# Pulmonary Valve-Sparing Surgery in Tetralogy of Fallot: Early Results of Pulmonary Flow Hemodynamics

**Özgür Yıldırım[1], İsmail Balaban[2]**

[1] Yeni Yuzyil University Gaziosmanpasa Hospital, Department of Cardiovascular Surgery, Istanbul, Turkey
[2] Yeni Yuzyil University Gaziosmanpasa Hospital, Department of Pediatric Cardiology, Istanbul, Turkey

## ABSTRACT

**Introduction:** Tetralogy of Fallot is the most common form of cyanotic congenital heart disease. We aimed to share our experience of pulmonary annulus preserving surgery as the current and increasingly preferred treatment option in this study.

**Patients and Methods:** In this study, the data of 30 pediatric patients who underwent corrective repair by preserving the pulmonary valve annulus were evaluated retrospectively. Demographic data, angiographic, and echocardiographic findings before and after surgery were recorded.

**Results:** In our study, 20 (66.7%) patients were male, 10 (33.3%) were female; median age of the patients was 29 months. In the preoperative evaluation, 16 patients had a pulmonary valve with two leaflets (53.3%), and 14 patients had three leaflets (46.7%). McGoon indexes calculated as mean 1.82 ± 0.23 by echocardiography and 2 ± 0.29 by angiography. Pulmonary valve annulus Z-scores were determined as mean -1.8 ± 1.1 echocardiographically and -0.9 ± 1.2 angiographically. Mean right ventricle systolic pressures measured in echocardiographic examination at 1st, 7th, and 14th days after surgery were 42.3 ± 6.5, 38.7 ± 4.9, and 35.8 ± 4.9 mmHg, respectively, and decreasing values were significant statistically. Pulmonary valve pressure gradients measured at postoperative 1st, 7th, and 14th days and found as mean 27.2 ± 5.6, 25.5 ± 6.2, and 24.4 ± 6.2 mmHg, respectively; this decrease was also statistically significant. There was no mortality or significant morbidity during the mean 7.97 ± 3.39 months follow-up period.

**Conclusion:** Preservation of pulmonary valve during surgery is an effective treatment option in the treatment of tetralogy of Fallot in terms of reducing early and late complications and should become a more prevalent technique.

**Key Words:** Tetralogy of fallot; pulmonary subvalvular stenosis; pulmonary valve stenosis

## Fallot Tetralojisi Cerrahisinde Pulmoner Kapak Koruma: Pulmoner Akım Hemodinamikleri Erken Dönem Sonuçları

## ÖZET

**Giriş:** Fallot tetralojisi en sık görülen siyanotik doğuştan kalp hastalığıdır. Çalışmada hastalığın güncel ve giderek daha çok tercih edilen tedavi seçeneği olarak pulmoner anülüs koruyucu cerrahi deneyimlerin paylaşılması ve literatüre katkı sağlanması amaçlanmıştır.

**Hastalar ve Yöntem:** Çocuk kalp damar cerrahisi kliniğinde pulmoner kapak anülüsü korunarak cerrahi tam düzeltici onarım yapılan 30 çocuk hastanın verileri retrospektif olarak değerlendirildi. Hastaların demografik verileri, operasyon öncesi ekokardiyografi ve anjiyografi bulguları ve sonrasında tekrarlanan ekokardiyografi bulguları kaydedildi.

**Bulgular:** Olguların 20 (%66.7)'si erkek, 10 (%33.3)'u kız; hasta ortanca yaşı 29 ay (10-212 ay) idi. İntraoperatif değerlendirmede 16 hastanın pulmoner kapak yapısının 2 (%53.3) yaprakcıklı, 14 hastanın ise 3 (%46.7) yaprakcıklı olduğu görülmüştür. McGoon indeksleri ekokardiyografi ile ortalama 1.82 ± 0.23; anjiyografik olarak ortalama 2 ± 0.29 olarak hesaplanmıştır. Pulmoner kapak anülüs Z skorları ekokardiyografi ile ortalama -1.8 ± 1.1; anjiyografik olarak ortalama -0.9 ± 1.2 saptanmıştır. Postoperatif 1, 7 ve 14. günlerde ekokardiyografi ile sağ ventrikül sistolik basınç ortalamaları sırasıyla 42.3 ± 6.5 mmHg, 38.7 ± 4.9 mmHg ve 35.8 ± 4.9 mmHg olarak ölçülmüş ve değerler arasında istatistiksel olarak anlamlı bir azalma tespit edilmiştir. Eşzamanlı bakılan pulmoner kapak gradientleri sırasıyla 27.2 ± 5.6 mmHg; 25.5 ± 6.2; 24.4 ± 6.2 mmHg saptanmış ve istatistiksel olarak anlamlı olarak düşüş olduğu görülmüştür. Ortalama 7.97 ± 3.39 ay takip süresince mortalite ve ciddi morbidite gözlenmemiştir.

**Sonuç:** Fallot tetralojisi tedavisinde cerrahi sırasında pulmoner kapağın korunması erken ve geç dönem komplikasyonların azaltılması bakımından etkili bir tedavi seçeneğidir.

**Anahtar Kelimeler:** Fallot tetralojisi; pulmoner subvalvüler darlık; pulmoner kapak darlığı

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**Correspondence**

**Özgür Yıldırım**

**E-mail:** yildirimozg@yahoo.com
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## INTRODUCTION

Tetralogy of Fallot (TOF) was first described by Etienne-Louis Arthur Fallot in 1888. It is the most common form of cyanotic congenital heart disease with characteristics of malalignment ventricular septal defect (VSD), dextroposition of the aorta, infundibular subpulmonic stenosis, and right ventricular hypertrophy[1].

The first intracardiac surgical repair was performed by C. Walton Lillehei in 1954, and in treatment process, mortality rates were decreased significantly in time with Kirklin and colleagues' starting to use pump oxygenator in 1955[2]. The final aim in surgical procedure is total correction including VSD closure with a patch and relieving right ventricular outflow tract (RVOT) stenosis.

Previously, surgical procedure was performed in two stages: systemic-to-pulmonary shunt in early infancy and intracardiac repair in late term, but in time, with technological improvements, single-stage surgery has started to be applied since the infantile period[3].

Transannular patch (TAP) technique is a widely used strategy in relieving RVOT stenosis; however, disruption of the structure of the pulmonary valve and chronic pulmonary insufficiency can cause progressive right ventricular dilation, biventricular dysfunction, and lead to undesirable results including exercise intolerance, ventricular arrhythmias, and even sudden cardiac death. Surgical or transcatheter pulmonary valve replacement has been emerged as a necessity over time because of these complications. Various surgical techniques have been developed and started to be applied in many centers to protect the pulmonary valve and its functions during repair to avoid the mentioned late sequelae[4-6].

In this study, clinical, echocardiographic, angiographic, and surgical data of 30 patients who underwent pulmonary valve-sparing corrective surgery with the diagnosis of TOF in our center were evaluated in detail. It is aimed to share our clinic's experience in pulmonary valve protective surgery in TOF cases and to contribute to future studies on this subject.

## PATIENTS and METHODS

The data of 82 pediatric patients who were admitted to pediatric cardiac surgery clinic with the diagnosis of TOF between January 2019 and May 2020 were evaluated retrospectively, and 30 patients who underwent total correction with pulmonary valve-sparing surgery (PVSS) were enrolled in the study. Thirty-three patients who underwent TAP technique, 11 patients who underwent total repair with conduit due to previous TAP, RVOT stenting, or coronary artery anomaly, and 8 patients who underwent other procedures including systemic-to-pulmonary shunt, open Brock operation, and RVOT stenting due to low weight or low pulmonary artery (McGoon) index were excluded from the study. Local "Ethics Committee" approved the study having number of 993 and dated June 09, 2020.

### Preoperative and Postoperative Cardiac Evaluation

Detailed transthoracic echocardiography and diagnostic catheter angiography were performed in all patients before the surgery. McGoon indexes were calculated by summing the right and left pulmonary artery diameters and dividing them into the descending aorta diameter with the help of transthoracic echocardiography. The diameter of pulmonary valve annulus was measured by two-dimensional echocardiography in short-axis imaging, and Z-scores were calculated according to patients' height and weight.

Diagnostic catheter angiography was performed in all patients to confirm pulmonary and coronary artery anatomy, to evaluate left ventricular volume, and to show additional VSDs. Angiographic pulmonary artery indexes were calculated by measuring the right and left pulmonary artery diameters at the hilar level and aorta diameter from the diaphragm level anteroposteriorly and left oblique angle imaging. Pulmonary annuluses were measured from the widest part of the valve annulus in systole, and Z-scores were calculated based on the weight and height of patients.

Echocardiography controls were performed regularly to evaluate ventricular contractions, pericardial and/or pleural effusions, residual and additional VSDs, right ventricle (RV) pressure, pulmonary valve sufficiency, RVOT, and peripheral pulmonary arteries in all patients after surgery. Echocardiography was performed on the 1$^{st}$, 7$^{th}$, and 14$^{th}$ postoperative days; the data were recorded.

### Surgical Technique

A cardiopulmonary bypass (CPB) surgery was performed and with standard aorto-bicaval cannulation, moderate hypothermia, and cold blood cardioplegia. Limited right ventriculotomy was performed in all of the patients for relieve RV stenosis. Pulmonary arteriotomy and reconstruction was performed if the patients had major pulmonary artery hypoplasia or peripheral pulmonary artery stenosis. Commissurotomy was performed if the patients had commissural fusion in the pulmonary valve. Valve opening was checked using Hegar dilators. If the dilator could fit under 1 mm of its expected pulmonary annulus size, it was considered sufficient for the valve-sparing surgery. Right ventriculotomy and pulmonary arteries were reconstructed with an autologous pericardial patch treated with glutaraldehyde. VSDs were closed with 6-0 or 5-0 polypropylene sutures and autologous pericardial patch through the transatrial approach. In patients with transpulmonary gradient

below 30 mmHg just after cardiopulmonary bypass termination with direct pressure measurement, repair was considered to be sufficient. In patients with transpulmonary gradient between 30 and 40 mmHg, it was decided to protect the annulus and follow the patients after intraoperative echocardiographic control. RVOT revision and TAP procedure were performed for patients with gradients above 40 mmHg and had hemodynamic deterioration after cardiopulmonary bypass.

**Statistical Analysis**

SPSS version 22 (SPSS, demo version, Chicago, IL, USA) was used for statistical analysis. Nominal data were depicted as percentages. Normality of the data was analyzed with Kolmogorov-Smirnov test, and parametric normally distributed data were shown as means ± standard deviation, and non-normally distributed data were shown as medians (minimum to maximum). Dependent samples t-test was used for comparisons as the parameters were consisted of dependent variables. A p-value of ≤ 0.05 was considered significant.

## RESULTS

Twenty (66.7%) of the patients who underwent PVSS were boys and 10 were girls (33.3%). The median age of the patients was 29 months (10-212 months), median height was 84.5 cm (65-162 cm), and median body weight was 10.8 kg (5.5-57 kg) at the time of surgery (Table 1).

The mean duration of CPB was 96 ± 4.7 minutes, and the mean arterial cross-clamp time was 72.4 ± 3.2 minutes in the operation. The median length of stay in the intensive care unit was 2 days (1-6 days), and postoperative extubation time was 9.8 ± 1.1 hours.

The reconstruction of left pulmonary arteries was performed in four cases, and bilateral pulmonary artery reconstruction was done in one case. In the perioperative evaluation, 16 patients' pulmonary valve structure was found to be bileaflet (53.3%) and 14 patients' pulmonary valve were trileaflet (46.7%). Commissurotomy was performed on all bileaflet valves, 7 of the trileaflet valves. One patient underwent pulmonary valve repair in addition to commissurotomy. The patient who underwent pulmonary valve repair had previously undergone an RVOT stent implantation.

In one patient, perioperative right ventricle-pulmonary artery gradient was 40 mmHg, and the patient was hemodynamically unstable; the RVOT was reconstructed with TAP.

McGoon indexes were calculated as mean 1.82 ± 0.23 by echocardiography and mean 2 ± 0.29 by angiography. The McGoon index values calculated by echocardiography were found to be significantly lower than the values calculated by angiography (mean difference in two different groups: 0.179 ± 0.187; t-test; p< 0.001).

Pulmonary valve annulus Z-scores were mean -1.8 ± 1.1 by echocardiography (max 0.2; min –4.1); angiographically, the mean was -0.9 ± 1.2 (max 2.3; min -3). Annulus Z-scores measured by echocardiography were found to be statistically significantly lower (t-test in two paired groups; p< 0.001) (Table 2).

The right ventricular systolic pressure (RVSP) measured by echocardiography on the first day was as 42.3 ± 6.5 mmHg. The mean RVSPs by echocardiography were found as 38.7 ± 4.9 and 35.8 ± 4.9 mmHg on the 7$^{th}$ and 14$^{th}$ days, respectively. A statistically significant pressure decrease was noted between the RVSPs measured on the 1$^{st}$ postoperative day and the values measured on the 7$^{th}$ and 14$^{th}$ days (p< 0.001 and p< 0.00, respectively, in two paired groups). Again, the RVSPs on the 14th day were noted to be decreased significantly compared to the 7th day values (35.8 ± 4.9 versus 38.7 ± 4.9 mmHg, p= 0.03; t-test in two paired groups). The pulmonary valve gradient (PVG) measured on the 1$^{st}$, and 7$^{th}$, and 14$^{th}$ postoperative days were compared. The mean PVG (24.4 ± 6.2 mmHg) measured on the 14$^{th}$ day was compared with that on the 7th

**Table 1. Demographic data and characteristics of clinical follow-up**

| Variable | Results | |
|---|---|---|
| Age (months) | Median (min–max) | 298 (10-212) |
| Weight (kg) | Median (min–max) | 10.8 (5.5-57) |
| Height (cm) | Median (min–max) | 84.5 (65-162) |
| Cross-clamp time (minutes) | Mean ± SD | 72.3 ± 17.7 |
| Cardiopulmonary bypass time (minutes) | Mean ± SD | 962 ± 6.2 |
| Intubation term (hours) | Mean ± SD | 9.8 ± 6.3 |
| Intensive care stay (days) | Median (min–max) | 2 (1-6) |
| Follow-up time after surgery without complication (months) | Mean ± SD | 7.97 ± 3.39 |

**Table 2. Measurements of McGoon index and pulmonary annulus**

| | Results (mean ± SD) | | | |
|---|---|---|---|---|
| **Variable** | **Echocardiography** | **Angiography** | **Difference** | **p** |
| McGoon index | 1.8 ± 0.23 | 2 ± 0.29 | 0.18 ± 0.19 | < 0.001 |
| Pulmonary annulus (mm) | 9.4 ± 2.9 | 11.1 ± 2.8 | 1.7 ± 2.4 | < 0.001 |
| Pulmonary annulus Z-score | -1.8 ± 1.1 | -0.9 ± 1.2 | 0.9 ± 1.1 | < 0.001 |

**Table 3. Changes in RVSP and PVG in early postoperative period**

| | Results (mean ± SD) | | | |
|---|---|---|---|---|
| **Postoperative time** | **RVSP (mmHg)** | **p** | **PVG (mmHg)** | **p** |
| 1st day | 42.3 (6.5) | | 27.2 (5.6) | |
| 7th day | 38.6 (4.9) | | 25.4 (6.1) | |
| 14th day | 35.8 (4.9) | | 24.3 (6.1) | |
| 1st-7th days difference | 3.7 (4.1) | 0.001 | 1.7 (3.5) | 0.013 |
| 7th-14th days difference | 2.8 (3.4) | 0.001 | 1.1 (2.6) | 0.03 |
| 1st-14th days difference | 6.5 (5.4) | 0.001 | 2.8 (3.6) | < 0.001 |

RVSP: Right ventricle systolic pressure, PVG: Pulmonary valve gradient.

day (25.5 ± 6.2) and the 1st day (27.2 ± 5.6 mmHg). PVG was found to be significantly decreased (14th day ~ 7th day p= 0.03; 14th day ~ 1st day p< 0.001; 7th day ~ 1st day p< 0.013; t-test in two paired groups) (Table 3). Postoperative echocardiography follow-up revealed trace pulmonary valve insufficiency in 19 patients (63.3%), mild insufficiency in 8 patients (26.6%), and moderate insufficiency (6.6%) in 2 patients. Severe insufficiency was observed in one patient who underwent TAP after surgery (3.3%).

Hemiparesis was detected in one patient on the second postoperative day due to intracranial infarction, and there were no sequelae after medical treatment and physical rehabilitation. There was no mortality or significant morbidity during the mean 7.97 ± 3.39 months follow-up period.

## DISCUSSION

Transannular patch technique is still believed to be the most popular approach in many centers in the treatment of TOF. Even though the early results were satisfactory in the early period, right ventricular volume loading and right heart failure due to pulmonary insufficiency in the long term are almost unavoidable and may lead to morbidity and even sudden death[7].

Protection of the pulmonary valve during surgery is an effective treatment option to prevent complications due to pulmonary regurgitation and has been tried to be applied recently[8]. Various surgical technics have been developed and performed for this purpose. The common goal of these techniques, which usually include valvuloplasty applications, is to protect the pulmonary valve integrity while expanding the RVOT and preventing right ventricular volume loading[5]. In a study of young adults conducted by Ducas et al. in Canada, it was found that patients who received TAP surgery had a significantly higher incidence of right ventricular dilation and dysfunction and the need for reintervention at follow-up (most often pulmonary valve replacement) in long term[9]. Similarly, long-term postoperative complications, adverse events, and mortality rates were significantly higher in patients with TAP compared to patients with preserved pulmonary valve in a large multicenter study conducted by Padalino et al. our study included patients who received PVSS[10]. In considering the total number of patients who underwent complete corrective repair (TAP: n= 33, PVSS: n= 30, total correction with conduit: n= 11), the PVSS rate was 40.5%, slightly higher than the results of the mentioned Italian study[10]. With this result, it has been evaluated that advanced international standards have been achieved in our center.

Commissurotomy is widely applied with various proportions and techniques during PVSS. In addition, intraoperative balloon pulmonary valvuloplasty is applied in some centers. Although the highest benefit will be obtained when applied to patients with moderate pulmonary stenosis or dysplasia, it has been observed in the follow-up of the more hypoplastic valves that the growth of the valve is similar to the traditional

methods, and the rate of pulmonary insufficiency is higher. Lozano-Balseiro et al. in their recent study had reported that positive results were obtained in early and midterm pulmonary stenosis with balloon valvuloplasty, but progressive pulmonary insufficiency may occur in the long term[11]. Similar progressive pulmonary insufficiency after balloon valvuloplasty was reported in the study conducted by Hofferberth et al., and it was emphasized that right ventricular dilation midterm results were similar to TAP. In addition, there was a need for reintervention due to residual pulmonary stenosis especially after the balloon valvuloplasty was performed in the early infancy period[4]. We do not prefer intraoperative balloon valvuloplasty technique considering these results. In our study, patients who received PVSS, 6.6% had shown moderate, 26.6% had mild, and 63.3% had trace pulmonary valve insufficiency in early period, and these rates were considered to be quite low.

It was observed in intraoperative valve anatomy that 53.3% of our patients had bileaflet and 46.7% had trileaflet pulmonary valve structure. These rates were similar to the findings reported by Arafat et al. (56.5% and 37%, respectively)[8]. In our study, 23 patients underwent pulmonary valve commissurotomy (76.6%). Valve anatomy was bileaflet in 16 and trileaflet in 7 of these patients. Commissurotomy was performed on all bileaflet valves; this rate was recorded as 50% in trileaflet valves. One patient underwent valve repair in addition to the commissurotomy for damaged pulmonary leaflet, which was thought to be due to the previously applied RVOT stenting.

Current surgical preferences are to protect the pulmonary valve as much as possible because of the long-term adverse effects and possible risks due to TAP and to consider the advantages of PVSS. Unfortunately, there is no consensus on valve evaluation method and annulus diameter measurement limits to make the decision on performing TAP or PVSS. Awori et al. had compiled studies conducted in different centers before and found that in only 5 studies, representing 25.5% of all patient files from 19 studies, the evaluation of pulmonary valve Z-scores were made by certain measurement techniques and data sets previously identified[12]. Jonas suggested repair with transannular incision if pulmonary valve annulus Z-score is less than -3. The lower limit Z-score value was taken as -4 in intraoperative measurements in a study by Stewart et al., and in smaller values, TAP was used for corrective repair[13,14]. During the decision process, examination of pulmonary annulus diameters can be performed with echocardiography, angiography, or scaled dilators intraoperatively. Pulmonary annulus diameters were measured both echocardiographically and angiographically, and Z-scores were calculated separately for both methods and determined as mean -1.8 ± 1.1 (maximum 0.2; minimum -4.1) and mean -0.9 ± 1.2 (maximum 2.3; minimum -3), respectively, in our study. There was a significant difference between the two methods. Angiographic measurements were evaluated more reliably for the possibility of imaging difficulty due to patient movements, transthoracic image quality, and measurement differences in echocardiographic findings. Similar findings were obtained in the intraoperative evaluations and measurements. The lower limit Z-score value was accepted as –3 for pulmonary valve protective approach in our clinic; the decision was made based on both literature information and our clinical experience. As per the measurements taken with Hegar dilator after muscle band resection and commissurotomy procedure during the operation, the patients who complied with these parameters were decided to receive pulmonary valve protection, and PVSS was performed in these patients. In some recent studies, alternative measurement methods have been proposed that can be used instead of the pulmonary annulus Z-score. Kasturi et al. suggested the use of "pulmonary annulus index," calculated indirectly by using the pulmonary and aortic annulus diameters and which expresses the proportion of observed and expected pulmonary annulus diameters along with the pulmonary annulus Z-scores[15]. Choi et al. stated that the ratio of pulmonary- to aortic annulus diameter and descending aorta diameter can be used for this purpose[16]. However, further studies are needed to include these new recommendations in clinical use.

If RVSP is increased, it requires an evaluation of residual RVOT stenosis in the early postoperative period. In many centers, absolute value of the right ventricular pressure is measured intraoperatively, and the ratio of the right ventricular pressure to the left ventricular pressure is calculated, and the course of the operation is decided on the basis of these measurements. If the right ventricle-pulmonary artery gradient is above 40 mmHg or the right-left ventricle peak pressure ratio is above 0.8, it is recommended to switch to TAP technique, although the initial operation plan was PVSS[16]. In the study by Stewart et al., 6 of 88 patients (6.8%) who had a PVSS plan had to be switched to TAP procedure on the basis of intraoperative pressure measurements, and also 33% of patients with a right-left ventricular pressure ratio of more than 0.7% needed reoperation in follow-up. They suggested the ratio limit should be 0.7 instead of 0.8[14]. Hickey et al. in their study reported that the pulmonary valve was protected in 296 (68%) of the 434 patients who underwent complete corrective repair of TOF. While the intraoperative RVSPs of successful procedures was mean 45 mmHg, this value was mean 56 mmHg in 14 patients (5%) with persistent RVOT stenosis who required TAP in continuation with operation. Thus, they considered that intraoperative early RVSP below 50 mmHg was an important component for successful surgery[17]. In our study, the mean intraoperative right ventricular pressure was 46.2 mmHg. In one patient (3.3%) with annulus-sparing surgery plan due to the preop-

erative evaluation, intraoperative measurements revealed right ventricular pressure as 60 mmHg, right-left ventricular pressure ratio of 0.7, and right ventricle-pulmonary artery pressure gradient as 40 mmHg. Also, because of unstable hemodynamics of the patient during operation, TAP repair was performed by switching to CPB again as suggested in the literature. RVSP was 30 mmHg in subsequent measurements postoperatively. In the study by Arafat et al., patients were evaluated with similar characteristics as in our study, the need for switching to TAP procedure was reported at a rate of 23.9%[8]. This apparent difference might be due to the detailed evaluation of patients before treatment and the effective selection of suitable patients in our center.

In the follow-up of our patients who received successful PVSS in the early postoperative period, RVSP was measured with echocardiography on the 1st, 7th, and 14th postoperative days and were found to be mean 42.3 ± 6.5 mmHg, 38.7 ± 4.9 mmHg, and 35.8 ± 4.9 mmHg, respectively; and a statistically significant gradual decrease was noticed in the follow-up. In addition to these findings, the mean PVG measured on the postoperative 14th day (24.4 ± 6.2 mmHg) was found to be significantly lower than the gradients measured both on the 7th day (25.5 ± 6.2) and the 1st day (27.2 ± 5.6 mmHg). Antunes et al. in their study evaluated patients with preserved pulmonary valves, which is similar to our findings. It was observed that the mean PVG at discharge (44.2 ± 22.6 mmHg) decreased significantly at the end of the sixth postoperative month (28.5 ± 14.3 mmHg); however, the right-left ventricular systolic pressure ratios in intraoperative measurements were above 0.6 in 80% of patients (mean 0.67 ± 0.18). The high rate of right-left ventricular pressure does not affect the results as the patients are hemodynamically in good condition and are followed up without any problems. However, the low number of patients (n= 22) and the short follow-up period are the limitations of this study[18]. The duration of intubation and intensive care stays were quite short considering the fact that our patients had a good clinical course in their follow-up. Patients were discharged without any problems, and there was a significant decrease in PVG and right ventricular pressures in the early follow-up period. It can be interpreted from the findings of our study that the patients who underwent PVSS can tolerate pressures and gradients which exceed the limits in a reasonable manner, provided that the literature information should not be denied. Follow-up time of our patients after surgery without complications was mean 7.97 ± 3.39 months, and it is considered as a respectable period to accept these patients have a good clinical condition after PVSS. In accordance with this information, in a study reported by Yoo et al. from South Korea, it was stated that right ventricular sizes and functions were not significantly affected in patients with pulmonary insufficiency, and patients with pulmonary insufficiency and additional residual pulmonary stenosis (mean PVG 34.2 ± 10 mmHg) after TOF repair[19].

With evaluation of the findings of our study and in consideration with the literature data, protecting the pulmonary annulus during TOF surgery has become our priority due to its advantages in short- and long-term follow-up of the patients. It was suggested that it would be in the best interest of the patients to enforce the limits to a reasonable level in consideration with the decrease in PVG and RVSPs after treatment.

Preservation of normal anatomy and function of the pulmonary valve with PVSS applications in the treatment of TOF should be developed and generalized in parallel with surgical techniques and technological developments as an important cause of low morbidity and mortality in childhood.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the Istanbul Yeni Yuzyil University Clinical Researchs Ethics Committee (Number: 993, Date: June 09, 2020.

**Informed Consent:** Written informed consent was obtained from patients who participated in this study.

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