Pulmonary valvotomy under normothermic caval inflow occlusion

LE NGOC THANH [1], DANG HANH DE [1], A. THOMAS PEZZELLA [2]

1 Department of Cardiovascular and Thoracic surgery   VietDuc University Hospital
40 Trang Thi - HaNoi - VietNam
2 Director, Special Projects, World Heart Foundation
Correspondence: A. Thomas Pezzella MD 17 Shamrock Street Worcester, MA, USA 01605
E.mail:tpezzella@hotmail.com - www.ichfund.org - www.world-heart.org

Abstract

Fifty nine patients underwent an operation between January, 1993 and April, 2000 for isolated pulmonary valve stenosis utilizing the inflow stasis technique. Patient ages ranged from 4 months to 44 years. All patients underwent preoperative two dimensional/doppler echocardiography (2D ECHO) to quantitate the peak systolic gradient between the right ventricle and pulmonary artery. Forty seven patients were studied postoperatively at one week, and forty nine were followed long term. The mean peak systolic gradient preoperatively was: 119.8 mmHg; one week postoperative: 30.07mmHg, and long term: 17.7 mmHg. The average operative time for operative commisurotomy was one minute, thirty five seconds. There were no neurological complications. No patient required reoperation for residual stenosis. There were two perioperative deaths secondary to bleeding, (2/59)(3.3%). The overall results were good to excellent in 92%, fair in 6% and poor in 2%. Clinical examination and non invasive 2D ECHO has replaced cardiac catheterization to both confirm the clinical diagnosis and assess the patients perioperatively. Pulmonary valvulotomy is an effective technique to alleviate isolated pulmonary valve stenosis, and is particularly applicable in emerging economies, like Vietnam.

Key words: Pulmonic stenosis - Pulmonary valvotomy - Inflow stasis.

Introduction

Isolated pulmonary valve stenosis with intact interventricular septum represents 4.7 to 11% of statistically recognised congenital heart diseases [1,2,3]. Historically, the therapeutic options for treatment of pulmonary valve stenosis included the Brock operation [4], the inflow stasis technique [5], pulmonary valvotomy utilizing cardiopulmonary bypass, and presently the interventional balloon dilation technique [6]. In 1951 Varco et al [5,7,8] introduced the technique of inflow stasis or occlusion for pulmonary valvulotomy under normothermia and direct vision. This technique was further adapted and utilized by Mistrot et al [7] in 1976 and Jonas et al [8] in 1985 with gratifying results.

At Viet Duc Hospital the Brock operation was the primary method for the surgical treatment of pulmonary stenosis through 1992 [9]. From 1993 until 2000, with further development in the areas of anesthesia, surgical techniques, and diagnostic 2D-echocardiography (2D-ECHO), the inflow stasis technique for isolated pulmonary valvotomy was adopted. This technique proved to be less complicated, cost-effective, and appropriate for use in centers without adequate facilities for cardiopulmonary bypass or percutaneous valvuloplasty.

Patients and Methods

Between 1993 and 2000, fifty-nine patients underwent pulmonary valvulotomy under normothermic conditions for isolated pulmonary valve stenosis. There were 44 men (69,4%) and 15 women (30,6%), ranging in age from 4 months to 44 years (mean age: 9.4 years). Complete physical examination, ECG, chest X-ray and 2D ECHO were performed on all patients pre and postoperatively. The 2D ECHO was performed by at least two cardiologists to ensure accurate quantitative assessment of the degree of pulmonary stenosis and the presence of associated lesions.

Clinically, exertional dyspnea was present in 37/59 (62.7%) of the patients. All patients had a grade 2-4/6 systolic ejection murmur at the left upper sternal border. The second heart sound was split in 20/59 (33.8%) and inaudible in 39/59 (66.2%). In patients who had an inaudible second heart sound, the gradient between right ventricle and pulmonary artery was greater than 100 mmHg. 18/59 (30.5%) patients had central and peripheral cyanosis. In these patients, 13 had an atrial septal defect with a predominant right to left shunt. The gradient for five of these patients was more than 120 mmHg. Hepatomegaly was found in seven patients.
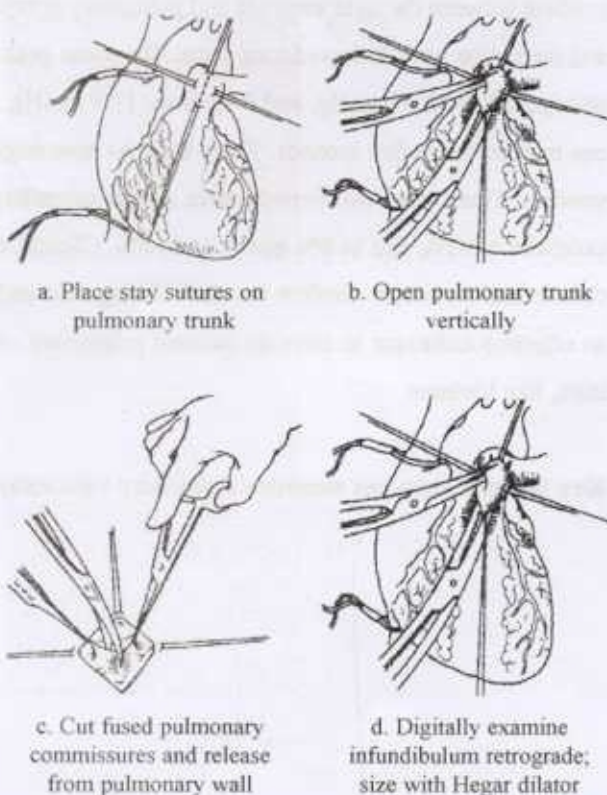
Chest X-ray showed a cardio-thoracic ratio greater than 0.55 in 16/59 (27.1%). Decreased pulmonary vascularity was observed in all patients. Post stenotic dilatation of the main pulmonary artery was seen in 40/59 (76.1%). On electrocardiograms, right ventricular hypertrophy was evident with mean axis QRS 111.30, (70%) of this
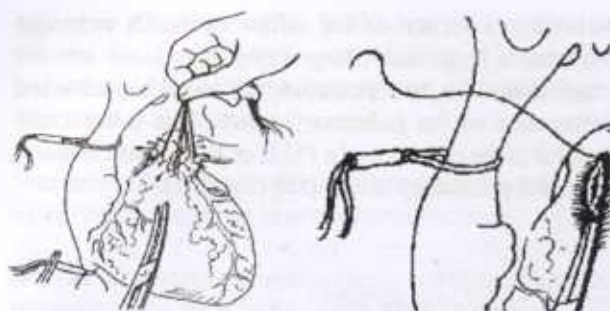
with QRS more than 1000. Mean RV1 18.8 mm, RV1 >12mm (92.6%).

2D ECHO revealed a thickened pulmonary valve leaflets in 58/59 (98%) with doming in systole, together with a stenotic orifice, fused commissures, and post stenotic dilatation of the main pulmonary artery. The mean peak instantaneous systolic gradient gradient between right ventricle and pulmonary artery was 119.8 mmHg, utilizing the simplified bernoulli equation ($?p = 4 \times Vmax2$) [3]. In 53/59 (89.8%) this ratio was more than 100 mmHg. Thirteen patients had an atrial septal defect which was found to be a patent foramen ovale with a floating membrane, and a right to left shunt. Tricuspid regurgitation was seen in 36/59 (61%). Patent ductus arteriosus was found in three patients.

All operations were performed under general anesthesia, with 100% oxygen ventilation maintained for ten minutes before and after valvulotomy. Blood transfusions were given for patients with more than 250 ml (adults) and 100 ml (children under five years old) blood loss. A midline sternotomy was performed in all patients. For young children or those with a small right ventricle, a clamp was directly applied to the vena cava. For older children or adults with an enlarged right ventricle, occluding tapes over tourniquets were placed around both vena cava and a combination of both techniques were used. Partial clamping and longitudinal pulmonary arteriotomy were performed on the majority of patients. The aorta or main pulmonary was not clamped. Transverse arteriotomy was used only by those surgeons more experienced with this technique. The valvulotomy was performed in a standard fashion, with incision of the commissure out to the annulus, from posterior commissure to right and left commissure. (Figure 1)

a. Place stay sutures on pulmonary trunk

b. Open pulmonary trunk vertically

c. Cut fused pulmonary commissures and release from pulmonary wall

d. Digitally examine infundibulum retrograde; size with Hegar dilator

e. Loosen the SVC tape; De-air the right ventricle

f. Loosen IVC tape; close pulmonary incision above side biting vascular clamp

Fig 1 - Inflow Stasis Technique [10]

[10] In patients with a patent ductus arteriosus, silk suture ligation was performed prior to pulmonary valvulotomy.

Results

There were no late deaths or sequelae. At follow up, no patients had symptoms of congestive cardiac failure. No patient required re-operation for residual pulmonary stenosis. At follow up, 19 patients had no audible systo-lic ejection murmurs. In the remainder, the intensity of the murmur had decreased. In all patients the second heart sound was audible.

For the 18 patients who were cyanotic preoperatively, all were acyanotic at follow up.

Post stenotic dilatation of the main pulmonary artery was observed in 10/49 (20.4%). There was decreased pulmonary vascularity in one patient. There were only two patients who had a cardio thoracic ratio greater than 0.55. The decrease of the right ventricular hypertrophy on ECG was specific, with a mean QRS 61.230.and a mean RV1 6.8 mm. All patient had adequate movement of the pulmonary valve leaflets and no associated pul-monary valve regurgitaion on post-op 2D ECHO. Eight of the thirteen patients who had an atrial septal defect preoperatively had no residual shunting. Five of 13 patients with ASD had a small residual interatrial shunt from left to right but this was not hemodynamically significant.

The mean systolic gradient between the right ventricle and pulmonary artery decreased post valvotomy and continued to decrease over time. (Fig.2).
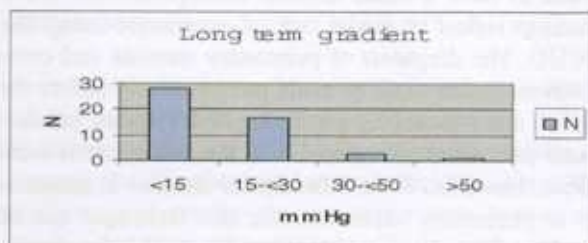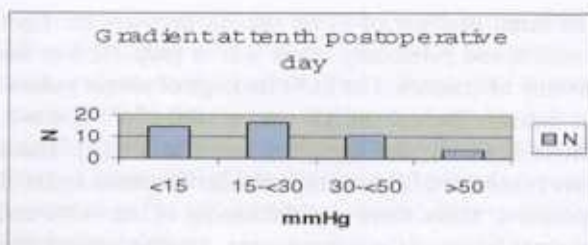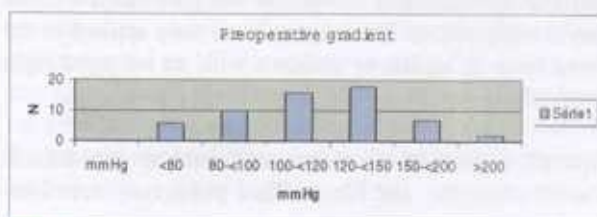
Fig2: The gradient between right ventricle and pulmonary artery

The mean preoperative gradient was 119.8 mmHg, and one week postoperatively: 30.07. Long term mean gra-dient was 17.7 mmHg. All patients followed at two years were doing well clinically.

Five patients had perioperative bleeding regarding blood transfusions. No patients had sternal wound infection, pericardial or pleural effusions. One patient had a super-ficial skin infection that was treated locally. There were two hospital deaths from early perioperative bleeding (2/59)(3.3%).

Intravenous antibiotics were administered for 72 hours postoperatively. All patients were discharged by the tenth postoperative day. The average follow up time for the 49 surviving patients was 26 months (8 to 52 months). There was no further follow-up beyond January, 2001.

Excellent results were defined as a gradient less than 15 mmHg and good results were defined as a gradient less than 30 mmHg (45/49 - 92%); fair results (3/49 - 6%) with a gradient of 30 to 50 mmHg; and poor results (1/49 - 2%) with a gradient of more than 50 mmHg.

Discussion

In recent years, 2D-ECHO has become the primary investigative modality for the diagnosis and evaluation of patients with congenital heart disease. The combina-tion of clinical findings and 2D-ECHO provides an effective diagnosis for isolated valvular pulmonary stenosis [11,12,13,14].

All patients in our study had isolated pulmonary stenosis. At operation the pulmonary valve was found to be thickened, with fused commissures and severe stenosis (47/59 - 96.6%). The mean pulmonary valve area was 0.3 cm/m2, in comparison with a normal value of 1.7 cm/m2.

The mean gradient of 119.8 mmHg between the right ventricle and pulmonary artery was in proportion to the severity of stenosis. The ECG findings of severe pulmonic stenosis include an RV axis of 100-170°; R wave, RS, or R in V1; and upright T wave in V1 [3]. There were two cases of pulmonary valvular dysplasia found at operation, where there was thickening of the valve and minimal fusion of the commissures. Another patient was noted to have a small annulus intraoperatively. These findings reflect an initial lack of experience using 2D-ECHO. The diagnosis of pulmonary stenosis and commissural fusion must be made preoperatively before the inflow stasis technique can be applied. Primary infundibular stenosis is not amenable to the inflow stasis technique. However, if the infundibular stenosis is secondary to pulmonary valve stenosis, this technique can be employed. Weyman et al [11] has shown that the significant echocardiographic features of infundibular stenosis are a small pulmonary artery without postdilatation of the main pulmonary artery and a fluttering pulmonary valve. The combination of clinical examination and non-invasive investigation has replaced cardiac catheterization in the diagnosis and preoperative assessment of pulmonary stenosis with intact interventricular septum. Errors in diagnosing pulmonary valvular and associated lesions were reduced when echocardiography was performed by at least two cardiologists thus ensuring accurate assessment. At present there are at least six techniques to consider for isolated congenital pulmonary valve stenosis. The original closed pulmonary valvotomy described by Brock utilizing Brock knives, or the Tubbs dilator [3] (figure 3)


Fig 3 Brock Procedure Utilizing Original rock Knives, or Tubbs Dilator [16]

has been modified to use progressive larger Hegar dilators, based on calculated Z valve for pulmonic valve, inserted via the RV infundibular outflow tract [15] (figure 4).
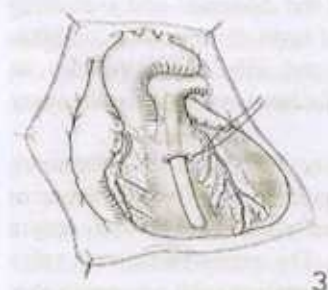
Fig 4 Modified Brock Procedure Using progressively larger Hegar dilators [15]

Secondly, a variant of the inflow occlusion technique includes a large side-biting clamp introduced into the transverse sinus, thus occluding the ascending aorta and bifurcation of the pulmonary artery. This is especially helpful in the presence of a PDA, or to decrease bleeding from the pulmonary artery [16] (figure 5).
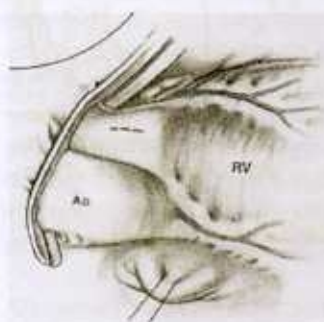
Fig 5 Inflow cclusion Modification of Clamping Aorta and Main pulmonary artery [16]

The third technique is the technique described in the present report. The fourth technique is open valvotomy employing cardiopulmonary bypass with either a cardioplegic arrested heart, or a beating heart when no shunts are present. The techniques utilizing CPB are the most precise in that they allow meticulous commissurotomy and release of fused leaflet tissue from the pulmonary artery wall [17]. Results are comparable with the catheter approach [18]. The fifth and presently the standard of care approach is the transvenous catheter balloon dilatation technique [5,19]. A sixth technique described is urgent or emergency operative balloon dilation in the setting of a failed transcatheter approach [20]. Complications associated with the transcatheter balloon technique include injury to the tricuspid value, AV node, pulmonary valve, and pulmonary, artery/branches [18].

Fair results were obtained with the closed Brock pulmonary valvulotomy. However, this is a "blind operation", and when infundibular hypertrophy is present, technical difficulties and bleeding can occur. Excellent results have been obtained performing open valvotomy on cardiopulmonary bypass, but it is not cost effective in developing countries or emerging economies, and complications related to cardiopulmonary bypass can still occur, especially in centers without adequate experience and facilities. Again, Mistrot et al [7] and Jonas et al [8] have demonstrated excellent results with the inflow stasis technique, which is also cost effective.

Our study shows our operative technique described to be safe, technically not complex, and appropriate for use in Vietnam. For children or patients who have a small right ventricle, direct clamping of the vena cava was applied without difficulty and valvotomy was performed without any complications. Tourniquets were only applied to the vena cava in adults, or children with an enlarged right ventricle.

Specific aspects of our technique should be emphasized. Partial clamping and longitudinal pulmonary arterioto-

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my, especially when used in infants, reduced the time of inflow stasis, and decreased bleeding. Transverse arteriotomy was used only by surgeons who were experienced with this technique.

Ventilating the patient with 100% oxygen pre and post valvulotomy improved post operative recovery.

We used a standard commissurotomy extending from the posterior to the right and left commisure. The operative field was cleared, and valvulotomy was performed simply with care taken to prevent laceration of the pulmonary artery. Complications can occur when performing the commissurotomy in the opposite direction (one death in our report, secondary to massive bleeding).

Complications associated with this technique were related to technical problems including blood loss caused by pulmonary artery laceration on clamp release. The risks of these complications are reduced with greater experience and training of the surgeon.

In this study there were two deaths, one due to technical error and intraoperative bleeding, as noted, and the other due to postoperative bleeding. Jonas et al [8] reported excellent results using this technique, and no mortality, with the majority of patients being infants. This confirmed that in a surgical center with good facilities and experienced surgeons, this operation is as safe as other techniques.

The mean time of inflow stasis was 1 minute 35 seconds. The time taken to achieve inflow stasis decreased with experience. This is consistent with findings in the literature where valvulotomy can be accomplished within 2 minutes [7,8].

All patients in our study were discharged from the hospital within 10 postoperative days. No patient required further medical treatment. There were no other post operative complications, including pericardial or pleural effusions or sternal wound infections.

Mid term results have been excellent and good in the majority of our patients (92%). One patient with a preoperative gradient of 210 mmHg had a residual gradient of 50 mmHg 8 months post operatively, yet a decrease in right ventricular hypertrophy on 2D ECHO. A phenomenon noted in several patients was persistence of early post-operative RV/PA gradient, which gradually resolved. This has been previously described [19]. In patients with isolated pulmonic stenosis and varying degrees of infundibular stenosis, there can occur a varying period of dynamic subvalvular abstraction relating to hypercontractility, the so called "suicidal right ventricle" [19]. It can be treated early with volume loading, ß blockers, and calcium channel blockers. It usually recedes over several weeks/months, as was observed in several patients in the present series. Eighteen patients who had peripheral and central cyanosis preoperatively were acyanotic.

There were no patients in congestive heart failure. Of the thirteen patients who had an ASD prior to operation, eight had no residual shunt. Five patients had a small residual left to right shunt, but this was not hemodynamically significant. These findings are consistent with those of Jonas et al [8]. In his study, no patients required re-operation for left to right shunting from a residual atrial septal defect.

Conclusion

In Vietnam, we have demonstrated that pulmonary valvulotomy under normothermic caval inflow occlusion is safe, and technically simpler to perform in comparison with other non-bypass techniques. The complications associated with cardiopulmonary bypass are avoided, and the treatment is cost effective with acceptable results.

Improved outcomes, and reduction in technical complications can be achieved with additional surgical experience and training. Our study suggests that the inflow stasis technique is an effective method for the treatment of isolated pulmonary stenosis with intact ventricular septum.

Though the interventional balloon catheter dilatation technique has become the procedure of choice in most cardiac centers [19,21], the present technique described offers a safe alternative, especially in emerging economies where advanced techniques are either unavailable, or not cost effective. It is also an effective approach for failed balloon catheter dilatation [10].

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