The THAI *Journal of* SURGERY

Official Publication of The Royal College of Surgeons of Thailand

Vol. 41 **October - December 2020** **No. 4**

The THAI Journal of SURGERY 2020;41(4):115-125.
Official Publication of The Royal College of Surgeons of Thailand

Original Article

Right Ventricular Outflow Tract Reconstruction Using Transannular Patch with Pericardial Monocusp in Patients with Tetralogy of Fallot

Nisit Poolthananant, MD* **Teera Hemrungrote, MD***

Prapat Ausayapao, MD† **Jitrawee Disrattakit, MD†**

Ketsarin Sirichuanjun‡ **Damri Sethachinda, MD***

* *Cardiothoracic Unit, Department of Surgery, Maharat Nakhon Ratchasima Hospital, Nakhon Ratchasima, Thailand*
† *Cardiology Unit, Department of Pediatrics, Maharat Nakhon Ratchasima Hospital, Nakhon Ratchasima, Thailand*
‡ *Doctoral candidate, Department of Epidemiology and Biostatistics (International Program), Faculty of Public Health, Khon Kaen University, Thailand*

Received for publication 14 June 2020; Revised 29 July 2020; Accepted 30 July 2020

Abstract

Background: Tetralogy of Fallot is the most common cyanotic heart disease in Thailand. Many patients have stenosis involving the pulmonic valve (PV) annulus which requires complex surgical procedures to relieve the obstruction at this level, especially by using a transannular patch (TAP). We analyzed the early results of TAP with pericardial monocusp, and compared this with the results of non-TAP operations.

Methods: A retrospective medical record review was conducted which included 69 patients who underwent definitive cardiac repair between January 2009 to December 2018. The results of patients who underwent TAP with the pericardial monocusp technique were compared to those who underwent the non-TAP technique.

Results: There were 30 patients in the non-TAP group (mean age 92.6 months) and 39 patients in the TAP group (mean age 90.4 months). Most patients in both groups had favorable and comparable preoperative characteristics, except the mean PV annulus diameter in the TAP group was smaller than that in the non-TAP group (mean z-score in the TAP group, -2.2, in the Non-TAP group, 0.6, p-value < 0.001). Bypass times were longer in the TAP group (non-TAP group 107± 42 mins, TAP group 138 ± 37 mins, p-value 0.002). Cross-clamp times were longer as well (Non-TAP group 79 ± 27 mins, TAP group 102 ± 27 mins, p-value 0.001). In-hospital mortality rate was higher in the TAP group (Non-TAP group 7%, TAP group 23%).

Correspondence address: *Nisit Poolthananant, MD, Cardiothoracic Unit, Department of Surgery, Maharat Nakhon Ratchasima Hospital, 49, Chang Phueak Rd, Mueang District, Nakhon Ratchasima; Tel.: +660 4423 5469, Fax: +660 4424 6389; E-mail: joenisit@gmail.com*

Overall survival was 88.4 % at 2 years (96.7% in non-TAP group, and 82.1% in TAP group). After exclusion of in-hospital deaths from both groups, freedom from at least moderate pulmonary stenosis or regurgitation at 2 years was 93.3 % in the non-TAP group, and 61.1 % in the TAP group, whereas freedom from re-intervention was excellent and comparable in both groups (Non-TAP group 100%, TAP group 96.4%).

Conclusion: TAP with monocusp technique can adequately relieve PV stenosis with good valvular function at least in the early period after surgery. Although the in-hospital mortality was higher with TAP, increasing experience should eventually reduce the mortality rate.

Keywords: Right ventricular outflow tract reconstruction, Tetralogy of Fallot, Transannular patch, Monocusp

Introduction

Tetralogy of Fallot (TOF) is the most common congenital cyanotic heart disease in Thailand. Its prevalence is approximately 2% of all congenital heart diseases[1]. A surgical program for TOF was established since 2009 at Maharat Nakhon Ratchasima hospital. Our program was developed to achieve the best outcome for patients with this complicated condition. TOF is a disease consisting of 4 lesions: right ventricular outflow tract stenosis (RVOT stenosis); ventricular septal defect (VSD); overriding of aorta; and, right ventricular hypertrophy. These defects cause difficulty for venous blood to pass from the right ventricle (RV) to the lungs. Venous blood from the RV needs to shunt through the VSD, forcing deoxygenated blood to mix with oxygenated blood before being pumped to the rest of the body, resulting in cyanosis. The severity of the disease depends on the RVOT morphology[2,3]. Surgical principles for correcting TOF include: (1) eliminating intracardiac shunt (2) reduction of RV pressure and volume load by relieving the RVOT stenosis, and (3) preservation of normal cardiac function. Surgery can be performed in one setting (primary repair). However, if the patient's size is too small for this complex operation, a staged procedure can be used, wherein a palliative procedure can be performed initially followed by definitive repair later in life[2,4-8].

The pulmonic valve (PV) separates the RV from the pulmonary artery. Thus, certain pathologies of the pulmonic valve can decrease the amount of blood passing to the lungs and affecting the function of the RV. PV with small annular size is one major risk factor for operative mortality[9]. In 1959, the transannular patch (TAP) technique was developed to enlarge PV annulus to deal with this problem[10]. The disadvantage of pure TAP is the inevitable development of postoperative severe pulmonary regurgitation, causing RV volume loading and increasing mortality in this subgroup of TOF patients, as compared to those with no need for transannular patch[10,11]. In 1994, a technique adding pericardial monocusp to TAP was developed[12]. This technique corrected the problem of pulmonic regurgitation by adding a reconstructed neo-pulmonic valve. In the present study, we analyzed the early outcome of transannular patch with pericardial monocusp at our institution.

Materials and Methods

The present study was approved by our institutional review board/research ethics committee. All medical records of patients who underwent definitive repair at our center between January 2009 to December 2018 were reviewed.

Patients with TOF pathophysiology including TOF with pulmonic stenosis (PS) or pulmonary atresia (PA) and double outlet of right ventricle with VSD and pulmonic stenosis (DORV with VSD and PS) were included in the study. All patients underwent definitive repair as a primary procedure or as a secondary procedure after palliative surgery. Patients who underwent palliative surgery alone and who underwent definitive repair using RVOT reconstruction other than the conventional non-TAP or TAP techniques were excluded.

Information retrieved preoperatively included demographic data, results of laboratory investigations, data from preoperative transthoracic echocardiography and cardiac catheterization. PV annulus size and z-scores were calculated using the method described by Boston Children's Hospital Group[13,14]. The size of pulmonary artery branches was evaluated and represented in terms of the McGoon ratio, which is calculated by summing the right and left pulmonary artery diameters at the point of first branching, and dividing by the diameter of descending aorta at the diaphragmatic level.

Definitive repair was performed under moderate (28°C to 32°C) hypothermic cardiopulmonary bypass

with single-dose cold crystalloid cardioplegia (Histidine-Tryptophan-Ketoglutarate solution). After the heart ceased beating, the VSD was closed trans-atrially using a patch of Dacron or autologous pericardium. RVOT obstruction was relieved by using combined trans-atrial and trans-pulmonary infundibulectomy. If the intraoperative measurement of the PV z-score revealed adequate size, e.g., z-score ≥ -2.0, the procedure ends at this point. If the PV z scores were less than -2.0 preoperatively or intraoperatively, we proceeded to perform annular enlargement of the PV by using transannular patch with pericardial monocusp augmentation as described by Gundry et al[12].

In summary, the surgical procedures included: (1) infundibulotomy by longitudinal incision extending from RVOT across PV annulus to the main pulmonary artery; (2) preparation of the autologous monocusp by cutting a triangular-shaped piece of pericardium; (3) placement of monocusp by suturing to the edge of the infundibulotomy up to the level of PV annulus. The upper edge of the monocusp was left unattached, so that the monocusp would lie against the posterior wall of the MPA and function as a neo-pulmonic valve. Finally, (4) TAP made from autologous pericardium is placed, which serve as the anterior wall of infundibulotomy and the MPA (Figure 1). The width of the TAP is such that the new PV annulus has a z-score of 0.

Patients were divided into 2 groups depending on the RVOT management: the conventional, no transannular patch (Non-TAP) group, and the transannular patch with pericardial monocusp (TAP) group. Recorded perioperative and postoperative data included cardiopulmonary bypass (CPB) time; cross-clamp (XCL) time; any additional operations or re-operations in the same admission; the length of ICU stay; the length of hospital stay; and hospital mortality. Evaluation of PV function by echocardiography was performed after the repair.

Follow-up data collected included PV function and any further reinterventions. Reintervention was defined as any procedure performed in order to correct significant pulmonic regurgitation or stenosis after surgery. The procedures included balloon dilatation and re-operative surgery such as repeat transannular patch and pulmonic valve repair or replacement.

Primary outcomes of the study included in-hospital mortality and pulmonic valve function. Pulmonic valve function was measured via echocardiography in terms of degree of regurgitation/stenosis as recommended by the American Society of Echocardiography[15,16]. Secondary outcomes included the probabilities of freedom from at least moderate PR/PS, or re-intervention, up to 2 years.

Categorical data were summarized in terms of counts and percentages. Continuous data were summarized in terms of mean, standard deviation (SD), and range.

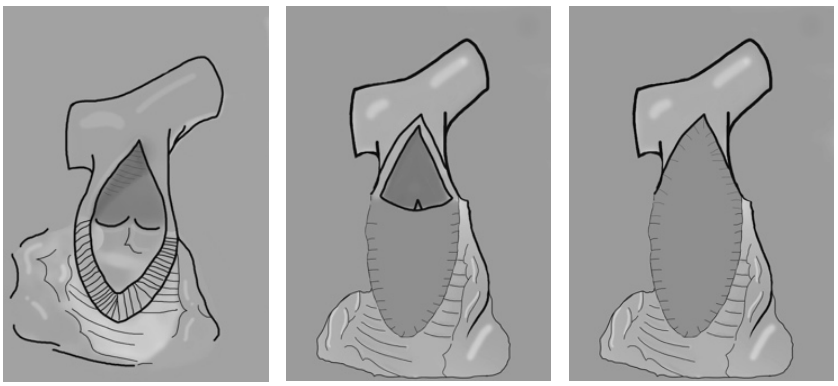

Figure 1 Demonstration of TAP with pericardial monocusp:
(a) Infundibulotomy by longitudinal incision extending from RVOT across PV annulus to main pulmonary artery
(b) Preparation of triangular-shaped autologous pericardium (monocusp) and placement by suturing to the edge of the infundibulotomy up to the level of PV annulus. The upper edge of monocusp was left freely mobile, to serve as a neo-valve.
(c) Placement of TAP to the edge of the infundibulotomy and MPA to serve as the roof.

Comparisons between groups were analyzed by using Student's *t* test for continuous variables and Pearson's Chi-square or Fisher's exact test for categorical variables. The Cox proportional hazard regression was used to determine significant associations between risk factors and outcomes, in terms of hazard ratios (HR) and 95% confidence intervals (CI). Significant p-values were defined as 0.05 or less.

Results

There were 79 patients with the diagnosis of TOF or its variants seen during the study period. Ten patients with the exclusion criteria were excluded, leaving a total of 69 patients in the study (Figure 2). Thirty patients underwent repair using the non-TAP technique and 39 patients underwent repair with the TAP technique.

Baseline characteristics are shown in Table 1. Repair of TOF was performed on patients with a mean the age of 74 months. The age at repair was not statistically different between the two groups. Most patients underwent definitive repair when their body weights were at least 15 kg. Approximately 46% of patients had PV z-scores not more than -2.0. The average PV z-scores in the TAP group was significantly less than that in the non-TAP group (-2.2 vs 0.6, *p*-value < 0.001). The prevalence of supravalvular pulmonic stenosis was significantly higher in the TAP group as compared to the non-TAP group (49% vs 3%, *p*-value < 0.001). Both groups had adequate size of pulmonary arteries, with average McGoon ratios > 2.0 (2.39 in the non-TAP group and 2.26 in the TAP group, *p*-value 0.716). Preoperative hematocrit was higher in the TAP group (48.7 vs 43.8, *p*-value 0.02). There were no statistically differences in RVOT gradient, RV end-diastolic pressure and repair strategy (staged repair or primary repair) between the 2 groups.

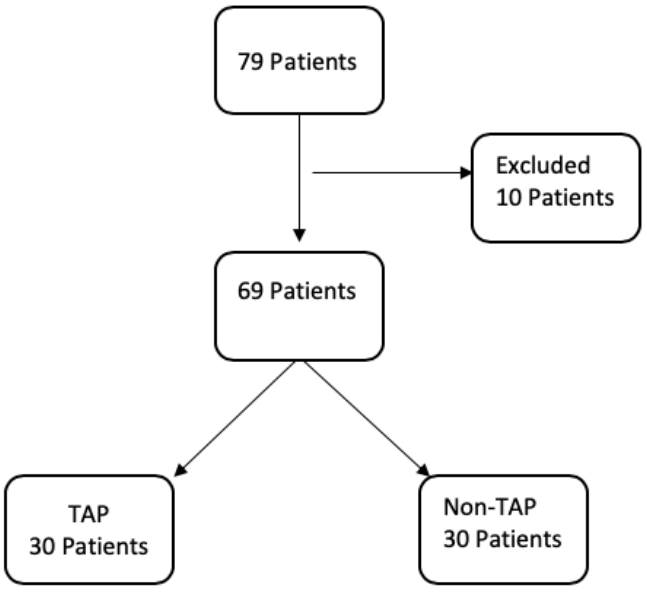

Figure 2 Flow chart of patient enrollment in the study

Operative times as reflected by CPB times and cross-clamp times, were longer for the TAP group (CPB time in the non-TAP group 107 ± 42 mins, TAP group 138 ± 37 mins, *p*-value 0.002; cross-clamp time in the non-TAP group 79 ± 27 mins, TAP group 102 ± 27 mins, *p*-value 0.001). There were significantly more additional operations in the non-TAP group, but the reoperation rates were not significantly different. The in-hospital mortality rates were 7% in non-TAP group and 23% in TAP group, but these were not statistically different. In the early era of our program (2009 to 2013), the mortality rate was 27%, which decreased to 21% in the later era (2014 to 2018); see Table 2.

Echocardiography was performed on 28 patients in the non-TAP group, and 36 patients in the TAP group. The proportion of patients who still had at least moderate pulmonic stenosis in the TAP group was higher than that in the non-TAP group, but this was of borderline significance. (4% in the non-TAP vs 28% in the TAP group, *p*-value 0.051). The proportion of patients who had no or mild PR in the TAP group was comparable to that in the non-TAP group (Table 3). The average ICU stay was 3.2 days in the non-TAP group and 4.7 days in the TAP group. The average hospital stay was 10.8 days in the non-TAP group vs 12.6 days in the TAP group. Neither the ICU stay nor hospital stay were significantly different between groups (Table 3).

The overall survival was 88.4 % at 2 years for both groups combined. The 2-year survival was 96.7% in the non-TAP group, and 82.1% in the TAP group (Figure 4). After exclusion of in hospital-mortality cases from both groups, the probability of freedom from at least moderate PR or PS at 2 years was 93.3 % in the non-TAP group, and 61.1 % in the TAP group, whereas the freedom from re-intervention at 2 years was 100% in the non-TAP group and 96.4% in the TAP group (Figure 5).

Univariable analysis revealed that possible risk factors for death were PV annulus z-score, RVEDP, primary repair, CPB time, MPA patch plasty and postoperative PS severity.

Table 1 Baseline characteristics of patients

Characteristics		Non-TAP	TAP	*p*-value
Total number (%)		30 (44)	39 (56)	
Female sex	Number (%)	7 (23)	16 (41)	0.122
Age (Months)	Range	24 to 528	36 to 432	0.916
	Mean	92.9	90.5	
Weight (kgs)	Range	12 to 59	12 to 71	0.927
	Mean	20.4	20.1	
	< 15 kgs: number (%)	9 (30)	11 (28)	
	≥ 15 kgs: number (%)	21 (70)	28 (72)	
Anatomy: number (%)	TOF with PS	25 (83)	29 (74)	0.557
	TOF with PA	0	0	
	DORV, VSD with PS	5 (17)	10 (26)	
PV annulus z-score	Range	-2.8 to 1.97	-4.1 to -0.61	**< 0.001**
	Mean	0.6	-2.2	
	< -2: number (%)	3 (10)	22 (56)	
	≥ -2: number (%)	24 (80)	16 (41)	
	Unknown	3 (10)	1 (3)	
RVOT gradient (mmHg)	Range	23 to 114	30 to 132	0.879
	Mean	70	71	
	< 70: number (%)	12 (43)	16 (41)	
	≥ 70: number (%)	17 (57)	21 (54)	
	Unknown	1	2	
Right ventricular end-diastolic pressure (mmHg)	Range	0 to 24	1 to 14	0.070
	Mean	7	6	
	< 7: number (%)	9 (30)	14 (36)	
	≥ 7: number (%)	21 (70)	12 (31)	
	Unknown	0	13	
McGoon Index	Range	1.2 to 4.0	1.3 to 3.3	0.716
	Mean	2.39	2.26	
	< 2: number (%)	6 (20)	9 (23)	
	≥ 2: number (%)	24 (80)	29 (74)	
	Unknown (n) (%)	0	1	
Supravalvular PS	Yes: number (%)	1 (3)	19 (49)	**< 0.001**
	No: number (%)	28 (97)	20 (51)	
	Unknown	1	0	
Chromosomal abnormality	Yes: number (%)	0	0	
	No: number (%)	29 (100)	38 (100)	
Preoperative Hct (%)	Range	34.9 to 69.1	31.3 to 70.2	0.020
	Mean	43.8	48.7	
Strategy of Repair: number (%)	Staged repair	10 (33)	19 (49)	0.199
	Primary repair	20 (67)	20 (51)	

Table 2 Operative data

Variable	Non-TAP N = 30	TAP N = 39	*p*-value
Bypass time, minutes: mean ± SD (range)	107 ± 42 (60 to 277)	138 ± 37 (84 to 285)	**0.002**
Cross-clamp time, minutes: mean ± SD (range)	79 ± 27 (42 to 162)	102 ± 27 (50 to 172)	**0.001**
Additional operation: number (%)	14 (47)	5 (13)	0.002
Pulmonic valve commissurotomy	4 (13)	0	
Supravalvular patch plasty	9 (30)	3 (8)	
Branch pulmonary arterioplasty	0	1 (3)	
Aortic valve repair	1 (3)	1 (3)	
Reoperation: number (%)	3 (9)	3 (8)	0.736
Bleeding	0	1 (3)	
Tamponade	1 (3)	0	
Chest exploration for blood clot	1 (3)	0	
Closure of residual VSD	1 (3)	2 (5)	
Operative death: number (%)	2 (7)	9 (23)	0.065
2009 to 2013	1/15 (7)	3/11 (27)	
2014 to 2018	1/15 (7)	6/28 (21)	

Table 3 Post-operative data

Variable	Non-TAP N = 28	TAP N = 36	*p*-value
Presence of PS: number (%)	21 (75)	27 (75)	0.999
None	7 (25)	9 (25)	
Mild	20 (71)	17 (47)	
Moderate	1 (4)	8 (22)	
Severe	0	2 (6)	
Presence of PR	15 (54)	26 (72)	0.123
None	13 (46)	10 (28)	
Mild	12 (43)	21 (58)	
Moderate	3 (11)	3 (8)	
Severe	0	2 (6)	
Length of ICU stay, days: mean ± SD (range)	3.2 ± 3.3 (1 to 17)	4.7 ± 5.1 (1 to 23)	0.166
Length of Hospital stay, days: mean ± SD (range)	10.8 ± 5.6 (4 to 17)	12.6 ± 7.4 (5 to 31)	0.253

On multivariable analysis, only PV annulus z-score < -2.0 (adjusted hazard ratio 3.63, *p*-value 0.017) and postoperative moderate to severe PS (adjusted hazard ratio 4.00, *p*-value 0.042) were significant, independent risk factors.

Discussion

TOF remains one of the most common cyanotic congenital heart diseases in Thailand[1]. Care of patients with this disease requires a significant number of financial resources. Surgical treatment aiming at anatomical correction is the mainstay, and life-long follow up due to possible recurrence of symptoms or complications after treatment is required[17].

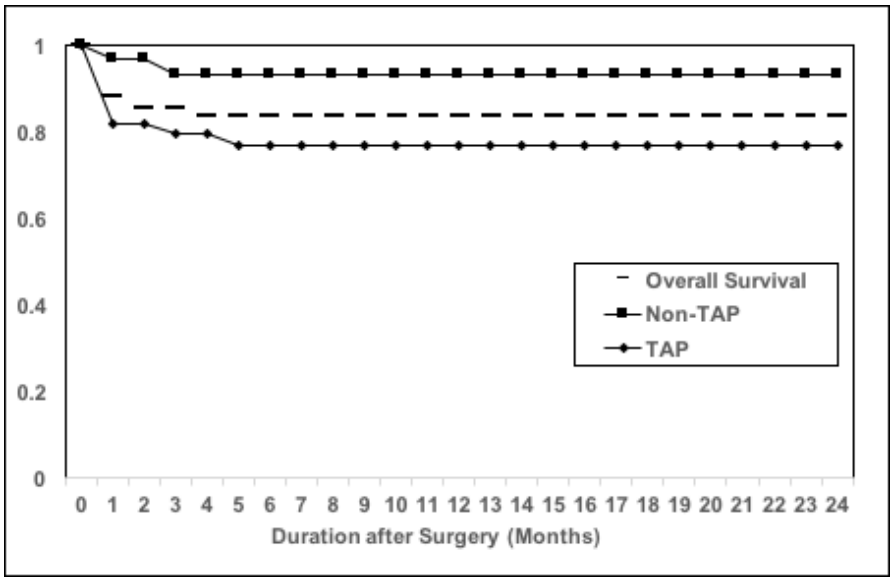

Figure 3 Survival after surgery

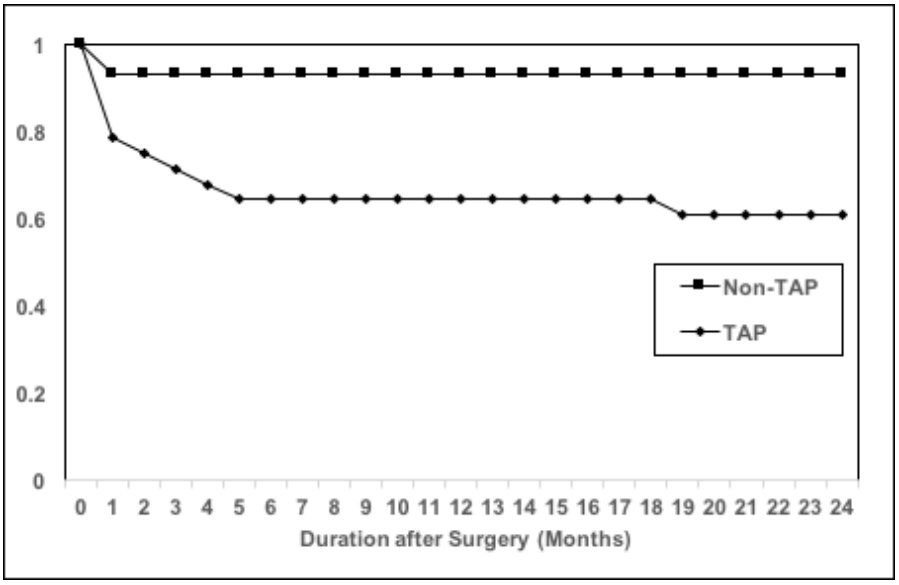

Figure 4 Freedom from at least moderate pulmonic stenosis or pulmonic regurgitation within 2 years

Lilliehei *et al* reported the first successful repair of TOF in 1955[7]. Kirklin *et al* developed a TAP technique to treat TOF with small PV annulus for the first time in 1959[10]. This technique effectively relieves obstruction at the valvular level. However, inevitable severe regurgitation occurs due to the requirement of breaking the pulmonic valve integrity when incising across the valve.

The deleterious effects of acute PR occurring after the surgery were demonstrated by clinical and experimental studies[18]. Chronic effects of PR were demonstrated in many studies as well[19–21]. One solution to this problem is to reconstruct a new, competent valve in addition to PV annular enlargement. Another solution is the replacement of RV-pulmonary artery conduit by homografts or xenografts. However, the scarcity, cost and durability are limitations of this latter option in our country. Gundry *et al* in 1994 developed TAP with a monocusp by using autologous pericardium for the first time[12]. The technique uses the patient's own pericardium to create a neo-valve with reasonable durability which greatly reduces mortality and improves survival after repair.

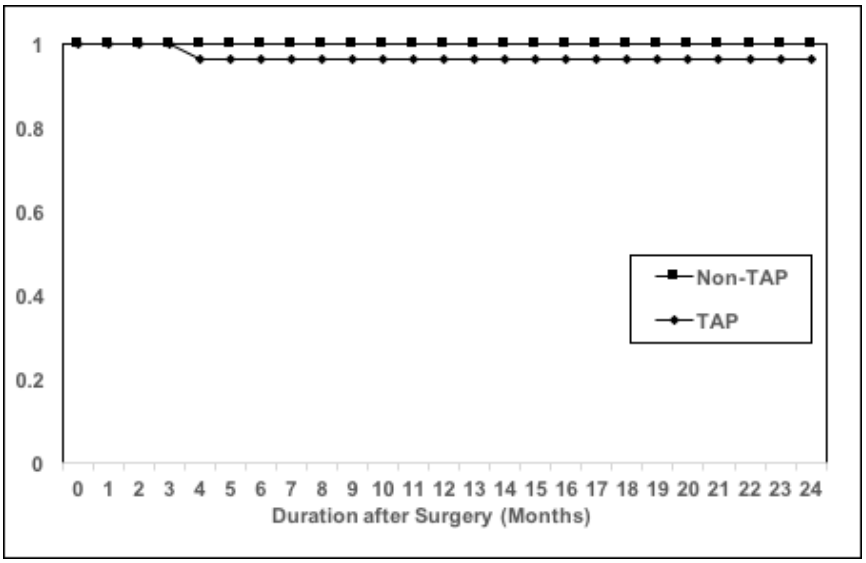

Figure 5 Freedom from re-intervention within 2 years

There is no general consensus on the indication for TAP, in terms of PV annulus size. Generally, z-scores between -2.0 to -3.0 have been used as a surrogate for inadequate PV. However, a study by Mark *et al* showed that even with a PV z-score of -1.3, there could be a 25% chance of significant pulmonic stenosis if TAP were not performed[22]. The proportion of patients with PV annulus z-score of -2.0 or less was quite high in our study (46%), implying that TAP was probably indicated for these patients.

There are some drawbacks with this technique. TAP with monocusp requires longer operative time as shown by an increase in CPB time and cross-clamp time, which might adversely affect cardiac function. There was a higher rate of moderate to severe pulmonic stenosis in our study. Theoretically, TAP should be able to relieve all stenosis at the pulmonic valvular level, but if the construction of TAP with monocusp is not correctly performed, it can result in inadequate relief of stenosis. Moreover, if the monocusp does not have good competence, significant PR may result. The worst-case scenario is to have both significant PS and PR. This produces both pressure load and volume load to an already thick, non-compliant hypertrophic RV which can progress to postoperative RV failure. This was a major cause of in-hospital deaths in our study.

From the beginning of our program, it is our policy that we avoid definitive surgery in small patients. In larger patients, definitive repair without TAP is more likely[23,24], so the burden and complications from the TAP technique can sometimes be avoided. There is no universally accepted cutoff value of body weight to defer definitive surgery, but If the patient is less than 15 kg and symptomatic, we will perform palliative procedures and let the patient grow, deferring definitive repair for later. The strategy of performing palliative procedure before definitive surgery (staged repair) was probably not a risk factor for in-hospital mortality.

The result of TOF repair depends on many factors, especially surgeon's experience and quality of perioperative care. In our study, the result of repair in the non-TAP group was very good. The in-hospital mortality rate was only 7%, when compared to a large study in the early years of TOF repair by Craig et al in 1998, which had a mortality of 11%[25]. But the in-hospital mortality rate of the TAP group was on the higher side (23%). We believe that our results were affected largely by the relative lack of experience, as the number of TOF cases in our institution were not many even though our program has been in place for 10 years. Thus, we have only slowly accumulated the experience of performing the TAP technique. Nonetheless, the in-hospital mortality has been improving in the last few years (down to 21%, from 27%).

The early survival probabilities and the freedom from reintervention of the TAP group were excellent and comparable to those of the non-TAP group. Though the monocusp valve deteriorated with time, as seen by the declining freedom from at least moderate PR or PS to 61% at 2 years, the monocusp still functioned adequately

enough such that reinterventions in the first few years were still mostly unnecessary. Our results were similar to those of previous studies, which demonstrated excellent valve function in the early period after surgery[12,26-27]. Therefore, we continue to perform the TAP with monocusp technique. In more recent reports, the surgical mortality rate was between 0 to 3% for all patients, and this should be the goal of all centers performing TOF repair[17].

In terms of predictors of in-hospital mortality, only two factors were identified as significant predictors in our study. The PV z-score <-2.0 seems to be an indirect factor, since this cutoff was an indication to perform TAP, and TAP itself increased the risk of mortality. Postoperative moderate to severe PS is unquestionably a true risk in itself, as demonstrated in the study by Kirklin *et al*.[28]

A limitation of the present study is the retrospective design, which is prone to confounding and selection biases. Furthermore, the number of patients in our study was small and the follow-up time was short, reducing the likelihood of detecting significant differences between the TAP and non-TAP groups, if they exist. Long-term effects of TAP could not be evaluated at this time, due to the relatively recent establishment of our program and the short follow-up. Future research is required, with more patients and longer follow up.

Conclusions

The results of the present study showed that the TAP with monocusp technique can adequately relieve PS and PR if correctly performed. The procedure, however, is technically challenging. Adopting this technique requires a dedicated surgical team which might be struggling at first, but the benefits to patients with this complex disease is worth the struggle.

REFERENCES

1. Cholkraisuwat E, Buddharaksa Y, Sayasathid J. Congenital heart disease in elementary school children in rural Thailand: The role of the trained noncardiologist. Asian Biomed. 2013;7:287-91.
2. Kouchoukos NT, Karp RB, Blackstone EH, Doty DB, Hanley FL, eds. Kirklin/Barratt-Boyes Cardiac Surgery. 3rd ed. Orlando: Churchill-Livingstone-Elsevier; 2004.
3. Rygg IH, Olesen K, Boesen I. The life history of tetralogy of Fallot. Dan Med Bull 1971;18:25-30.
4. Blalock A, Taussig HB. The surgical treatment of malformations of the heart: In which there is pulmonary stenosis or pulmonary atresia. J Am Med Assoc 1945;128:189-202.
5. Potts WJ, Smith S, Gibson S. Anastomosisof the aorta to a pulmonary artery: certain types in congenital heart disease. J Am Med Assoc 1946;132:627-31.
6. De Leval MR, McKay R, Jones M, Stark J, Macartney FJ. Modified Blalock-Taussig shunt. Use of subclavian artery orifice as flow regulator in prosthetic systemic-pulmonary artery shunts. J Thorac Cardiovasc Surg 1981;81:112-9.
7. 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.
8. Kirklin JW, Blackstone EH, Pacifico AD, et al. Routine primary repair vs two-stage repair of tetralogy of Fallot. Circulation 1979;60:373-86.
9. Kirklin JW, Blackstone EH, Jonas RA, et al. Morphologic and surgical determinants of outcome events after repair of tetralogy of Fallot and pulmonary stenosis: A two-institution study. J Thorac Cardiovasc Surg 1992;103:706-73.
10. Kirklin JW, Ellis FH, McGoon DC, et al. Surgical treatment for the tetralogy of Fallot by open intracardiac repair. J Thorac Surg 1959;37:22-51.
11. Fuster V, McGoon DC, Kennedy MA, et al. Long-term evaluation (12 to 22 years) of open heart surgery for tetralogy of Fallot. Am J Cardiol 1980;46:635-42.
12. Gundry SR, Razzouk AJ, Boskind JF, et al. Fate of the pericardial monocusp pulmonary valve for right ventricular outflow tract reconstruction: Early function, late failure without obstruction. J Thorac Cardiovasc Surg 1994;107:908-13.
13. Sluysmans T, Colan SD. Structural measurements and adjustment for growth. In: Mertens LL, Geva T, Cohen MS, Lai WW, eds. Echocardiography in pediatric and congenital heart disease: From fetus to adult. Oxford: Wiley-Blackwell; 2009.
14. Colan SD. Normal echocardiographic values for cardiovascular structures. In: Lai WW, Mertens LL, Cohen MS, Geba T, editors. Echocardiography in pediatric and congenital heart disease: From fetus to adult, 2nd ed. New Jersey: John Wiley & Sons; 2016.
15. Zoghbi WA, Adams D, Bonow RO, et al. Recommendations for noninvasive evaluation of native valvular regurgitation: A report from the American Society of Echocardiography developed in collaboration with the Society for Cardiovascular Magnetic Resonance. J Am Soc Echocardiogr 2017;30:303-71.
16. Baumgartner H, Hung J, Bermejo J, et al. Echocardiographic assessment of valve stenosis: EAE/ASE recommendations for clinical practice. J Am Soc Echocardiogr 2009;22:1-102.
17. Van der Ven JPG, van den Bosch E, Bogers AJCC, Helbing WA. Current outcomes and treatment of tetralogy of Fallot. F1000Res 2019; doi:10.12688/f1000research.17174.1.
18. Austen WG, Greenfield LJ, Ebert PA, Morrow AG. Experimental study of right ventricular function after surgical procedures involving the right ventricle and pulmonic valve. Ann Surg 1962;155:606-13.
19. Carvalho JS, Shinebourne EA, Busst C, et al. Exercise capacity after complete repair of tetralogy of Fallot: Deleterious effects of residual pulmonary regurgitation. Br Heart J 1992;67:470-3.
20. Roest AAW, Helbing WA, Kunz P, et al. Exercise MR imaging in the assessment of pulmonary regurgitation and biventricular function in patients after tetralogy of Fallot repair. Radiology

2002;223:204-11.
21. Gatzoulis MA, Balaji S, Webber SA, et al. Risk factors for arrhythmia and sudden cardiac death late after repair of tetralogy of Fallot: A multicentre study. Lancet 2000;356:975-81.
22. Awori MN, Leong W, Artrip JH, O'Donnell C. Tetralogy of fallot repair: Optimal z-score use for transannular patch insertion. Eur J Cardio-thoracic Surg 2013;43:483-6.
23. Gustafson RA, Murray GF, Warden HE, Hill RC, Rozar EJ. Early Primary Repair of Tetralogy of Fallot. Ann Thorac Surg. 1988;45(3):235-41.
24. Touati GD, Vouhe PR, Amodeo A, et al. Primary repair of tetralogy of Fallot in infancy. J Thorac Cardiovasc Surg 1990;99:396-403.
25. Knott-Craig CJ, Elkins RC, Lane MM, et al. A 26-year experience with surgical management of tetralogy of Fallot: Risk analysis for mortality or late reintervention. Ann Thorac Surg 1998;66:506-10.
26. Anagnostopoulos P, Azakie A, Natarajan S, et al. Pulmonary valve cusp augmentation with autologous pericardium may improve early outcome for tetralogy of Fallot. J Thorac Cardiovasc Surg 2007;133:640-7.
27. Sasson L, Houri S, Sternfeld AR, et al. Right ventricular outflow tract strategies for repair of tetralogy of Fallot: Effect of monocusp valve reconstruction. Eur J Cardio-thoracic Surg 2013;43:743-51.
28. Kirklin JW, Blackstone EH, Pacifico AD, et al. Risk factors for early and late failure after repair of tetralogy of Fallot, and their neutralization. Thorac Cardiovasc Surg 1984;32:208-14.

บทคัดย่อ **ผลการรักษาของโรคหัวใจพิการแต่กำเนิดชนิดเขียวเตตราโลจี ออฟ ฟาลโลต์ด้วยวิธีการผ่าตัดขยายลิ้นหัวใจร่วมกับการทำลิ้นหัวใจขึ้นรูปเป็น 1 ลิ้น จากเยื่อหุ้มหัวใจ ณ โรงพยาบาลตติยภูมิ**

นิสิต พูลธนะนันท์, ธีระ เหมรุ่งโรจน์, ประภัสร์ อัศยเผ่า, จิตรวี ดิษรัฐกิจ, เกษรินทร์ ศิริชวนจันทร์, ดำริ เศรษฐจินดา

ความเป็นมา: โรคเตตราโลจี ออฟ ฟาลโลต์เป็นโรคหัวใจพิการแต่กำเนิดชนิดเขียวที่พบได้บ่อยมากที่สุดในประเทศไทย ผู้ป่วยหลายรายมีการตีบไปจนถึงตำแหน่งลิ้นหัวใจพัลโมนิกร่วมด้วย ซึ่งต้องการผ่าตัดรักษาที่ซับซ้อนโดยเฉพาะอย่างยิ่งการผ่าตัดขยายลิ้นหัวใจเพื่อแก้ไขการอุดกั้นในตำแหน่งดังกล่าว คณะผู้นิพนธ์ได้ทำการศึกษาวิเคราะห์เทคนิคการผ่าตัดขยายลิ้นหัวใจร่วมกับการทำลิ้นหัวใจขึ้นรูปเป็น 1 ลิ้น จากเยื่อหุ้มหัวใจ

วิธีการศึกษา: การวิจัยนี้เป็นการศึกษาย้อนหลังซึ่งรวบรวมผู้ป่วยที่ได้รับการผ่าตัดเพื่อแก้ไขทั้งสิ้น 69 ราย โดยเป็นผู้ป่วยที่ได้รับการรักษาตั้งแต่ มกราคม พ.ศ. 2552 จนถึง ธันวาคม พ.ศ. 2561 ผลการรักษาในกลุ่มที่ใช้เทคนิคการผ่าตัดขยายลิ้นหัวใจร่วมกับการทำลิ้นหัวใจขึ้นรูปเป็น 1 ลิ้น จากเยื่อหุ้มหัวใจ (TAP group) ได้นำมาเปรียบเทียบกับในกลุ่มที่ไม่ใช้เทคนิคดังกล่าว (Non-TAP group)

ผลการศึกษา: ผู้ป่วยมีทั้งหมด 30 รายในกลุ่ม Non-TAP (อายุเฉลี่ย 92.6 เดือน) และ 39 รายในกลุ่ม TAP (อายุเฉลี่ย 90.4 เดือน) ส่วนใหญ่ผู้ป่วยทั้ง 2 กลุ่มมีลักษณะเฉพาะที่เหมาะสมก่อนการผ่าตัด ยกเว้นขนาดโดยเฉลี่ยของเส้นผ่าศูนย์กลางลิ้นหัวใจพัลโมนิกในกลุ่ม TAP จะมีขนาดเล็กกว่าในกลุ่ม non-TAP (mean z-score กลุ่ม TAP -2.2, กลุ่ม Non-TAP 0.6, p-value < 0.001). ระยะเวลาที่ใช้เครื่องหัวใจและปอดเทียมระหว่างการผ่าตัดในกลุ่ม TAP ยาวนานกว่า (กลุ่ม TAP 138 ± 37 นาที vs กลุ่ม Non-TAP 107 ± 41 นาที, p-value < 0.002) ระยะเวลา Cross clamp ในกลุ่ม TAP ยาวนานกว่าเช่นกัน (กลุ่ม TAP 102 ± 42 นาที, กลุ่ม Non-TAP 79 ± 27 นาที, p-value 0.001) การเสียชีวิตในโรงพยาบาลในกลุ่ม TAP สูงกว่า (กลุ่ม TAP 23%, กลุ่ม Non-TAP 7%) โอกาสรอดชีวิตโดยรวม 88.4% ในช่วง 2 ปีแรก, 96.7% ในกลุ่ม Non-TAP, 82.1% ในกลุ่ม TAP) ภายหลังจากการยกเว้นผู้ป่วยที่เสียชีวิตไปแล้ว พบว่าโอกาสเป็นอิสระต่อการเกิดลิ้นหัวใจพัลโมนิกตีบหรือรั่วในระดับกลางขึ้นไปพบว่าเป็น 93% ในกลุ่ม Non-TAP และ 61% ในกลุ่ม TAP ในขณะที่โอกาสเป็นอิสระต่อการต้องทำมาตรการแก้ไขซ้ำที่ลิ้นหัวใจพัลโมนิกนั้นดีมาก และพอๆ กันในทั้ง 2 กลุ่ม (กลุ่ม TAP 96.4%, กลุ่ม Non-TAP 100%)

สรุปผลการศึกษา: เทคนิคการผ่าตัดขยายลิ้นหัวใจร่วมกับการทำลิ้นหัวใจขึ้นรูปเป็น 1 ลิ้นสามารถแก้ไขการตีบของลิ้นหัวใจพัลโมนิกได้อย่างเพียงพอ ร่วมกับมีความสามารถป้องกันการรั่วได้ดีในช่วงระยะแรกหลังการผ่าตัด ถึงแม้ว่าการเสียชีวิตในโรงพยาบาลค่อนข้างสูง ด้วยประสบการณ์ที่มากขึ้นย่อมจะทำให้ปัญหานี้ดีขึ้นในที่สุด