

Indications, Results and Mortality of Pulmonary Artery Banding Procedure: a Brief Review and Five- year Experiences

Hamid Hoseinikhah¹, Aliasghar Moeinipour¹, Ahmadrza Zarifian², Mohammad Sobhan Sheikh Andalibi², Yasamin Moeinipour³, Mohammad Abbassi Teshnisi⁴, Abbas Bahreini⁵

¹Assistant Professor, Department of Cardiac Surgery, Atherosclerosis Prevention Research Center, Imam Reza Hospital, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran.

²Student Research Committee, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran.

³Medical Student, Faculty of Medicine, Mashhad University of Medical Science, Mashhad, Iran.

⁴Associated Professor, Department of Cardiac Surgery, Atherosclerosis Prevention Research Center, Imam Reza Hospital, Faculty of Medicine, Mashhad University of Medical Sciences, Iran.

⁵Department of Neurosurgery, Shiraz University of Medical Sciences, Shiraz, Iran.

Abstract

Background

Pulmonary artery banding (PAB) is a technique of palliative surgical therapy used by congenital heart surgeons as a staged approach to operative correction of congenital heart defects.

Materials and Methods

We report 5- year experiences from January 2011 to January 2016 of Imam Reza Hospital center (a tertiary referral hospital in Mashhad city, North East of Iran) that consist of 50 patients with congenital heart disease with left to right shunt that pulmonary artery banding procedure was performed for them were studied.

Results

Age of patients (n=50) was 1 to 9 months (mean=4.6 ± 1.3). In this study, the most common disease that need to PAB procedure was Ventricular septal defect (VSD) with twenty-eight patients (56%). Mean of extubation time (hour) was 10.4 ± 0.8 and mean of hospital stay (day) was 13.3 ± 2.4 respectively.

Conclusion

Although the number of pulmonary artery banding palliation surgery was decreased, but in selected group of congenital heart disease, this palliation to reduce over circulation of Pulmonary system, can use successfully with acceptable results and low mortality. We suggest pulmonary artery banding palliative surgery in these selected patients.

Key Words: Cardiac surgery, Children, Congenital heart disease, Pulmonary artery banding.

*Please cite this article as: Hoseinikhah H, Moeinipour A, Zarifian A, Sheikh Andalibi MS, Moeinipour Y, Abbassi Teshnisi M, et al. Indications, Results and Mortality of Pulmonary Artery Banding Procedure: a Brief Review and Five- year Experiences. Int J Pediatr 2016; 4(5): 1733-44.

*Corresponding Authors:

Mohammad Abbassi Teshnisi, Department of Cardiac Surgery, Atherosclerosis Prevention Research Center, Imam Reza Hospital, Mashhad University of Medical Sciences, Iran. Postal code: 9137913316.

Email: AbbasiM@mums.ac.ir

Received date: Jan 27, 2016; Accepted date: Mar 12, 2016

1- INTRODUCTION

Historically first report of pulmonary artery Banding (PAB) was recorded in 1952 by Muller and Danimann (1, 2). PA Banding was noticed as a palliative surgery to reduce pulmonary over circulation when total corrective surgery is not possible (2-4). Among all of congenital heart disease, patients with left to right shunt are candidate for this palliation surgery. The most common disease that need to PAB procedure is Ventricular septal defect (VSD). After VSD, Atrioventricular (AV) canal and VSD+ Coarctation of the aorta (CoA) and some type of Transposition of the Great Arteries (TGA) also are candidate (4-6).

Recently especially in developed countries with increase of cardiac surgeon experience and possibility of Cardiopulmonary bypass (CPB) in very young infant with low birth weight and also better postoperative care, many of children that previously had to tolerated initially PA Banding procedure before corrective surgery, today have a chance for total corrective surgery with good result and success and low mortality. At current in some centers there is also noticeable percentage of this palliative surgery for congenital heart disease with pulmonary over circulation to prevent of irreversible pathologic changes in pulmonary vasculature and lung parenchyma (7, 8). The Pulmonary artery banding procedure has been widely used as a initially palliative procedure to prevent right heart failure caused by volume and pressure overload, but this procedure might have significant drawbacks including a high surgical mortality caused by bleeding, band migration, later pulmonary stenosis need to reconstruction, sudden cardiac arrest, or pulmonary thrombus (9,10). In this retrospective study we decide to evaluate 5- year experience and indication and results of PAB procedure in Imam

Reza Hospital of Mashhad University of Medical Sciences, Iran.

1-1. Pathophysiology

Congenital heart defects with left-to-right shunting and unrestricted pulmonary blood flow (PBF) due to a drop in pulmonary vascular resistance result in pulmonary overcirculation. In the acute setting, this leads to pulmonary edema and CHF in the neonate. Within the first year of life, this unrestricted flow and pressure can lead to medial hypertrophy of the pulmonary arterioles and fixed pulmonary hypertension. Pulmonary artery banding creates a narrowing, or stenosing, of the Main pulmonary artery (MPA) that decreases blood flow to the branch pulmonary arteries and reduces PBF and pulmonary artery pressure. In patients with cardiac defects that produce left-to-right shunting, this restriction of PBF reduces the shunt volume and consequently improves both systemic pressure and cardiac output. A reduction of PBF also decreases the total blood volume returning to the left ventricular (or the systemic ventricle) and often improves ventricular function. Pulmonary artery banding may not be tolerated in patients who have cardiac defects that depend on mixing of the systemic and pulmonary venous blood to maintain adequate systemic oxygen saturations. This is particularly true if a restrictive communication is present between the 2 atria. Therefore, ensuring that such patients have an unrestricted atrial communication is important to allow adequate mixing at the atrial level before proceeding with pulmonary artery banding. This can be accomplished with a balloon atrial septostomy or an operative atrial septectomy at the time of pulmonary artery banding (5, 6, 9).

1-2. Indications

Currently, patients who are selected for pulmonary artery banding (PAB) and staged cardiac repair are determined based

on the experience and training of the pediatric cardiologists and congenital heart surgeons at any given institution. Most of these patients fall into 2 broad categories: (1) those with pulmonary overcirculation and left-to-right shunting who require reduction of pulmonary blood flow (PBF) as a staged approach to more definitive repair and (2) those with transposition of the great arteries (TGA), where require training of the left ventricle (LV) as a staged approach to the arterial switch procedure.

1-2-1. Patients in the first category who are considered for pulmonary artery banding include those with the following diagnoses:

- Multiple muscular ventricular septal defects (VSDs) with a "Swiss cheese" septum that is technically difficult to repair in the neonate or requires a ventriculotomy;
- Single or multiple VSDs with coarctation of the aorta or interrupted aortic arch;
- Single ventricle defects (eg, tricuspid atresia) that are associated with increased PBF in the neonate;
- Unbalanced atrioventricular canal (AVC) defects in which the LV is hypoplastic but the potential exists for a 2-ventricle repair with further growth and development;
- Cardiac defects that require a homograft conduit (eg, dextro-transposition of the great arteries [D-TGA] with subpulmonic stenosis requiring a Rastelli-type repair) for complete repair: Use of pulmonary artery banding may allow time for growth of the patient before the complete repair. Interim growth of the patient permits placement of a larger conduit at the time of repair and potentially increases the longevity of the conduit and length

of freedom from reoperation. With current clinical practice, most patients with D-TGA pulmonary stenosis (PS) undergo a Rastelli procedure and placement of a right ventricle (RV) to pulmonary artery (PA) conduit. If a staged repair is indicated, a pulmonary artery banding is not usually performed because of already decreased pulmonary blood flow. In this situation, a systemic-to-pulmonary shunt is performed.

1-2-2. Patients in the second category who are considered for pulmonary artery banding include those with the following diagnoses:

- D-TGA that requires preparation of LV for an arterial switch procedure following initial late presentation or diagnosis in patients older than 1 month;
- D-TGA that requires preparation of LV for an arterial switch procedure following a previous Mustard or Senning procedure with the development of right ventricular failure or levo-transposition of the great arteries (L-TGA) that requires preparation of the LV prior to the arterial switch procedure (11-15).

1-3. Relevant Anatomy

In most patients with cardiac defects requiring pulmonary artery banding (PAB), the length of main pulmonary artery (MPA) is sufficient to allow placement of the band in the mid portion of the artery without impingement on either the pulmonary valve, coronary arteries proximally or the branch pulmonary arteries distally. The inferior wall of the right pulmonary artery (PA) arises slightly more proximal on the MPA than the left PA. The right PA also arises from the MPA at more of an acute angle. Both of these factors increase risk of right PA impingement by a distally placed band.

The tissue connecting the aorta and MPA in the aortopulmonary window usually must be divided with surgical dissection. In patients with pulmonary overcirculation, the MPA may be quite large compared to the aorta. Additionally, the MPA vessel wall may be thinned out by this dilatation, and the adventitia may be quite attenuated. These changes increase risk of tearing the wall of the MPA at the time of pulmonary artery banding (16, 17).

1-4. Contraindications

Patients who have single ventricle defects in which the aorta arises from an outflow chamber (eg, double inlet left ventricle, tricuspid atresia with TGA) have the potential for development of significant subaortic obstruction. The risk is higher when these lesions are also associated with aortic arch anomalies. Pulmonary artery banding (PAB) is contraindicated in the presence of such obstruction and in patients who are at high risk for such obstruction. The ventricular hypertrophy that develops in response to pulmonary artery banding may cause rapid progression of subaortic obstruction leading to a combination of both ventricles having outflow tract obstruction and progressive hypertrophy.

These patients are identified by careful preoperative assessment, including echocardiography and, if necessary, cardiac catheterization with pullback pressure measurements across the subaortic region. The presence of a gradient more than 15-20 mm Hg or an echocardiographic outlet foramen area index of less than $2\text{cm}^2/\text{m}^2$ precludes pulmonary artery banding. Instead, these patients should undergo the Damus-Kaye-Stansel procedure and a systemic-to-pulmonary artery shunt. This achieves adequate pulmonary blood flow (PBF) with protection of the pulmonary vasculature and bypasses the subaortic

obstruction. Another well-described complication of pulmonary artery banding is the development of subaortic obstruction from conal hypertrophy, particularly in patients with a single ventricle and a subaortic outflow chamber. It may also result from hypertrophy of an abnormally positioned moderator band.

Pulmonary artery banding is not used in patients diagnosed with truncus arteriosus. Although a main pulmonary artery (MPA) is present in truncus arteriosus type I, it usually is very short and does not allow for successful pulmonary artery banding without impingement on the right pulmonary artery (PA) or the origin of the MPA from the truncal artery. In truncus arteriosus types II and III, bilateral pulmonary artery banding is necessary to effectively reduce PBF. Previous experience has shown that balancing PBF to the right and left lungs is extremely difficult. Furthermore, subsequent complete repair is complicated by bilateral PA stenosis requiring extensive reconstruction. For these reasons, pulmonary artery banding is avoided in this group of patients (18-22).

1-5. Medical therapy

Preoperative treatment of patients with pulmonary overcirculation and congestive heart failure (CHF) should focus on minimizing left-to-right shunting, improving cardiac function with inotropic support, systemic afterload reduction, and aggressive diuresis. Mechanical ventilator support may be necessary to maintain adequate ventilation and oxygenation in the setting of pulmonary edema. Maintaining higher carbon dioxide levels and lower fraction of inspired oxygen (FIO₂) during ventilation may assist in reducing pulmonary blood flow (PBF) and pulmonary edema. If a patent ductus arteriosus (PDA) is present, attempts should be made to reduce or close it with

medical therapy (eg, indomethacin) to reduce this source of PBF (3, 6, 23, 24).

1-6. Surgical therapy

In the surgical treatment of congenital heart defects, pulmonary artery banding is a palliative intervention that is performed as a staged approach to a more definitive surgical repair. The goals of pulmonary artery banding include reduction of PBF to reduce left-to-right shunting and CHF, protection of the pulmonary vasculature from hypertensive changes, and training of the left ventricle (LV) in anticipation of an arterial switch procedure (25-27).

1-7. Postoperative details

Patients undergoing PAB are initially treated in the intensive care unit (ICU). They often benefit from a course of intravenous inotropic support and require careful attention to fluid balance and volume status. Following PAB, improved hemodynamics and greater left ventricular output often allow for diuresis and gradual resolution of CHF. The assessment of a patient following PAB should ideally be made under conditions of balanced volume status and in the absence of atelectasis or ongoing pulmonary pathology. Although measured parameters from the operating room are helpful guidelines, the overall clinical status of the patient is the most important assessment.

This includes changes in systemic blood pressure, heart rate, oxygen saturation, and overall cardiac function. Hypotension, bradycardia, and ischemic electrocardiographic changes all indicate an excessive band gradient and imminent cardiac failure or arrest. The advantage of an adjustable PAB is that it allows for rapid loosening of the band with a hemoclip remover in the ICU, if necessary. Catheter debanding is also an invaluable technique in selected cases. Evaluation of the PAB is made by color flow Doppler echocardiography at the bedside; it usually

provides an accurate assessment of band tightness, band gradient, band position, and overall cardiac function. Any impingement or stenosis of the branch pulmonary arteries can also be observed with this study. Rarely, cardiac catheterization and direct measurement of PA pressure and band gradient is necessary. More recently, cinemagnetic resonance imaging and 3-dimensional reconstruction have been useful as noninvasive methods of evaluation (28, 29).

1-8. Follow-up

Most patients undergoing pulmonary artery banding for pulmonary overcirculation are monitored for 3-6 months and then undergo more definitive repair of their cardiac defect. Also, the degree of right ventricular hypertrophy that develops in response to any given pulmonary artery banding gradient varies greatly among infants. Those infants who develop rapid and severe right ventricular hypertrophy in response to pulmonary artery banding should be considered for earlier definitive repair to prevent long-term right ventricular dysfunction. Patients with D-TGA who undergo pulmonary artery banding for training of the LV must be monitored with serial echocardiography to assess "readiness" of the LV before the arterial switch operation.

After either technique, patients are monitored with serial echocardiography that allows quantitative measurements of left ventricular mass index, as well as qualitative assessment of ventricular septal geometry. Left-to-right septal bowing is an indication that the LV can generate near-systemic pressure. Left ventricular preparation is usually accomplished within 7-10 days, after which patients may undergo an arterial switch procedure, takedown of shunt, and pulmonary artery banding. The early mortality rate is 4-5%, only slightly greater than that for a primary

arterial switch procedure. In infants, this may be several weeks, but older children may require longer periods of banding to achieve adequate results (6, 9, 30, 31).

1-9. Complications

Although pulmonary artery banding is a seemingly simple operation, it has been associated with numerous complications. One of the most common complications of pulmonary artery banding is impingement and stenosis of one or both of the branch pulmonary arteries. The right pulmonary artery (PA) is involved in most cases of branch stenosis for anatomical reasons already mentioned.

The diagnosis of branch PA impingement is often suggested by a chest radiograph that shows asymmetric vascular markings between the right and left lungs. Definitive diagnosis can usually be made by echocardiography, and fractional pulmonary blood flow (PBF) to each lung can be determined with radionuclide lung perfusion scanning. If significant branch stenosis is uncorrected, it can lead to underdevelopment of the involved lung with alveolar hypoplasia. Early recognition of branch PA stenosis should allow a revision of the pulmonary artery banding before the development of this late sequela. Limiting dissection of the tissue between the aorta and the main pulmonary artery (MPA) and fixing the band with sutures on the proximal MPA adventitia both reduce risk of this complication. Use of the incisional pulmonary artery banding technique prevents distal band migration and generally avoids this complication.

Conversely, if the band is placed too proximal on the MPA, it may distort the pulmonary valve and ultimately create dysplastic changes in the pulmonary valve leaflets. This is particularly devastating when PAB is performed as preparation for an arterial switch procedure because the pulmonary valve becomes the neo-aortic valve after the arterial switch procedure. In

addition, proximal placement of the band can lead to obstruction of coronary blood flow by direct impingement, usually of the circumflex coronary artery. Anomalous origin of a coronary artery may increase risk of this complication. These complications can generally be avoided by placement of the band more than 15 mm distal to the pulmonary valve cusps. Preoperative demonstration of coronary anatomy is helpful, but intraoperative vigilance during the banding procedure should avoid these types of complications.

In patients with erosion of the band into the PA, scarring and fibrosis around the band site usually prevents the life-threatening bleeding from occurring. Hemolytic anemia and local thrombus formation have been reported. Erosion seems to occur with increased frequency when narrow banding material is used, although it can occur with any material. PA pseudoaneurysm is a rare complication of pulmonary artery banding.

It may be preceded by local infection and, like band erosion, is heralded by loss of the band murmur and gradient. Imaging studies demonstrate an enlarged mediastinal shadow on chest radiography and a markedly enlarged PA on echocardiography or MRI. The diagnosis of PA pseudoaneurysm formation mandates urgent surgical intervention. Repair is performed on cardiopulmonary bypass with patch repair of the MPA. Glutaraldehyde-treated autologous pericardium is preferred to synthetic material because this condition is sometimes associated with infection (26, 32-36).

1-10. Outcome and prognosis

Pulmonary artery banding (PAB) should result in improved hemodynamics and overall clinical improvement in the patient. The signs and symptoms of congestive heart failure (CHF) should resolve or become medically manageable,

cardiomegaly should decrease, and pulmonary vascular resistance should decrease. Pulmonary artery banding affords protection to the pulmonary vasculature against fixed irreversible pulmonary hypertension secondary to pulmonary overcirculation and elevated pulmonary artery (PA) pressures.

The mortality rate of pulmonary artery banding is clearly associated more with the complexity of cardiac defect and overall condition of the patients than with the procedure itself. Patients who are selected for pulmonary artery banding and a staged repair are often chosen because they are considered too high risk to undergo definitive repair. Therefore, the mortality rates from earlier series have been as high as 25%. A decreasing mortality rate with pulmonary artery banding can be related to improved operative techniques, better patient selection, and timing of intervention. Additionally, improvements in anesthetic and postoperative management have also resulted in a decreased mortality rate. Current mortality rates for pulmonary artery banding are reported in some series to be as low as 3-5% (27, 37-40).

2- MATERIALS AND METHODS

In this study we report 5- year experiences of Imam Reza Hospital center of Mashhad- Iran, that consist of 50 patients who known cases of and documented congenital heart disease that PAB procedure was performed and all of them were studied. Also, all of cases were confirmed with pediatric cardiologist with use of transthoracic echocardiography to confirm pulmonary artery catheter placement. The mid-term results were evaluated in the all survivors with a follow-up mean of 12 months.

All of the procedure had performed with single cardiac surgery team and had same anesthesiology protocole. In 34(68%) patients median sternotomy was used and

in remaining 16 (32%) patients left thoracotomy approach was used. After opening pericardium PAB procedure was performed with unique technique that use of piece of Gortex Patch around the pulmonary artery and then tighten of it depend of parameter that was estimated at operation time. We estimate the effectiveness of PAB with measuring the pressure of pulmonary trunk proximal and distal to site of Banding with distal pressure was about half of proximal pressure and also maintain Oxygen saturation between 75- 85%. After completing procedure, intubated patients, were transferred to the ICU and routine postoperative care and received the necessary care.

3- RESULTS

Age of patients was 1to 9 months (mean= 4.6 ± 1.3) and weight 2.6 to 10 kg (mean= 5.3 ± 1.7). Thirty- four (68%) of patients were male. Mean of extubation time was 10.4 ± 0.8 (3-72 hours). Mean of ICU stay was 5.2 ± 1.8 (2-11 days). Mean of hospital stay was 13.3 ± 2.4 (8-17 days). Significant morbidity was seen in 4 patients that have temporary renal failure without need for renal replacement like peritoneal dialysis.

Also, before discharge from hospital, all of patients, had control echocardiography in the intensive care unit.

Alive children has at least 6 months follow-up. Forty-two (84%) patients were alive and 8 patients (16%) were dead; and all of them have expired between 1 to 5 days after procedure with symptoms and signs of heart failure and pulmonary congestion with hemodynamic insufficiency and pulmonary crisis and pulmonary edema.

Demographic data and information of all patients are listed in (**Table.1**). Results of PAB procedure in patients are shown in (**Table.2**).

Table 1: Demographic data of PAB procedure in patients

Variables	Number (%)
VSD	28(56)
Complete AV Canal	12(24)
VSD+ COA	5(10)
TGA+VSD	4(8)
TGA+ AV Canal	1(2)

Table 2: Results of PAB procedure in patients [Mean±SD, Number (%)]

Variables	Mean ± SD
Mean of extubation time (hour)	10.4± 0.8 (3-72)
Mean of ICU stay (day)	5.2± 1.8(2-11)
Mean of hospital stay (day)	13.3± 2.4(8-17)

Variable	N (%)
Death rate (person)	8(16%)

4- DISCUSSION

Pulmonary Artery Banding (PAB) is simple palliative procedure that is performed in subgroup of patients with congenital heart disease (9). Recently and in last two decades number of PAB surgery is decreased steadily due to advance and improvement in technique of cardiac surgery and family of cardiac surgeons with cardiopulmonary bypass and better cardiac protection and also better care of patients after surgery in ICU (8, 41). Main indication of this type of palliative surgery is all of congenital heart disease with left to right shunting resulting in pulmonary over circulation. Cardiac defects like VSD, ASD, TAPVC, PAPVC, AVSD and PDA have potential for left to right shunt with increase in pulmonary flow and hyperemia of lung parenchyma (4-6, 10, 42). Chronic pulmonary over circulation can lead to increase of pulmonary vascular resistance and finally fibrosis of Pulmonary artery (43, 44). This process finally can reach the pressure of pulmonary artery near to or equal to systemic pressure and right side heart failure (45). This process that named Eisenmenger syndrome, finally result in

reverse in direction of shunt via cardiac defect and lead to bidirectional shunt. In pediatric congenital disease that reach to this advanced stage total correction and repair of anomaly is not possible and lead to increasing mortality (40, 46), the only options in this situation is heart and lung transplant although due to limited donor for this patients, few of them can benefit from transplant(47). One of the most common diseases need to initial PA Banding, is VSD. In the case of VSD, PAB increases resistance to blood flow through the pulmonary artery and decrease pulmonary over circulation (48). Today with advances in rapid diagnosis of congenital heart disease, such advanced cases of cardiac heart diseases was seen rarely (43). For known cases of left to right shunts congenital heart disease we can divide the strategy to palliative procedure and total correction procedure(49).

Historically for total correction of this malformation there is some limitation for surgery like low weight for cardiopulmonary bypass and lack of experience for corrective surgery in small child and also difficulty in postoperative care. Other reasons why avoid of possibility of total correction health status like respiratory failure, pulmonary infection, urinary tract infection, and low birth weight. In this situation cardiac surgeons decide to palliative procedure to prevent of Eisenmenger syndrome (4-6). One major difficulty with PAB procedure is further complication, especially band migration and possibility to fibrosis of PA and significant PS that need to reconstruction of PA in PAB that exit for long time (50).

Historically first report of PAB was recorded by Muller and Dammann presented PAB for palliation of congenital heart disease(CHD) with pulmonary hypertension (PAH) and over circulation secondary to increased pulmonary blood flow in 1952 because of too low birth

weight and pulmonary infection total correction was not possible (1, 2). The need of PAB was to protect respiratory system from unrestricted pulmonary over circulation and irreversible pathologies changes in pulmonary vasculature and finally allowing to corrective surgery to be postponed to a later stage, when the cardiac structures of the child was bigger and have a good weight (40, 51). Pulmonary artery banding itself has not been an entirely benign procedure, being associated with morbidity and mortality. Palliation as initial surgery in congenital heart disease consist of PAB, systemic to pulmonary shunt, septostomy that were performed with many type of congenital heart disease (3, 4).

Recently number of PAB procedure was decreased steadily because of better results of total corrective surgery at early childhood and also well known mortality and morbidity and documented complications of it. Branch pulmonary artery distortion secondary to band migration, band erosion into pulmonary artery lumen, pulmonary stenosis resulting from chronic obstructing structure, pulmonary valve distortion, sub annular ventricular hypertrophy are well known complications (9, 10, 43).

From the last guideline, indications for primary PAB are all of cases with pulmonary over circulation consist of multiple ventricular septal defects especially Swiss cheese type, VSD coexisting with coarctation of the Aorta, atrioventricular or ventricular septal defects (AVSD)(4-6). Low weight and extremely septic infant, or in patient, who presents with a contraindication for CPB, eg., recent intracranial bleed, necessitate palliative procedure. PAB procedure can be performed via median sternotomy and thrototomy approach although with sternotomy it is easier (53, 54). After open heart surgery, pericardium evaluation of cardiac anomaly was accomplished. Then

after dissecting of pulmonary artery and separating of it from ascending aorta, a piece of tape or patch or heavy silk suture has used to encircle main pulmonary artery. Tighting of pulmonary artery in PAB procedure should be performed with notice to systemic pressure and oxygen saturation. Due to reducing of left to right shunt and pulmonary circulation, expect that systemic pressure have increased and systemic saturation decreased. Perfect and effective PAB when is called that pulmonary pressure distal to band is about 50% of proximal of its pressure and systemic oxygen saturation is in 75%-85% (40, 41). Also, postoperative care of patients, who have PAB procedure, is not much different to other congenital heart procedure. Patients usually are extubated after few hours at same day of surgery and stay at ICU for 2-4 days.

5- CONCLUSION

PA Banding is palliative cardiac surgery that although the number of pulmonary artery banding palliative surgery was decreased, but in selected group of congenital heart disease especially in young infant with low weight and with pulmonary infection, this palliation to reduce over circulation of pulmonary system can use successfully with acceptable results and low mortality. We suggest pulmonary artery banding palliative surgery in selected congenital heart disease with left to right shunt and pulmonary congestion.

6- CONFLICT OF INTEREST: None.

7- ACKNOWLEDGMENTS

We thank all nurses, staff (Mr. Abdolali Ghazmeh and Mrs. Maryam Argi), and patients' parental, for their kind cooperation with our research project.

8- REFERENCES

1. Patel MS, Kogon BE. Care of the adult congenital heart disease patient in the United States: a summary of the current system. *Pediatric Cardiology* 2010; 31(4):511–14.
2. Bolger AP, Coats AJS, Gatzoulis MA. Congenital heart disease: the original heart failure syndrome. *European Heart Journal* 2003; 24(10):970–76.
3. Faber MJ, Dalinghaus M, Lankhuizen IM, Steendijk P, Hop WC, Shomaker RG, et al. Right and left ventricular function after chronic pulmonary artery banding in rats assessed with biventricular pressure-volume loops. *American Journal of Physiology—Heart and Circulatory Physiology* 2006; 291(4):H1580–H1586.
4. Babu-Narayan SV, Kilner PJ, Li W, Moon JC, Goktehin O, Davlouros PA, et al. Ventricular fibrosis suggested by cardiovascular magnetic resonance in adults with repaired tetralogy of Fallot and its relationship to adverse markers of clinical outcome. *Circulation* 2006; 113(3):405–13.
5. Chowdhury U K, Sathia S, Ray R, Singh R, Pradeep KK, Venugopal P. Histopathology of the right ventricular outflow tract and its relationship to clinical outcomes and arrhythmias in patients with tetralogy of Fallot. *The Journal of Thoracic and Cardiovascular Surgery* 2006;132(2):270.e4–277
6. Choudhary SK, Talwar S, Airan B, Mohapatra R, Juneja R, Kothari SS. et al. A new technique of percutaneously adjustable pulmonary artery banding. *J Thorac Cardiovasc Surg* 2006;131:621–24.
7. Corno AE, Hurni M, Payot M, Sekarski N, Tozzi P, von Segesser LK. Adequate left ventricular preparation allows for arterial switch despite late referral. *Cardiol Young*2003;13:49–52.
8. Corno AF, Bonnet D, Sekarski N, Sidi D, Vouhe P, von Segesser LK. Remote control of pulmonary blood flow: initial clinical experience. *J Thorac Cardiovasc Surg* 2003;126:1775–80.
9. Corno AF, Ladusans EJ, Pozzi M, Kerr S. Flow watch versus conventional pulmonary artery banding. *J Thorac Cardiovasc Surg* 2007;134:1413–19.
10. Muramatsu Y, Kosho T, Magota M, Yokotsuka T, Ito M, Yasuda A, Kito O, et al. Progressive aortic root and pulmonary artery aneurysms in a neonate with Loeys–Dietz syndrome type 1B. *Am J Med Genet A* 2010; 152A:417–21.
11. Idriss FS, Riker WL, Paul MH. Banding of the pulmonary artery: a palliative surgical procedure. *J Pediatr Surg* 1968; 3(4):465-74.
12. Valente AS, Mesquita F, Mejia JA, Maia IC, Maior MS, Branco KC, et al. Pulmonary artery banding: a simple procedure? A critical analysis at a tertiary center. *Rev Bras Cir Cardiovas* 2009; 24(3):327-33.
13. Tingelstad JB, Lower RR, Howell TR, Eldredge WJ. Pulmonary artery banding in tricuspid atresia without transposed great arteries. *Am J Dis Child* 1971; 121(5):434-37.
14. Sasaki T, Takahashi Y, Ando M, Wada N, Kawase Y, Seki H. Bilateral pulmonary artery banding for hypoplastic left heart syndrome and related anomalies. *Gen Thorac Cardiovasc Surg* 2008; 56(4):158-62.
15. Murugesan C, Banakal SK, Garg R, Keshavamurthy S, Muralidhar K. The efficacy of aprotinin in arterial switch operations in infants. *Anesth Analg* 2008; 107(3):783-87.
16. Sievers HH, Lange PE, Arensman FW, et al. Influence of two-stage anatomic correction on size and distensibility of the anatomic pulmonary/functional aortic root in patients with simple transposition of the great arteries. *Circulation* 1984; 70(2):202-8.
17. Yacoub MH, Radley-Smith R, Maclaurin R. Two-stage operation for anatomical correction of transposition of the great arteries with intact interventricular septum. *Lancet* 1977; 18. 1(8025):1275-78.
18. Franklin RC, Sullivan ID, Anderson RH, et al. Is banding of the pulmonary trunk obsolete for infants with tricuspid atresia and double inlet ventricle with a discordant ventriculoarterial connection? Role of aortic arch obstruction and subaortic stenosis. *J Am Coll Cardiol* 1990; 16(6):1455-64.
19. Huddleston CB, Canter CE, Spray TL. Damus-Kaye-Stansel with cavopulmonary connection for single ventricle and subaortic obstruction. *Ann Thorac Surg* 1993; 55(2):339-45.
20. Brooks A, Geldenhuys A, Zuhlke L, Human P, Zilla P. Pulmonary artery banding:

still a valuable option in developing countries? *Eur J Cardiothorac Surg* 2012; 41(2):272-76.

21. Freedom RM, Sondheimer H, Sische R, Rowe RD. Development of "subaortic stenosis" after pulmonary arterial banding for common ventricle. *Am J Cardiol* 1977; 39(1):78-83.

22. Tomoyasu T, Miyaji K, Miyamoto T, Inoue N. The bilateral pulmonary artery banding for hypoplastic left heart syndrome with a diminutive ascending aorta. *Interact Cardiovasc Thorac Surg* 2009; 8(4):479-81.

23. Corno AF, Bonnet D, Sekarski N, et al. Remote control of pulmonary blood flow: initial clinical experience. *J Thorac Cardiovasc Surg* 2003;126(6):1775-80.

24. Winlaw DS, McGuirk SP, Balmer C. Intention-to-treat analysis of pulmonary artery banding in conditions with a morphological right ventricle in the systemic circulation with a view to anatomic biventricular repair. *Circulation* 2005; 111(4):405-11.

25. Trusler GA, Mustard WT. A method of banding the pulmonary artery for large isolated ventricular septal defect with and without transposition of the great arteries. *Ann Thorac Surg* 1972; 13(4):351-55.

26. Rodefeld MD, Ruzmetov M, Schamberger MS, et al. Staged surgical repair of functional single ventricle in infants with unobstructed pulmonary blood flow. *Eur J Cardiothorac Surg* 2005; 27(6):949-55.

27. Horowitz MD, Culpepper WS 3rd, Williams LC 3rd, et al. Pulmonary artery banding: analysis of a 25-year experience. *Ann Thorac Surg* 1989; 48(3):444-50.

28. Holmström H, Bjørnstad PG, Smevik B, Lindberg H. Balloon dilatation of pulmonary artery banding: Norwegian experience over more than 20 years. *Oct 9, 2009.*

29. Simpson IA, Valdes-Cruz LM, Berthoty DP, et al. Cine magnetic resonance imaging and color Doppler flow mapping in infants and children with pulmonary artery bands. *Am J Cardiol* 1993; 71(16):1419-26.

30. Yasui H, Kado H, Yonenaga K, et al. Arterial switch operation for transposition of the great arteries, with special reference to left ventricular function. *J Thorac Cardiovasc Surg* 1989; 98(4):601-10.

31. Wernovsky G, Giglia TM, Jonas RA, et al. Course in the intensive care unit after

"preparatory" pulmonary artery banding and aortopulmonary shunt placement for transposition of the great arteries with low left ventricular pressure. *Circulation* 1992; 86(5 Suppl):II133-9.

32. Fletcher BD, Garcia EJ, Colenda C, Borkat G. Reduced lung volume associated with acquired pulmonary artery obstruction in children. *AJR Am J Roentgenol* 1979; 133(1):47-52.

33. Steussy HF, Caldwell RL, Wills ER, Waller BF. High takeoff of the left main coronary artery from the pulmonary trunk: potentially fatal combination with pulmonary trunk banding. *Am Heart J* 1984; 108(3 Pt 1):619-21.

34. Daskalopoulos DA, Edwards WD, Driscoll DJ, et al. Fatal pulmonary artery banding in truncus arteriosus with anomalous origin of circumflex coronary artery from right pulmonary artery. *Am J Cardiol* 1983; 52(10):1363-4.

35. Warnecke I, Bein G, Bucherl ES. The relevance of intraoperative pressure and oxygen saturation monitoring during pulmonary artery banding in infancy. *J Cardiothorac Anesth* 1989; 3(1):31-6.

36. Kutsche LM, Alexander JA, Van Mierop LH. Hemolytic anemia secondary to erosion of a Silastic band into the lumen of the pulmonary trunk. *Am J Cardiol* 1985; 55(11):1438-39.

37. Mahle S, Nicoloff DM, Knight L, Moller JH. Pulmonary artery banding: long-term results in 63 patients. *Ann Thorac Surg* 1979; 27(3):216-24.

38. Kron IL, Nolan SP, Flanagan TL, Gutgesell HP, Muller WH Jr Pulmonary artery banding revisited. *Ann Surg* 1989; 209(5):642-7; discussion 647.

39. Dajee H, Benson L, Laks H. An improved method of pulmonary artery banding. *Ann Thorac Surg* 1984; 37(3):254-7.

40. Takayama H, Sekiguchi A, Chikada M, Noma M, Ishizawa A, Takamoto S. Mortality of pulmonary artery banding in the current era: recent mortality of PA banding. *Ann Thorac Surg* 2002; 74(4):1219-23; discussion 1223-4.

41. Viassolo V, Lituania M, Marasini M, et al. Fetal aortic root dilation: a prenatal feature of the Loeys–Dietz syndrome. *Prenat Diagn* 2006; 26:1081–83.

- 42.** Yetman AT, Beroukhim RS, Ivy DD. Importance of the clinical recognition of Loey's–Dietz syndrome in the neonatal period. *Pediatrics* 2007;119:1199–1202.
- 43.** Fridez P, Jordan A, Montavon JC, Stergiopoulos N. FloWatch: an implantable device for telemetric control of flow after pulmonary artery banding. *Cardiovasc Eng* 2002; 7: 51.
- 44.** Corno AF, Sekarski N, Bernath MA, Payot M, Tozzi P, von Segesser LK. Pulmonary artery banding: long-term telemetric adjustment. *Eur J Cardiothorac Surg* 2003; 23: 317-22.
- 45.** Le Bret E, Lupoglazoff JM, Borenstein N, Fromont G, Laborde F, Bachet J, et al. Cardiac "fitness" training: an experimental comparative study of three methods of pulmonary artery banding for ventricular training. *Ann Thorac Surg.* 2005; 79(1):198-203.
- 46.** Corno AF, Prosi M, Fridez P, Zunino P, Quarteroni A, von Segesser LK. The non-circular shape of FloWatch®-PAB prevents the need for pulmonary artery reconstruction after banding. *Computational fluid dynamics and clinical correlations.* *Eur J Cardiothorac Surg* 2006; 29: 93-9.
- 47.** Afrasiabi A, Samadi M, Montazergaem H. Valved patch for ventricular septal defect with pulmonary arterial hypertension. *Asian Cardiovasc Thorac Ann* 2006; 14:501–4.
- 48.** Muhammad Aasim, Amir Mohammad, Niaz Ali, Mohammad Zahidullah, Mumtaz Anwar, Raheela Aasim, Sumayya Rehman, Muhammad Rehman. VSD Closure Following Pulmonary Artery Banding in Congenital VSD with Significant Pulmonary Hypertension. *Gomal Journal of Medical Sciences* 2014; 12(1):23-6.
- 49.** Dyer K, Graham TP. Congenitally corrected transposition of the great arteries: current treatment options. *Curr Treat Options Cardiovasc Med* 2003; 5:399–407
- 50.** Changizi A, Yaghoubi A, Azarasa M, Ghaffari S, Montazerghaem H. A study on mortality and complications rate following percutaneous adjustable Pulmonary artery Banding. *J Cardiovasc Thorac Res.* 2014; 6(4):253-55.
- 51.** Janjua AM, Saleem K, Khan I, Rashid A, Khan AA, Hussain A. Double flap patch closure of VSD with elevated pulmonary vascular resistance: an experience at AFIC/NIHD. *J Coll Physicians Surg Pak* 2011; 21:197-201.
54. Novick WM, Sandoval N, Lazorhysynets VV, Castillo V, Baskevitch A, Mo X, et al. Flap valve double patch closure of ventricular septal defects in children with increased pulmonary vascular resistance. *Ann Thorac Surg* 2005; 79:21–8.