https://doi.org/10.63181/ujcvs.2025.33(3).49-56
UDC 616-039.75

**Olga S. Borodinova**, PhD in Medical Sciences, Pediatric Cardiologist, https://orcid.org/0000-0002-5550-1318
**Anzhelika O. Mykhailovska**, Pediatric Cardiologist, Department of Ultrasound and Functional Diagnostics, https://orcid.org/0009-0004-0429-4453;

State Institution "Scientific and Practical Medical Center of Pediatric Cardiology and Cardiac Surgery of the Ministry of Health of Ukraine", Kyiv, Ukraine

# Long-Term Outcomes of Tetralogy of Fallot Repair with Pulmonary Valve Preservation and with Transannular Patch

**Abstract**

**Introduction.** Tetralogy of Fallot (ToF) is a prevalent cyanotic congenital heart defect, with surgical repair strategies focused on relieving right ventricular outflow tract obstruction (RVOTO). The choice between a transannular patch (TAP) and a valve-sparing non-transannular patch (NTAP) remains controversial due to the trade-off between pulmonary regurgitation and the risk of residual RVOTO.

**Aim.** To evaluate the predictive value of intraoperative echocardiographic parameters – particularly the RVOT z-score – for identifying severe residual RVOTO in children with ToF and to analyse their long-term outcomes after ToF repair.

**Materials and Methods.** This retrospective single-center study included 132 patients who underwent complete ToF repair. Intraoperative transesophageal echocardiography (ITEE) was used to assess RVOT anatomy and hemodynamics. The study assessed baseline characteristics and perioperative measurements of pulmonary valve (PV) and RVOT dimensions, pressure gradients, and long-term echocardiographic parameters. The primary endpoint was reoperation due to significant RVOTO. Statistical analysis included ROC curves, AUC calculation, threshold determination, sensitivity, and specificity. Group comparisons were performed using Student's t-test or the Mann–Whitney U test, as appropriate.

**Results.** NTAP was performed in 82.6 % and TAP in 17.4 % of patients. Patients in the TAP group had a significantly higher rate of RVOT-related reoperations (36.3 % vs 11.1 %; p = 0.0029), mainly due to severe pulmonary valve insufficiency and the need for RV–PA conduit implantation. The most accurate predictor of significant RVOTO requiring reintervention was an intraoperative RVOT z-score <-3.2, assessed by ITEE (AUC = 0.925; sensitivity 85.0 %, specificity 90.1 %). Other parameters, such as the Prv/Plv ratio, RV–PA gradients, and PV z-score, showed lower predictive accuracy.

**Conclusions.** Reoperations on the RVOT were more common after TAP than NTAP (36.3 % vs 11.1 %, p = 0.0029), mainly due to residual RVOTO and PV insufficiency. An intraoperative RVOT z-score < -3.2 was the strongest predictor of significant RVOTO. Assessing RVOT and PV z-scores during surgery may help reduce reinterventions, support valve-sparing approaches, and lower the risk of late surgeries for PV insufficiency.

***Keywords:*** *congenital heart defects, surgical correction, prenatal diagnosis, increasing the pulmonary blood flow, endovascular interventions, transannular plasty, valve–sparing surgery.*

**Introduction.** Tetralogy of Fallot (ToF) is one of the most common cyanotic congenital heart defects, accounting for approximately 10 % of all cases [1]. First described by Étienne-Louis Arthur Fallot in 1888 [2], the defect is characterized by four main anatomical features: a ventricular septal defect (VSD), right ventricular outflow tract obstruction (RVOTO), overriding of the aorta, and right ventricular (RV) hypertrophy. Without timely surgical intervention, this pathology leads to severe hypoxia and heart failure in early childhood.

The first attempt at palliative surgical treatment of ToF – the creation of a systemic-to-pulmonary shunt – was performed by Alfred Blalock in 1944 to increase pulmonary blood flow, and this approach is still in use today [3]. In recent decades, an alternative technique – patent ductus arteriosus (PDA) stenting – has been actively implemented, first performed by J. L. Gibbs [4].

A key aspect of total ToF repair is the relief of RVOT obstruction, which is typically achieved using one of two

main techniques: the transannular patch (TAP) [5] or the valve-sparing technique – non-transannular patch (NTAP) [6]. In the late postoperative period, the main challenges remain the need for reintervention, driven by factors such as pulmonary valve (PV) insufficiency or residual RVOTO. With the advancement of cardiac surgery, alternative approaches (transatrial and transpulmonary) have been developed to avoid ventriculotomy and preserve RV structure and function. However, even with contemporary techniques, the issues of residual RVOTO and the need for TAP remain controversial. TAP effectively relieves RVOTO but creates a risk of severe PV regurgitation, which over time can lead to RV volume overload, dilation, systolic dysfunction, and arrhythmias [7]. On the other hand, the NTAP technique reduces the risk of significant pulmonary regurgitation but increases the likelihood of residual RVOTO, which may result in progressive RV hypertrophy due to elevated intracavitary pressure and diastolic dysfunction [8]. Accurate assessment of the anatomical and functional characteristics of the RVOT in the perioperative period is a key factor in the successful total repair of ToF.

Intraoperative transesophageal echocardiography (ITEE) has become an important tool for evaluating RVOT patency, especially in the NTAP method. ITEE allows real-time assessment of RVOT dimensions, RV pressures, and the quality of surgical reconstruction. Several authoritative sources recommend routine ITEE during every ToF repair to ensure the adequacy of RVOT reconstruction and prevent future RVOT reinterventions [9].

A normalized RVOT diameter index relative to body size (RVOT z-score) < -3.2 [10] has demonstrated high sensitivity and specificity in predicting significant RVOT obstruction in patients undergoing ToF repair. The relevance of this study lies in the comparison of long-term outcomes of ToF repair with pulmonary valve preservation versus transannular patching.

**Aim.** To investigate and analyze preoperative, intraoperative, and postoperative parameters to identify predictors of significant residual RVOTO in children after total ToF repair, and to compare the long-term outcomes between TAP and NTAP methods.

**Materials and Methods.** This retrospective study included 132 consecutive patients diagnosed with ToF who underwent total repair at a single institution. Prenatal diagnosis was established in 61 patients (50.0 %). Classic ToF was diagnosed in 127 patients (96.2 %), while double outlet right ventricle with tetralogy-type anatomy was identified in 5 patients (3.8 %).

Additionally diagnosed: right aortic arch in 27 patients (20.5 %), PA branch stenosis in 13 (9.8 %), persistent left superior vena cava in 7 (5.3 %), additional muscular VSDs in 3 (2.3 %), vascular ring in 3 (2.3 %), and a circumflex aortic arch in 1 patient (0.75 %). Genetic abnormalities were present in 12 patients (9.1 %), including trisomy 21 (n=5), Di-George syndrome (n=5), and unspecified chromosomal abnormalities (n=2). Comorbid conditions were identified in 5 patients (3.8 %) and included: anorectal fistula (n=1), CHARGE syndrome (n=1), obstructive hydrocephalic syndrome (n=1), rhabdomyoma (n=1), and hypospadias (n=1). Previous interventions (all balloon pulmonary valvuloplasty) were performed in 16 patients (12.1 %), with a median of 4.22 months [3.37; 6.28] (range: 0.93 to 10.2 months) prior to total repair. The mean age at the time of surgery was 9.03 ± 4.33 months, and the mean body weight – 7.6 ± 1.4 kg. (Table 1) The mean Nakata index prior to surgery was 171.4 ± 33.6 $mm^2/m^2$.

**Table 1**

*Preoperative characteristics of patients with ToF*

| Parameter | Total cohort (n=132) |
|---|---|
| Prenatal diagnosis, n (%) | 61 (50.0) |
| Genetic abnormalities, n (%) | 12 (9.1) |
| Concomitant anomalies, n (%) | 5 (3.8) |
| Sex (male), n (%) | 81 (61.4) |
| Previous intervention (BPVP), n (%) | 16 (12.1) |
| The mean age at the time of surgery, months | 9.03 ± 4.33 |
| The mean body weight, kg | 7.6 ± 1.4 |
| ***Additional congenital anomalies*** | |
| Right aortic arch, n (%) | 27 (20.5) |
| PA branches stenosis, n (%) | 13 (9.8) |
| Persistent left superior vena cava, n (%) | 7 (5.3) |
| Additional muscular VSDs, n (%) | 3 (2.3) |
| Vascular ring, n (%) | 3 (2.3) |
| Circumflex aortic arch, n (%) | 1 (0.75) |

The study analyzed baseline patient characteristics; preoperative, intraoperative, and postoperative measurements of PV, RVOT dimensions and RVOT pressure gradients, and key echocardiographic parameters during the long-term follow-up period. The primary endpoint for determining predictors of RVOTO was the occurrence of significant RVOTO requiring reoperation.

Statistical analysis included the use of ROC curves, calculation of the area under the curve (AUC), threshold values, sensitivity, and specificity. Comparison of quantitative data between groups was performed using Student's t-test for normally distributed variables and the Mann–Whitney U test for non-parametric data.

**Results.** A valve-sparing repair (NTAP) was performed in 109 patients (82.6 %), while 23 patients (17.4 %) underwent total repair with PV annulus incision and transannular patching (TAP).

In the TAP group, the median Hegar z-score before annulus incision was -4.4 (range: -8.4 to -0.9), and after the procedure, it was -0.8 (range: -1.8 to 2.0). The mean RVOT pressure gradient measured via ITEE after PV plasty was 13.2 ± 7.2 mmHg, while the median RVOT diameter z-score was 0 (range: -6.6 to 1.8). The average Prv/Plv ratio was 76.8 ± 12.3% (Table 2). During surgery, 3 patients required additional resection of residual RVOT tissue,

**Table 2**
*Intraoperative and postoperative characteristics in both patient groups*

| Parameter | TAP (n=23) | NTAP (n=109) | P<0,05 |
|---|---|---|---|
| Hegar z-score before PV plasty | -4.4 (-8.4; -0.9) | -3.1 (-8.4; 0.8) | 0.76 |
| ***After PV plasty*** | | | |
| Hegar z-score | 0.8 (-1.8; 2.0) | -1 (-3.5; -0.9) | 0.03* |
| RVOT pressure gradient (ITEE), mmHg | 13.2 ± 7.2 | 27.1 ± 9,0 | <0.0001* |
| RVOT z-score | 0 (-6.6; 1.8) | -1,4 (-8.4; 0.9) | 0.073 |
| RV/LV ratio, % | 76.8 ± 12.3 % | 69.8 ± 12.6 | 0.022* |
| RVOT pressure gradient (direct measurement), mmHg | 20.4 ± 9.4 | 21.5 ± 8.5 | 0.32 |
| Duration of artificial lung ventilation, hours | 23 (3; 227) | 16 (1; 138) | 0.0073* |
| ICU stay, days | 4 (2; 18) | 3 (2; 19) | 0.0014* |

*Note*: * – the difference is statistically significant

causing significant obstruction. The median duration of artificial lung ventilation after surgery was 23 hours (range: 3 to 227 hours), and the median length of stay in the intensive care unit (ICU) was 4 days (range: 2 to 18 days) (Table 2). Pulmonary artery branch plasty due to significant stenosis was required in 2 patients (8.7 %) during the same hospitalization.

In the NTAP group, the median Hegar z-score before PV plasty was -3.1 (range: -8.4 to 0.8), and after – -1.0 (range: -3.5 to 0.9). The mean RVOT pressure gradient via ITEE postoperatively was 27.1 ± 9.0 mmHg, and the median RVOT diameter z-score was -1.4 (range: -8.4 to 0.9). The mean Prv/Plv ratio was 69.8 ± 12.6 % (Table 2). Intraoperatively, 6 patients (5.5 %) required additional resection of RVOT tissue due to significant residual obstruction. The median duration of artificial lung ventilation was 16 hours (range: 1 to 138 hours), and ICU stay was 3 days (range: 2 to 19 days) (Table 2). One patient (0.92 %) required reoperation during the same hospitalization due to residual ventricular septal defect (VSD) shunting.

*Long-Term Outcomes*

The median follow-up period was 5.2 years (range: 0.4 to 8.57 years). Two patients were lost to follow-up – one from the TAP group and one from the NTAP group.

In the TAP group (n = 22), the mean residual RVOT pressure gradient at the last follow-up visit was 14.9 ± 8.7 mmHg, and the median PV z-score was 0.5 (range: -1.7 to 3.6) (Figure 1, Figure 2, Table 3). During follow-up, 8 patients (36.3 %) required reinterventions at a mean of 1.35 years postoperatively (range: 0.1 to 8.3 years) (Table 3). One patient (4.5 %) required RVOT plasty due to severe RVOTO; PA trunk and branches plasty, resection of residual infundibular stenosis, and closure of re-VSD were required in another patient (4.5 %). Two patients (9.1 %) underwent PA branches plasty, and four patients (18.2 %) underwent RV–PA conduit implantation due to severe PV insufficiency and progression of RV systolic dysfunction. Valve implantation in the RVOT position was performed on average 6.1 years (range: 1.3 to 8.3 years) after total repair. At the time of the last evaluation, severe PV regurgitation was present in 15 patients (68.2 %), moderate regurgitation in 3 (13.6 %), and mild regurgitation in 4 (18.2 %) patients – all of whom had already undergone RV–PA conduit implantation owing to severe PV insufficiency.

In the NTAP group (n = 108), the mean residual RVOT pressure gradient during follow-up was 22.45 ± 9.7 mmHg, and the median PV z-score was -0.1 (range: -2.7 to 2.2) (Figure 1, Figure 2, Table 3). Twelve patients (11.1 %) required reintervention at a mean of 1.24 years postoperatively (range: 0.67 to 5.5 years) (Table 3).

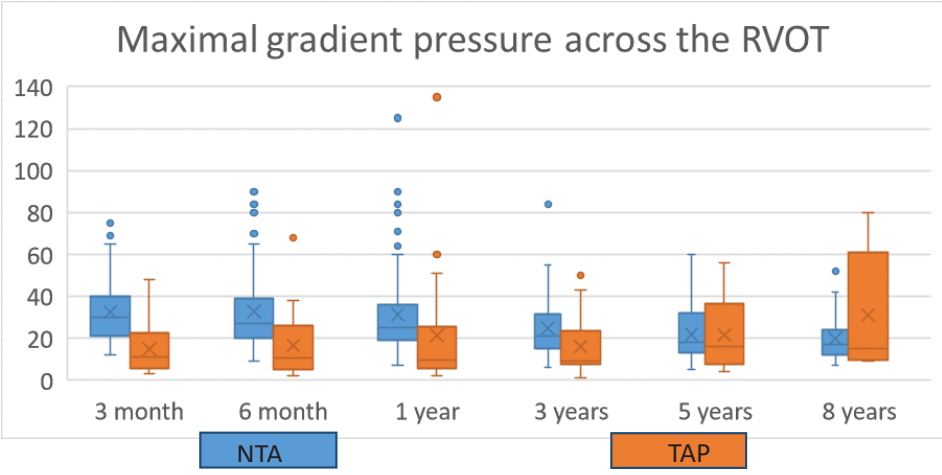


**Figure 1.** *Dynamics of changes in the maximum pressure gradient across the right ventricular outflow tract (RVOT) in both patient groups over an 8-year follow-up period*

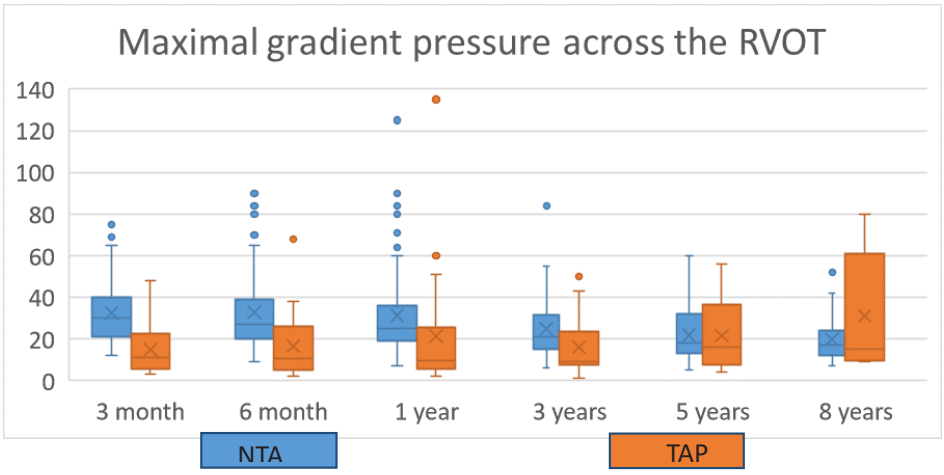


**Figure 2.** *Dynamics of the PV z-score after ToF repair in both patient groups over an 8-year follow-up period*

**Table 3**

*Postoperative characteristics of two groups in the long-term period*

| Parameter | TAP (n=22) | NTAP (n=108) | P<0,05 |
|---|---|---|---|
| RVOT pressure gradient, mmHg | 14.9 ± 8.7 | 22.4 ± 9.7 | 0.004* |
| PV z-score | 0,5 (-1.7; 3.6) | -0.1 (-2.7; 2.2) | 0.25 |
| Reoperations on the RVOT | 8 (36.3 %) | 12 (11.1 %) | 0.0029* |

*Note*: * – the difference is statistically significant

Four patients (3.7 %) underwent balloon pulmonary valvuloplasty (BPVP), five patients (4.6 %) underwent excision of residual subvalvular obstruction with preservation of the pulmonary valve, and three patients (2.7 %) required TAP due to severe RVOTO and PV annulus hypoplasia. During long-term follow-up, PV was competent in nine patients (8.3 %), 50 patients (46.3 %) had mild PV regurgitation, 12 patients (11.1 %) had mild-to-moderate regurgitation, 21 patients (19.5 %) had moderate regurgitation, nine patients (8.3 %) had moderate-to-severe regurgitation, and seven patients (6.5 %) had severe PV regurgitation, including three patients who underwent TAP due to severe RVOTO and PV annulus hypoplasia.

**Thus,** over the 8-year follow-up period, patients in the TAP group required significantly more RVOT-related reoperations compared to the NTAP group (8 patients, 36.3 % vs 12 patients, 11.1 %; p = 0.0029) (Tab.3). This difference is primarily due to the need for RV–PA conduit implantation in TAP patients resulting from severe PV insufficiency, and the number of such reoperations is expected to increase further over time.

The graph presents the dynamics of the maximal pressure gradient across the RVOT in the two groups over an eight-year period following surgical correction. The data are shown as a time-distributed chart, with measurements taken at the following postoperative intervals: 3 months, 6 months, 1 year, 3 years, 5 years, and 8 years after total repair.

In the early postoperative period, both groups exhibited relatively elevated RVOT pressure gradients, with mean values around 30–40 mmHg in the NTAP group and 15–25 mmHg in the TAP group. During the first year of follow-up, the median gradients remained stable; however, isolated cases of increasing gradients exceeding 60 mmHg were observed, reflecting progressive RVOTO and the need for reintervention.

In the subsequent years (up to 3–5 years), the gradients remained stable or slightly decreased, likely due to somatic growth and annular enlargement of the PV. Interestingly, at eight years of follow-up, the TAP group demonstrated an increase in both the median RVOT gradient and its variability, with several cases exceeding 80 mmHg. This trend is attributed to rising gradients across the RV–PA conduit, which required reintervention with conduit implantation in 18.2 % of patients in this group.

The graph presents changes in the pulmonary valve Z-score over time in groups following total repair of ToF. Measurements were taken at 3 months, 1 year, 3 years, and 8 years postoperatively.

At all follow-up points, the Z-score in the TAP group remained consistently higher than in the NTAP group, possibly indicating a larger annular size following TAP repair. In the TAP group, median Z-scores remained positive (0.5-2.0), whereas in the NTAP group, values hovered around 0 or were slightly negative. The lowest Z-scores in the NTAP group were recorded at 3 months postoperatively (with some values below -4), suggesting relative annular hypoplasia in this cohort. By 8 years, Z-score values remained stable in both groups, although a higher proportion of patients in the TAP group exhibited supranormal Z-scores, potentially associated with annular dilation after transannular patching.

Overall, 14 patients (10.6 %) from both groups required reoperation during the follow-up period due to

residual RVOTO. Analysis of preoperative, intraoperative, and postoperative echocardiographic and hemodynamic parameter (PV z-score, RV/LV pressure ratio, RV–PA gradient (measured directly and via ITEE), and RVOT z-score) revealed that the most powerful predictor of significant RVOTO was the RVOT z-score, measured intraoperatively via ITEE. RVOT z-score < -3.2 demonstrated high sensitivity (85.0 %) and specificity (90.1 %), with an area under the ROC curve (AUC) of 0.925, indicating strong diagnostic accuracy.

Other intraoperative parameters, such as Prv/Plv ratio, RV–PA gradient and PV z-score, showed substantially lower predictive ability. Thus, for Prv/Plv ratio with a cutoff > 0.78 had 60 % sensitivity, 67.6 % specificity, and AUC = 0.673. For directly measured RV–PA gradient with a threshold > 27 mmHg had 47.4 % sensitivity, 73.9 % specificity, and AUC = 0.583 and for RV–PA gradient via ITEE with a cutoff > 39 mmHg showed 50.0 % sensitivity, 91.0 % specificity, and AUC = 0.721. For PV z-score at a threshold < -1.5 had 50.0 % sensitivity, 84.7 % specificity, and AUC = 0.659 (Figure 3).

Furthermore, a correlation was identified between the RVOT z-score and the Prv/Plv ratio ($r = -0.58$, $p < 0.01$), indicating a certain interdependence between the anatomical and functional assessments of the RVOT. However, the RVOT z-score demonstrated a **superior predictive value** for determining the need for reintervention compared to the Prv/Plv ratio.

**Discussion.** Although the era of cardiac surgery began with the first total repair of ToF in 1954 by Lillehei C.W. [12], the investigation of surgical approaches and long-term outcomes of ToF repair remains highly relevant today. Reconstruction of the RVOT during ToF repair is a common procedure. While valve-sparing repair (non-transannular patch, NTAP) is generally preferred, determining which patients are suitable candidates for this approach remains controversial [13].

According to Linda J. Schulte et al. [14], valve-sparing repair is considered safe in patients with a PV Z-score > -2. In a meta-analysis by Sitanggang et al. [15], a PV z-score ≥ -2.59 (sensitivity 81.3 %, specificity 75 %) was associated with a lower risk of residual RVOTO following NTAP. In our study, the lowest risk of reintervention was observed in patients with a PV z-score ≥ -1.5 (sensitivity 50.0 %, specificity 84.7 %, AUC = 0.659).

Siddiqi U. et al. [16] identified the intraoperative RVOT gradient with a threshold > 45 mmHg assessed by ITEE as the most reliable predictor of reintervention. This finding closely aligns with our result, where an intraoperative RV–PA gradient > 39 mmHg predicted the

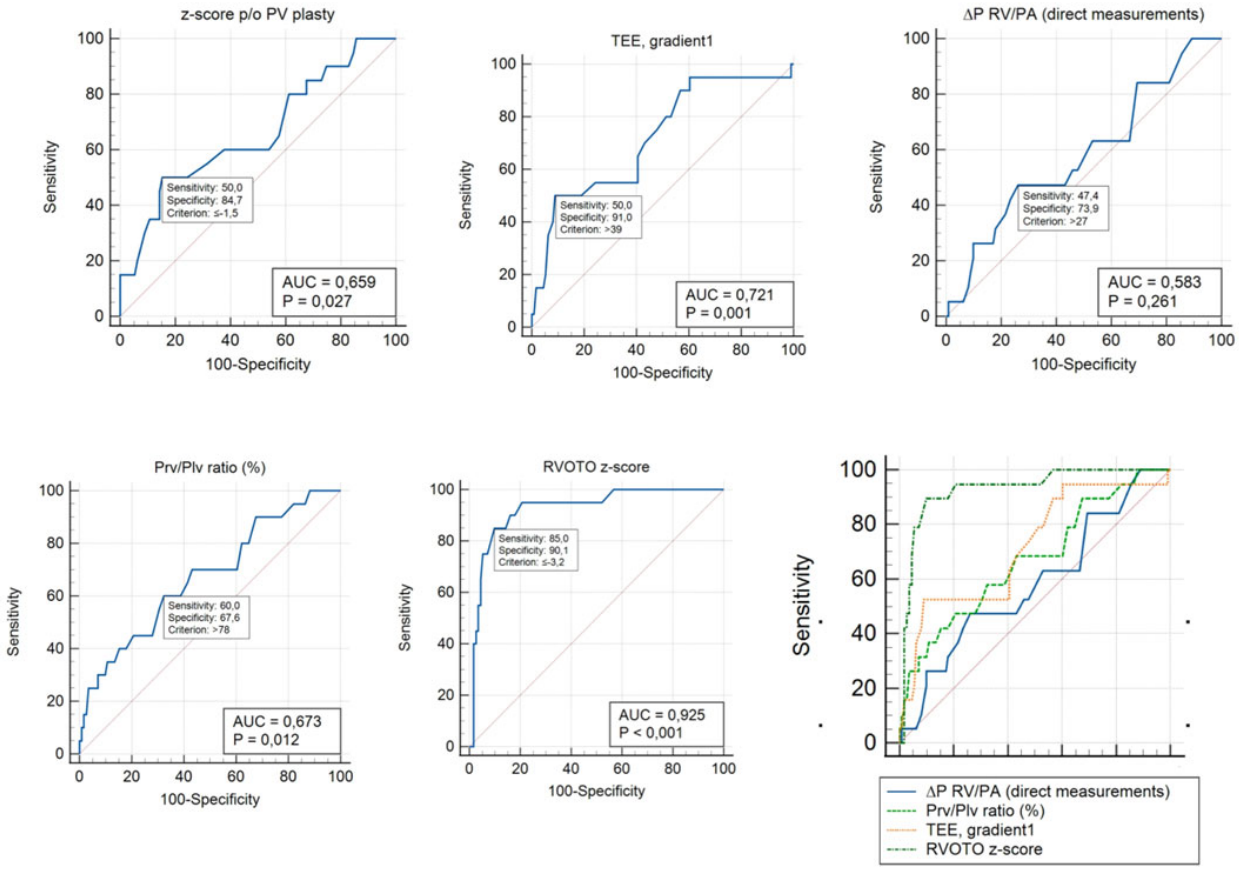


**Figure 3.** *Receiver operating characteristic (ROC) curves of individual parameters predicting residual RVOT obstruction in patients after tetralogy of Fallot (ToF) repair*

need for reoperation due to RVOTO (sensitivity 50.0 %, specificity 91.0 %, AUC = 0.721).

The prognostic value of the Prv/Plv ratio remains controversial. Boni L. et al. (2009) reported successful valve-sparing ToF repair in patients with intraoperative PV z-score ≥ -3 and postoperative Prv/Plv < 0.9, provided stable hemodynamics and absence of subvalvular stenosis [17]. Hickey et al. found that a postoperative R systolic pressure < 50 mmHg was associated with a lower risk of RVOTO [6]. Toshkhani D. et al. [18] also emphasized the relevance of intraoperative gradients but noted their susceptibility to variation based on anesthesia and systemic hemodynamics. In our study, a Prv/Plv ratio > 0.78 predicted residual RVOTO with a sensitivity of 60 % and specificity of 67.6 % (AUC = 0.673). These conflicting data regarding hemodynamic parameters highlight the advantage of anatomical indices, such as the RVOT z-score, which are less affected by physiological fluctuations.

According to our previously published data (2020) [10], an RVOT z-score < -3.2 had the highest predictive value among all assessed parameters for identifying significant residual RVOTO (AUC = 0.979; p < 0.0001). In the current study, conducted on a larger patient cohort with extended follow-up, the RVOT z-score < -3.2 again demonstrated the highest sensitivity (85.0 %) and specificity (90.1 %) for predicting RVOT obstruction (AUC = 0.925; p < 0.001), compared to other echocardiographic and hemodynamic parameters (PV z-score, Prv/Plv ratio, direct RV-PA gradient, and ITEE data).

Thus, the RVOT z-score proved to be the most effective intraoperative predictor and may be recommended for routine use during ToF total repair. This parameter may aid in the development of a standardized intraoperative decision-making algorithm. Based on our data, if the intraoperative PV z-score measured with a Hegar after commissurotomy is ≥ -3.2, valve-sparing repair can be safely performed. In cases with PV z-score < –3.2, TAP repair is indicated. If the PV z-score is ≥ -3.2 after infundibulectomy, it is necessary to assess the RVOT z-score. When the RVOT z-score is ≥ -3.2 based on ITEE findings, PV annulus can be preserved and the operation completed. However, if the RVOT z-score is < -3.2, it is advisable to return to cardiopulmonary bypass and perform a more aggressive resection of the subvalvular structures. Following this algorithm may reduce the number of reoperations due to residual RVOTO, broaden the indications for valve-sparing surgery, and decrease the number of RVOT interventions required due to severe PV insufficiency in the long term.

**Conclusions.** The long-term results of ToF repair with TAP and NTAP differ in the presence of reoperations on the RVOT due to residual RVOTO and PV insufficiency (8 (36.3 %) vs 12 (11.1 %), 0.0029). RVOT z-score < -3.2 was identified as the most accurate intraoperative predictor of significant RVOTO and can be used to guide surgical decision-making. Intraoperative assessment of both RVOT z-score and PV z-score during ToF repair may reduce the need for reinterventions due to residual RVOTO, broaden the indications for valve-sparing procedures, and decrease the incidence of late RVOT surgeries caused by severe PV insufficiency.

***Prospects for further research.*** Future studies should focus on validating the predictive value of the RVOT z-score in larger patient cohorts and different surgical centers. Development of standardized intraoperative protocols incorporating RVOT z-score may improve surgical decision-making and reduce reintervention rates. Additionally, combining anatomical and functional parameters into integrated risk models may enhance the selection of valve-sparing techniques and guide long-term follow-up strategies in patients after ToF repair.

**Compliance with ethical requirements.** The study was conducted in accordance with the core principles of the Declaration of Helsinki (1975), as revised in 2000. All diagnostic and therapeutic procedures, as well as the evaluation of clinical outcomes, were reviewed and approved by the bioethics committees of the Center for Pediatric Cardiology and Cardiac Surgery and the Bogomolets National Medical University. Clinical and laboratory assessments were carried out only after written informed consent was obtained from the patients' legal representatives.

**Funding and conflict of interest.** The authors report no conflicts of interest related to this publication. This study received no external financial support.

**Author contributions.** A. Mykhailovska – performed the literature review, data collection and prepared the draft of the article;

O. Borodinova – performed the data collection, critical review of the content and statistical analysis of the data;

V.-S. Galich – performed the stylistic correction of the article and literature review.

All authors made a significant contribution to the preparation of this article and approved its final version.

**Список використаної літератури**
**References**

1. Kordopati-Zilou K, Sergentanis T, Pervanidou P, Sofianou-Petraki D, Panoulis K, Vlahos N, Eleftheriades M. Neurodevelopmental Outcomes in Tetralogy of Fallot: A Systematic Review. Children (Basel). 2022 Feb 15;9(2):264. https://doi.org/10.3390/children9020264
2. Fallot E. Contribution a lanatomie pathologique de la maladie bleue (cyanotic cardiaque). Marseille méd 1888;25:77,138,207,341,403. https://numerabilis.u-paris.fr/ressources/pdf/medica/bibnum/epo0300/epo0300.pdf
3. Vricella LA, Jacobs ML, Cameron DE. The birth of a new era: the introduction of the systemic-to-pulmonary artery shunt for the treatment of cyanotic congenital heart disease. Cardiol Young. 2013 Dec;23(6):852-7. https://doi.org/10.1017/S1047951113001996

4. Gibbs JL, Rothman MT, Rees MR, Parsons JM, Blackburn ME, Ruiz CE. Stenting of the arterial duct: a new approach to palliation for pulmonary atresia. Br Heart J. 1992 Mar;67(3):240-5. https://doi.org/10.1136/hrt.67.3.240
5. Wei X, Li T, Ling Y, Chai Z, Cao Z, Chen K, Qian Y. Transannular patch repair of tetralogy of Fallot with or without monocusp valve reconstruction: a meta-analysis. BMC Surgery. 2022. Vol. 22, no. 1. URL: https://doi.org/10.1186/s12893-022-01474-6
6. Hickey E, Pham-Hung E, Halvorsen F, Gritti M, Duong A, Wilder T, Caldarone CH, Redington A, Arsdell G.V. Annulus-Sparing Tetralogy of Fallot Repair: Low Risk and Benefits to Right Ventricular Geometry. The Annals of Thoracic Surgery. 2018. Vol. 106, no. 3. P. 822–829. https://doi.org/10.1016/j.athoracsur.2017.11.032
7. Symakani A, Genuchten V, Zandbergen LM, et al. The right ventricle in tetralogy of Fallot: adaptation to sequential loading. Front Pediatr 2023;11:1098248. https://doi.org/10.3389/fped.2023.1098248
8. Ganni E, Yen Ho S, Reddy S, Therrien J, Kearney K, Roche SL, Dimopoulos K, Mertens LL, Bitterman Y, Friedberg M, Saraf A, Marelli A, Alonso-Gonzalez R. Tetralogy of Fallot Across the Lifespan: A Focus on the Right Ventricle. CJC Pediatr Congenit Heart Dis. 2023 Oct 20;2(6Part A):283-300. https://doi.org/10.1016/j.cjcpc.2023.10.009.
9. Miller J.R., Stephens EH, Goldstone AB, Glatz AC, Kane L, et al. The American Association for Thoracic Surgery (AATS) 2022 Expert Consensus Document: Management of infants and neonates with tetralogy of Fallot. The Journal of Thoracic and Cardiovascular Surgery. 2022. URL: https://doi.org/10.1016/j.jtcvs.2022.07.025
10. Olga Borodinova, Yaroslav Mykychak, Illya Yemets. Transesophageal Echocardiographic Predictor of Significant Right Ventricular Outflow Tract Obstruction After Tetralogy of Fallot Repair. Seminars in Thoracic and Cardiovascular Surgery. 2020;2(32):282-289. https://doi.org/10.1053/j.semtcvs.2019.09.011
11. Lillehei CW, Cohen M, Warden HE, et al. Direct vision intracardiac surgical correction of the tetralogy of Fallot, Pentalogy of Fallot, and pulmonary atresia defects; report of first ten cases. Ann Surg 1955;142:418-42. https://doi.org/10.1097/00000658-195509000-00010
12. Sen DG, Najjar M, Yimaz B, Levasseur SM, Kalessan B, Quaegebeur JM, Bacha EA. Aiming to Preserve Pulmonary Valve Function in Tetralogy of Fallot Repair: Comparing a New Approach to Traditional Management. Pediatr Cardiol. 2016 Jun;37(5):818-25. https://doi.org/10.1007/s00246-016-1355-1
13. Blais S, Marelli A, Vanasse A, et al. Comparison of long-term outcomes of valve-sparing and transannular patch procedures for correction of tetralogy of Fallot. JAMA Netw Open 2021;4:e2118141. https://doi.org/10.1001/jamanetworkopen.2021.18141.
14. Linda J. et al. Evolution of Pulmonary Valve Management During Repair of Tetralogy of Fallot: A 14-year Experience. The Annals of Thoracic Surgery. 2023, Volume 115, Issue 2, 462 – 469. https://doi.org/10.1016/j.athoracsur.2022.05.063
15. Sitanggang JS, Purba S, Fakhri D, Busro PW, Arvant A Z. Meta-analysis and systematic review of pulmonary valve annulus Z-score as a predictor of valve preservation in Tetralogy of Fallot right ventricle outflow tract reconstruction. 2025. Cardiology in the Young. medRxiv https://doi.org/10.1101/2025.01.31.25321449.
16. Siddiqi U, Adewale A, Pena E, Schulz K, Ilbawi M, El-Zein C, Vricella L, Hibino N. Preserving the pulmonary valve in Tetralogy of Fallot repair: Reconsidering the indication for valve-sparing. J Card Surg. 2022 Dec;37(12):5144-5152. https://doi.org/10.1111/jocs.17156.
17. Boni L, García E, Galletti L, Pérez A, Herrera D, Ramos V, et al. Current strategies in tetralogy of Fallot repair: pulmonary valve sparing and evolution of right ventricle/left ventricle pressures ratio. Eur J Cardiothorac Surg. 2009 May;35(5):885-9; discussion 889-90. https://doi.org/10.1016/j.ejcts.2009.01.016
18. Toshkhani D, Arya VK, Kajal K, Thingnam SKS, Rana SS. Comparison of right ventricular outflow tract gradient under anesthesia with post-operative gradient in patients undergoing tetralogy of Fallot repair. Ann Pediatr Cardiol. 2021 Jan-Mar;14(1):18-25 https://doi.org/10.4103/apc.apc_147_19

## Довгострокові результати корекції тетради Фалло зі збереженням клапана легеневої артерії або з трансанулярною латкою

Бородінова О.С., Михайловська А.О.

ДУ «Науково-практичний медичний центр дитячої кардіології та кардіохірургії МОЗ України», м. Київ, Україна

**Резюме**

**Вступ.** Тетрада Фалло (ТФ) – поширена ціанотична вроджена вада серця, хірургічне лікування якої спрямоване на усунення обструкції вихідного тракту правого шлуночка (ВТПШ). Вибір між трансанулярною пластикою (ТАР) та клапанозберігаючою технікою (NTAP) залишається дискусійним, що пов`язано з наявністю недоліків кожного з методів – вираженою регургітацією на клапана легеневої артерії та ризиком залишкової обструкції.

**Мета.** Оцінити прогностичну цінність інтраопераційних ехокардіографічних параметрів, включно з RVOT z-score, для діагностики значимої залишкової обструкції ВТПШ у дітей з ТФ та проаналізувати їх довгострокові результати після проведення радикальної корекції вродженої вади серця.

**Матеріали та методи.** Це ретроспективне одоцентрове дослідження включало 132 пацієнти, які отримали радикальну корекцію ТФ. Інтраопераційна черезстравохідна ехокардіографія (ITEE) застосовувалась для оцінки анатомії ВТПШ та гемодинаміки. Оцінювалися базові характеристики та періопераційні показ-

ники розмірів клапана легеневої артерії, ВТПШ, градієнтів тиску на ньому та зміни ехокардіографічних показників у віддаленому періоді. Статистичний аналіз включав побудову ROC-кривих, розрахунок AUC, визначення порогових значень, чутливості та специфічності. Порівняння груп проводилося з використанням t-критерію Стьюдента або критерію Манна–Уітні, залежно від розподілу.

**Результати.** У 82,6 % пацієнтів було виконано NTAP, у 17,4 % – TAP. У групі TAP значно частіше спостерігалися реоперації, пов'язані з ВТПШ (36,3 % проти 11,1 %; p = 0,0029), переважно через виражену недостатність клапана легеневої артерії (ЛА) та потребу в імплантації правошлуночково-легеневого кондуїта. Найбільш точним предиктором значимої обструкції ВТПШ, що вимагала повторного втручання, був інтраопераційний RVOT z-score < -3,2, визначений за допомогою ITEE (AUC = 0,925, чутливість 85,0 %, специфічність 90,1 %). Інші параметри, такі як співвідношення Prv/Plv, градієнт тиску правим шлуночком та ЛА між та z-score клапана ЛА, мали нижчу прогностичну точність.

**Висновки.** Частота повторних втручань на ВТПШ була вищою після TAP, ніж після NTAP (36,3 % проти 11,1 %, p = 0,0029), переважно через виражену недостатність клапана ЛА та обструкцію ВТПШ. Інтраопераційний RVOT z-score < -3,2 був найсильнішим предиктором значимої обструкції ВТПШ. Оцінка ВТПШ і z-score клапана ЛА під час операції може зменшити потребу в реопераціях, сприяти вибору клапанозберігаючої тактики та знизити ризик наступних хірургічних втручань через недостатність клапана легеневої артерії.

***Ключові слова:*** *вроджені вади серця, хірургічна корекція, пренатальна діагностика, збагачення легеневого кровотоку, ендоваскулярні втручання, трансанулярна пластика, клапанозберігаюча операція.*

Стаття надійшла в редакцію / Received: 31.07.2025
Після доопрацювання / Revised: 12.08.2025
Прийнято до друку / Accepted: 27.08.2025