ventrikül fonksiyonunu iyileştirmek için, ameliyat sağ ventrikül hacminde ve fonksiyonlarında geriye dönüşü olmayan değişiklikler başlamadan önce yapılmalıdır.

Anahtar sözcükler: Doğuştan kalp hastalığı; pulmoner kapak yetmezliği; pulmoner kapak replasmanı.

Tetralogy of Fallot (TOF) is the most frequently seen cyanotic congenital heart disease with a prevalence of 2.6 to 8%.[1,2] Surgery of TOF has been performed with low morbidity and mortality rates, in parallel with the evolution in cardiac surgery and postoperative care fields.[1,2] Despite these improvements in TOF surgery, however, reoperation is inevitable in nearly 50% of survivors in the following three decades after the initial procedure.[3] The most frequent reoperation is the pulmonary valve replacement (PVR) which is performed for chronic pulmonary valve insufficiency.[3] In this article, we present our early surgical outcomes of PVR in patients who underwent right ventricle outflow tract reconstruction (RVOTR).

PATIENTS AND METHODS

In our clinic, 196 patients with TOF were operated (161 of them were operated using a transannular patch) between January 2009 and September 2016, and 76 patients (34 males, 42 females; mean age 11.4±5.8 years; range 7 to 18 years) had PVR for pulmonary insufficiency which developed after RVOTR. Of these patients, 54 were symptomatic for chronic pulmonary insufficiency (CPI). Symptoms including exercise intolerance or arrhythmias that are attributed to right ventricular volume overload or dysfunction with or without branch pulmonary artery stenosis were considered as surgical indications for PVR. None of these patients had magnetic resonance imaging (MRI). In 22 patients who were asymptomatic for CPI, the PVR indication was the presence of two or more of the following criteria: right ventricular end-diastolic volume index (RV-EDVI) greater or equal to 150 mL/m², right ventricular end-systolic volume index (RV-ESVI) greater or equal to 80 mL/m², right ventricular ejection fraction less than 47%, left ventricular ejection fraction less than 55%, large right ventricular outflow tract aneurysm, on MRI and QRS duration longer than 160 msec on electrocardiography (ECG). None of the patients underwent MRI in the postoperative term, but were followed with regular echocardiography (ECHO), ECG, and rhythm Holter. Symptomatic and asymptomatic patients were compared according to demographic, ECHO, and postoperative follow-up properties. The study protocol was approved by the Medical Faculty of Başkent University Ethics Committee. The study was conducted in accordance with the principles of the Declaration of Helsinki.

In all patients, either symptomatic or asymptomatic, the pre- and postoperative ECHO examinations included the right ventricular area index (RVAI) and right ventricular volume index (RVVI) normalized according to body surface area and right ventricular ejection fraction (RVEF) were calculated with the Simpson's method.

All patients were anticoagulated with oral warfarin for three months with the international normalized ratio (INR) values kept between 2 and 2.5. The warfarin treatment was replaced with 5 m/kg/day of acetylsalicylic acid at the end of the third month. All data were collected through the patient reports and directly from patients through telephone calls.

Surgical procedure

Median sternotomy was performed and cardiopulmonary bypass was achieved through aortic and bicaval cannulation. The operations were performed on beating heart in 49 patients in whom there were no intracardiac defects such as atrial septal defect (ASD) or ventricular septal defect (VSD). Eleven patients with residual VSD, seven patients with ASD, and nine patients in whom reconstruction of the pulmonary artery branches were needed underwent PVR operations under cardioplegic arrest. All of these residual defects were closed during PVR operation. The transanular patch used for the RVOTR or the conduits were incised vertically. The pulmonary arteriotomies were performed according to the right ventricular or pulmonary artery branch reconstructions planned preoperatively. The incision was advanced to left pulmonary artery, or to the origin of both pulmonary branches according to the reconstruction plan. The largest possible biological valve was chosen (stented bovine pericardial valve-Biocor) considering the age and weight of the patient. The valve was implanted in the right ventricular outflow. The valve was covered with pericardial xenograft. Pulmonary artery plasty was performed in six patients to left pulmonary artery and in three patients to both pulmonary arteries.

Statistical analysis

Statistical analysis was performed using the PASW version 18.0 software (SPSS Inc., Chicago, IL, USA). Data were expressed in mean ± standard deviation (SD) or frequency (%) as appropriate. Comparisons between independent groups were performed using the Mann-Whitney U test. A p value of <0.05 was considered statically significant.

RESULTS

The patient demographics are shown in Table 1. The majority of the patients were operated for TOF. The RVOTR was performed using a transannular patch technique in 55 patients. In nine patients with Fallot-type double outflow right ventricle

Table 1. Patient demographics (n=76)

	Symptomatic (n=54)		Asymptomatic (n=22)	
	n	Mean±SD	n	Mean±SD
Initial diagnosis				
Tetralogy of Fallot	41		18	
Double outflow right ventricle-pulmonary stenosis	6		3	
Ventricular septal defect-pulmonary atresia	7		1	
Age at initial operation (years)		1.6±3.1		1.8±2
Age at pulmonary valve replacement (years)		11.9±3.7		12.1±1.7
İnterval between operations (years)		9±2.5		8.2±3.4
Right ventricular outflow tract reconstruction type				
Transannular patch	29		26	
Conduit	18		3	
Arrhythmia				
Atrial fibrillation	4		0	
Ventricular tachycardia	7		0	
Sinus node dysfunction	1		0	

(DORV-PS), in four TOF patients with coronary anomalies and in eight patients with VSD-PA, RVOT reconstructions were performed using conduits. The perioperative echocardiographic results are demonstrated in Table 2. The majority of the patients who underwent PVR were symptomatic. A total of 84% of these patients had functional capacity New York Heart Association (NYHA) Class II. The time intervals between the initial operation and PVR in symptomatic and asymptomatic patients were 8±2.5 and 10±1.4 years, respectively.

ECHO and MRI measurements

The perioperative RVEF, area and volume index measurements, and tricuspid valve annulus measurements of symptomatic and asymptomatic patients are shown on Table 2. The mean RVEF value in symptomatic patients increased in the postoperative term, although this result was not statistically significant. There was a decline in the RVAI, RVVI, and tricuspid annulus measurements, compared to preoperative values. Compared to the symptomatic patients, the increase in the RVEF and the decrease in the RVAI, RVVI, and tricuspid annulus was less prominent in asymptomatic patients, although this difference was not statistically significant. The mean preoperative pulmonary valve annulus was calculated as 21.4±2.8 mm. High-grade pulmonary valve insufficiency was detected in all patients via ECHO. In 22 asymptomatic patients who were operated according to the MRI results, the calculated RV-EDVL and RV-ESVI were 154±7.1 mL/m^2 and 83±4.7 mL/m^2, respectively.

Procedural data

The cardiopulmonary bypass and cross-clamp times were 110±41.5 and 61±39.5 min, respectively. The mean procedural time was 4.7±1.2 hours in patients with a transannular patch and 5.1±1.8 hours in patients with conduits, indicating no significant difference. The mean size of the implanted valve was 27.6±1.9 mm. In addition to PVR, VSD closure in 11 patients, ASD closure in seven patients, and pulmonary artery reconstruction in nine patients were performed.

Table 2. Changes in echocardiographic and electrocardiographic measurements in symptomatic and asymptomatic patients

	Symptomatic			Asymptomatic		
	Preoperative	Postoperative	p^*	Preoperative	Postoperative	p^*
Right ventricular ejection fraction	40.6±9.3	43.3±10	0.08	41.6±6.1	42.1±2.3	0.07
Right ventricular area index (mm^2/m^2)	25±8.7	22±4.9	0.07	27.6±9.3	26.1±3.1	0.08
Right ventricular volume index (mm^3/m^2)	47.7±17.9	45±10.7	0.06	49.6±5.3	48.1±2.3	0.08
Tricuspid annulus (mm)	22.8±3.4	21.3±2.4	0.08	25.1±3.3	24.6±3.2	0.06
QRS duration (msec)	143±3.1	142±2.3	0.07	144±6.1	143±2.7	0.07

Follow-up

The mean follow-up was 60±19 (range 17-108) months. There was no early mortality and late mortality. In the ECHO measurements, the mean gradient in the pulmonary valve was calculated as 19±14 mmHg, there was no pulmonary insufficiency. There was no need for reoperation due to implanted valve-related problems. The functional capacity of the symptomatic patients increased significantly (all reached NYHA Class I). No arrhythmia was detected using ECG or Holter measurements.

The length of intensive care unit and in hospital stays were 1.7±0.9 and 5.9±3.4 days in symptomatic patients, respectively and 2.1±1.6 and 7.1±2.9 days in asymptomatic patients, respectively, indicating no significant difference. Among nine patients who had pulmonary artery reconstruction, three patients developed diaphragm paralysis and one patient developed recurrent nerve paralysis.

DISCUSSION

The TOF operations have been performed over five decades. The morbidity and mortality rates have been significantly reduced with evolving technology and surgical experience.[4] On the other hand, the operated TOF patients still face the risk of a secondary procedure related to pulmonary valve insufficiency.[1,2]

In the past, TOF procedure-related pulmonary valve insufficiency was believed to be harmless to the cardiac functions in the postoperative period; however, with the use of innovative screening methods such as cardiac MRI, it is now widely accepted that chronic pulmonary valve insufficiency deteriorates the right ventricular functions.[5] Gatzoulis et al.[5] demonstrated that pulmonary valve insufficiency caused right ventricular dilatation and dysfunction, intolerance to exercise, newly developing arrhythmias, and even sudden death over time. It is a common belief that pulmonary valve replacement leads to improvement in the right ventricular functions, decrease in the ventricular volumes, and increase in functional capacity.[6,7]

The pulmonary valve replacement procedure is performed with low mortality. Lee et al.[8] reported 98% of 10-year-survival after the procedure. There was no mortality in our cohort in the early postoperative period or during three-year-follow up. In the literature, two-thirds of the PVR patients either needed reintervention or developed structural changes in the valve after 10 years; this was five times faster in children compared to the adults due to metabolism and growth rate.[9,10] The need for reintervention may partially be avoided using larger-size valve implants as in our patients.

There are contradictory reports about the effects of PVR on the right ventricular functions, volumes, QRS duration, and arrhythmias. Several authors showed fast recovery of the right ventricular functions and volumes along with a significant decline in the QRS duration and in the rate of arrhythmias,[8] whereas some others did not.[11,12] In our study, we observed postoperative decrease in the right ventricular volumes and QRS duration along with improved right ventricular functions, compared to the preoperative results in the symptomatic patients, although the difference was not statistically significant. Pulmonary valve replacement is usually performed much later in asymptomatic patients, compared to symptomatic patients; therefore, the beneficial changes in the right ventricular volumes, QRS duration, and right ventricular functions were less prominent in asymptomatic patients. The intensive care unit and hospital stay lengths were also longer in the asymptomatic group; however, this difference was not statistically significant. This can be associated with the preoperative condition of the symptomatic patients that they underwent operation before right ventricular dilatation developed, in other words, before irreversible changes in the right ventricular developed. The procedural times were also longer in the patients in whom conduit was used instead of a transannular patch in the RVOTR. This may be related to the adhesion of the conduit to the neighboring tissues.

In addition, transcatheter PVR is reported as a new alternative method to conventional surgery.[13] Prosthetic valve migration, guidewire-related pulmonary artery branch or tricuspid valve injury, and stent fractures are among the reported complications of this new technique.[14]

On the other hand, in all of our patients, the effects of PVR on the right ventricular functions were shown using ECHO, but not with MRI. In none of the patients, implanted valve-related reoperation was needed in the mid-term follow-up; however longer follow-up is essential to identify the actual reintervention need in PVR patients.

In conclusion, pulmonary valve replacement can be performed with low morbidity and mortality rates. To relief the right ventricle function, the operation should be performed before the irreversible changes in the right ventricular volumes and functions occur.

We believe that larger implant sizes may diminish the need for reoperations.

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