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Pulmonary artery banding: a simple procedure? A critical analysis at a tertiary center

Bandagem da artéria pulmonar: uma cirurgia simples? Uma análise crítica em um centro terciário

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Abstract

Objective: **Although pulmonary artery banding (PAB) seems to be a technically simple procedure it presents several peculiarities and is related to a significant morbidity and mortality. The aim of this study is to analyze the experience of a tertiary hospital on the PAB by assessing and correlating many aspects related to the procedure.**

Methods: **Between January 2000 and December 2008, 61 patients undergone PAB due to congenital heart disease with increased pulmonary blood flow at Messejana Heart Hospital were assessed as for mortality, complications, stay in mechanical ventilation and need for intensive care unit (ICU), use of vasoactive drugs, difficulties in the adjustment on the banding and reoperations. Some statistical analyzes were performed to compare the subgroups.**

Results: **In 36.17% of the patients the intended pressoric adjustment was not achieved and in 6.5% it was necessary another surgery to readjust the banding. The mean time of mechanical ventilation was 14.1±49.6 days and ICU 14.16±10.92 days. In 82.6% of the patients vasoactives drugs were administrated for 10.3±12.79 days. Severe complications were noted in 49.15% of patients and cardiac insufficiency was the most common one with an incidence of 44%. The mortality rate was 8.2% and it was not influenced by weight or associated procedures with the PAB neither if univentricular or biventricular heart disease.**

Conclusion: **The PAB can be performed with acceptable mortality rates compatible with the ones of the world literature. Nevertheless, the adjustment of the banding is difficult to be assessed during the surgery by making the**

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procedure complex and justifying the high incidence of complications and long stay in ICU. It wasn't found any specific risk factor significant to mortality neither uni- or biventricular heart disease.

Descriptors: **Cardiac surgical procedures. Pulmonary artery/surgery. Heart ventricles. Heart defects, congenital/ surgery.**

Resumo

Objetivo: **A bandagem da artéria pulmonar (BAP) é um procedimento tecnicamente simples, mas envolto em várias peculiaridades que o fazem apresentar elevadas taxas de morbidade e mortalidade. O objetivo deste estudo é analisar a experiência de um hospital de referência na bandagem da artéria pulmonar, avaliando e correlacionando diversas variáveis relacionadas ao procedimento.**

Métodos: **Entre janeiro de 2000 e dezembro de 2008, 61 pacientes submetidos a BAP por cardiopatia congênita de hiperfluxo no Hospital do Coração de Messejana-Fortaleza/ CE foram avaliados quanto a mortalidade, complicações, permanência em ventilação mecânica (VM) e terapia intensiva (UTI), uso de drogas vasoativas, dificuldade de ajustes transoperatórios e reoperações para reajuste. Análise estatística foi realizada para comparações entre subgrupos.**

Resultados: **Em 46,8% dos pacientes, não se conseguiu o ajuste pressórico pretendido e 6,5% precisaram ser reoperados para reajustes. O tempo médio UTI e VM foi 14,16 ± 10,92 dias e 14,1 ± 49,6 dias, respectivamente. Em 82,6% dos pacientes foram administradas drogas vasoativas por 10,30 ± 12,79 dias. Complicações graves incidiram em 49,15% dos pacientes, com predominância da insuficiência cardíaca (44%). A taxa de mortalidade foi de 8,2%, não influenciada por peso, procedimentos associados ou cardiopatia univentricular ou biventricular.**

Conclusão: **Neste estudo, a BAP foi realizada com taxas de mortalidade aceitáveis, compatíveis com a literatura mundial. No entanto, os ajustes transoperatórios são de difícil análise, tornando o procedimento complexo e justificando elevados índices de complicações, resultando em longa permanência em UTI. Nenhuma variável isolada representou significante fator de risco, dentre as quais, fisiologia uni ou biventricular.**

Descritores: **Procedimentos cirúrgicos cardíacos. Artéria pulmonar/cirurgia. Ventrículos do coração. Cardiopatias congênitas/cirurgia.**

INTRODUCTION

Since the initial proposition of Muller and Danimann [1] in 1952, the techniques for surgical creation of an obstruction to pulmonary flow have evolved, as well as its clinical indications. However, what could be considered a simple surgery - the pulmonary artery banding (PAB) – is currently still accompanied by high morbidity and mortality, with significant complication rates [2-4]. This fact is due to the difficulty of assessing the degree of pulmonary constriction to be produced, considering that this assessment is performed in very special circumstances, since the patient is under general anesthesia, muscle relaxant, with the chest opened and ventilation controlled. Thus, what could be considered an appropriate adjustment in these circumstances, can be shown excessive or inefficient when the patient recovers his physiological condition. The complexity of heart disease also interferes with the mortality of the procedure, ranging from 3% to 25% in the literature [5-7].

The intensity of the intraluminal obstruction is also a difficult aspect to be assessed, as well as its effect on the flow. A stenosis produced by a constriction of the pulmonary artery (PA) which presents, by external inspection, as mild or moderate, may represent a much greater luminal narrowing due to the invagination of the vessel wall to its lumen, producing a greater obstruction than expected.

Currently, there are three main indications for PAB: heart disease with increased pulmonary hyperflow and unbalanced biventricular physiology, whose definitive surgery at some momment would be at high risk, requiring staged correction; heart disease of pulmonary hyperflow with univentricular physiology, as a palliative for protection of the pulmonary system as for the main pressures, until the child can undergo surgical steps of the cavopulmonary connection, for preparing of the subpulmonary ventricle in hypotrophic condition due to the transposition of the great arteries (TGA) for further Jatene's surgery procedure [8-10].

The world literature lacks of long analysis on PAB. At the Messejana Heart Hospital, in Fortaleza, CE, the main referral center for complex congenital heart diseases of the state, about 250 to 300 pediatric heart surgeries are performed a year. In about 10 cases per year it is necessary to perform the PAB. Thus, the aim of this study is to assess the service experience in PAB surgery, detailing and correlating the main aspects observed as for its distribution and clinical outcome.

METHODS

Between January 2000 and December 2008, 76 patients underwent PAB for treatment of various congenital heart diseases with pulmonary hyperflow. The data were obtained by retrospective assessment of the medical records. 15 patients were excluded from analysis due to lack of data. The study included 61 patients, with 28 female. The distribution of heart disease is shown in Figure 1. The main heart disease was ventricular septal defect (VSD), by 19.31% of patients. These children, specifically, had undergone PAB for not presenting clinical conditions for total correction at some point (malnutrition, infection) and/or due to unfavorable anatomy of the VSD (apical, multiple, etc.). Cases of banding for ventricular preparation in the TGA were not considered because of the small experience in our service, with few cases operated and because we consider it is a very specific condition with peculiar aspects of adjustment and assessment, which may be approached, specifically, in another study. This study was approved by the Research Ethics Committee at Messejana Heart Hospital.

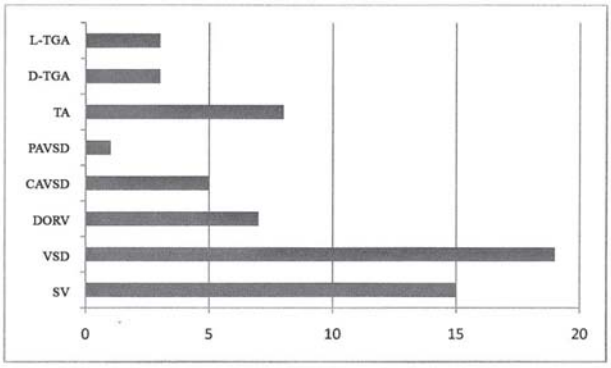

Fig. 1 – Distribution by heart disease. SV = single ventricle; VSD = ventricular septal defect; DORV = double outlet right ventricle; CAVSD = complete atrioventricular septal defect; PAVSD = partial atrioventricular septal defect; TA = tricuspid atresia; D-TGA = transposition of the great arteries; L-TGA = Congenitally corrected transposition of the great arteries

Surgical technique

The patients underwent surgery under general anesthesia and orotracheal intubation (OTI). In 50 cases, the access to the heart was performed through a classic sternotomy; in three cases through mini-sternotomy with partial opening of the pericardium, and in eight cases, left thoracotomy was performed (six of these presented aortic coarctation which was corrected during surgery). When present, the patent ductus arteriosus (PDA) was connected. In all cases fixed banding was performed, aiming at reducing pulmonary pressure after the PAB to about 30% of sytemic pressure (SAP), since there was no destabilization, a condition where the highest tolerated constriction was maintained. In cases of single ventricle heart defect, it was also noted the value of pulmonary artery pressure, which ideally should be maintained below 20mmHg. The minimal arterial oxygen saturation was allowed at least 75%-80%, with fraction of inspired oxygen of 40%.

Parameters assessed

Some patients were not considered for analysis of certain parameters due to incomplete data from medical records or lack of relationship between the variable and the surgical procedure. In the variables where this occurred, we specified the total number of "valid patients". The parameters assessed in this study were: weight and age distribution, incidence of cases where the ideal adjustment was not tolerated (47 valid patients). It was considered as an ideal pressure adjustment a PAP/SAP ratio as close as possible to normal, around 30%. In the present study, we standardized this ratio as ideal if up to 0.39, assessment of associated procedures (61 valid patients - PDA was not considered), duration of intubation (49 valid patients), length of stay in intensive care unit - ICU (44 valid patients), incidence of reoperations for adjustment of banding (61 valid patients), use and duration of vasoactive drugs (dopamine and/or dobutamine and adrenaline specifically - 46 valid patients) and incidence of serious complications (heart failure, renal failure, low cardiac output syndrome (LCOS), severe bradyarrhythmias or tachyarrhythmias, reversed cardiac arrest and death - 59 valid patients).

Patients listed by LCOS presented severe hemodynamic instability without other significant clinical or radiological evidence of heart failure. For the characterization of heart failure, the clinical parameters (congestive hepatomegaly, significant pulmonary congestion, low cardiac output) and radiological or echocardiographic parameters were considered. For the characterization of renal failure, urinary output and laboratory values of nitrogenous compounds were considered.

Statistical analysis was performed to assess the relationship between death and body weight, associated procedures, univentricular or biventricular physiology and complications, as well as correspondence between these different cardiac physiologies and the difficulty of adjusting the banding.

Statistical analysis

The data for weight, age and time were described as mean ± standard deviation. For the relationship between

weight of patients who died and those who survived, we applied the Student's t test for analysis of unknown and equal variances. The chi-square test was applied to contingency tables, assessing the relationship between associated procedure and complications. To assess the relationship between univentricular or biventricular heart disease and incidence of complications or inadequate adjustment of the banding, it was applied the normal test for equality of proportions. In all cases, the level of significance was 5%.

RESULTS

Weight and age

We considered for this study 61 patients with ages ranging from 5.6 ± 9.5 months and weighing 4.34 ± 2.13 kg.

Associated procedures

In 13 (21.3%) cases, other procedures associated with PAB were performed: six AoCo corrections, four atrioseptostomy without cardiopulmonary bypass (CPB), one correction of cor triatriatum, one atrioseptostomy with CPB and one implant of definitive pacemaker.

Appropriate adjustment of the banding

In 24 patients of 47 (36.17%) it was not possible to adjust the banding to allow a PAP/SAP ratio ≤ 0.39. The distribution of the measures is shown in Figure 2.

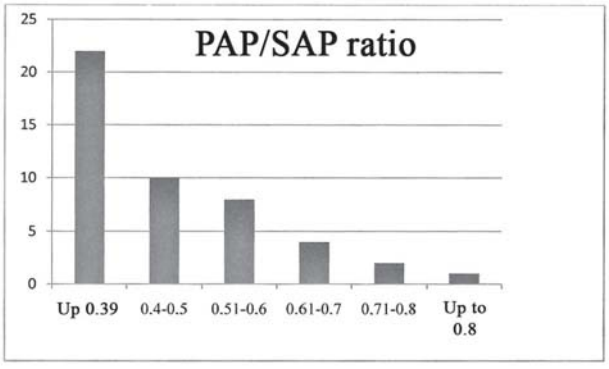

Fig. 2- PAP/SAP (pulmonary arterial pressure/systemic arterial pressure) ratio- 22 patients up to 0.39; 10 patients among 0.4 and 0.5; 8 patients between 0.51 and 0.6; 4 patients between 0.61 and 0.7; 2 patients between 0.71 and 0.8; and 1 patient above 0.8

OTI time and ICU stay

The patients remained on mechanical ventilation in OTI for 14.1 ± 49.6 days. The length of stay in ICU was 14.16 ± 10.92 days.

Use and duration of vasoactive drugs

In 82.6% of patients, dopamine and/or dobutamine for an average time of 10.30 ± 12.79 days were administered. The need for adrenaline, specifically, in the most unstable cases, was required in 19.6% of patients, for an average time of 3.5 ± 2.1 days.

Incidence of reoperations for adjustment of banding

It was required in four (6.5%) cases. Three and one patients presented biventricular and univentricular physiology, respectively.

Heart failure

In 26 (44.0%) patients, there was a significant degree of heart failure in their evolution.

Renal failure

Six (10.1%) patients presented renal failure, in three of them peritoneal dialysis was required.

Severe complications (considering heart and renal failure)

57 severe complications were found in this group, affecting 29 (49.15%) patients. The distribution of all complications is shown in Table 1.

Table 1. Severe complications after the procedure

Complications	Total
Malignant Tachyarrhythmia	2
Bradyarrhythmias	5
Reversed CRA	9
Heart failure	26
Renal failure	6
LCOS	3
Reoperation for bleeding	1

LCOS – Low cardiac output syndrome

Deaths

Five (8.2%) patients died, four and one of them presented heart disease with biventricular and univentricular physiology, respectively.

Analysis results

There is no significant difference between the weights of died children and those who survived (*P*=0.1012).

Patients who underwent PAB in association with another procedure did not present a higher rate of severe complications (*P*=0.1032).

The comparison between heart disease with univentricular or biventricular physiology and incidence

of complications were not different (*P*=0.2224). Similarly, no statistically significant difference in comparison with heart diseases with these two physiologies and higher incidence of improper adjustments were found (*P*=0.8728).

DISCUSSION

Pediatric cardiac surgery, in constant evolution, now experiences the moment of total corrections, increasingly early, of the vast majority of congenital heart diseases. However, in some circumstances, PAB is still a necessary procedure, not only as protection as for the increase of pulmonary vascular resistance in single ventricle heart disease, but also as palliation in patients with heart disease of biventricular pulmonary hyperflow arriving at specialized centers in unfavorable conditions for a total correction at the time.

The difficulty in obtaining an appropriate banding and assessing its hemodynamic effect can be better understood when we consider the observation made by Poiseuille, on which the blood flow is related to the fourth power of the radius of the vessel. Thus, small changes in vessel diameter have a large impact on the flow and pressure gradient through the banding, providing the procedure, although simple, a development with variable - but significant - morbidity and mortality [5-7]. Proposals for pre-established perimeters, such as the classic rule of Trusler [11], in which the authors preconized a perimeter of the pulmonary artery to be obtained with the banding of 20 mm or 24 mm, by adding 1 mm/kg of weight, if the heart disease is cyanotic or acyanotic, respectively, rarely correspond to reality, although such proposals can be used as a reference to "starting point" of the constriction.

Little effort has been observed in the world literature for publication and analysis of large samples of PAB. In our Service, we perform about ten of these procedures per year and experienced the difficulties described in the few clinical reports in the literature. The mean time of OTI and ICU stay of two weeks were high, as well as the need for vasoactive drugs in most patients. The use of adrenaline was considered separately because, although the use of dopamine or dobutamine may even be a routine in the early hours in some services, adrenaline, invariably, is a rescue drug, used in extreme situations, required by nearly 20% of the patients assessed. These long-term use of drugs, mechanical ventilation and ICU stay result in high costs and are compatible with those found in the treatment of complex congenital heart disease.

It can be emphasized the high number of patients who did not tolerate greater tightening of the banding in search of a more physiological pressure ratio (36.17%). In seven (11.4%) patients, only a small constriction was tolerated, and in 6.5%, further surgery was necessary to tighten the banding. These data show the difficulty and empiricism in attempting to adjust in very special conditions. Ideally, one should install the banding and after making necessary adjustments, with the patient awake and recovered from surgery. Adjustable devices can be the solution [12-16].

The unreality of the intraoperative adjustment is also characterized by the discrepancy observed between the RV-PT gradient (right ventricle/pulmonary trunk) measured during surgery in some patients and the postoperative echocardiogram. As this practice was not performed regularly by lack of standardization, the data was not the aim of our study and therefore not approached in our results. In this study, the presence of only one normal functioning ventricle or both did not affect the difficulty of adjustment.

The incidence of serious complications in the study was high, reaching 49.15% of patients. Cardiac arrhythmias, renal and heart failure with a considerable number of nine cases of reversed CRA characterize well the complicated postoperative of this severe children undergone an abrupt ventricular overload with no time for previous adaptation. Again, heart diseases with uni- or biventricular physiology showed no difference in the rate of complications. Although not approached in the results, the potential anatomical problems related to PAB deserve to be mentioned. This occurs when the bandind migrates close to the bifurcation of the pulmonary branches or the pulmonary valve, causing distortion of the structure [17]. In our series, the latter occurred in one patient.

Correlations between complications and echocardiographic assessments were not reported in this study because there was no standardization of the time of the examination in the postoperative period. However, in cases on which such assessment was performed in the presence of heart failure, only one patient presented significant ventricular dysfunction. Echocardiograms in irregular periods of late postoperative showed no cases of sustained ventricular dysfunction.

Five (8.2%) patients died, an incidence that, although consistent with the literature, is significant, especially if we consider that the mortality rate expected for correction of a ventricular septal defect - most common congenital heart disease - is around 2% -3%. The weight of children who died was not statistically different from the overall average and it was not determinant factor for death.

Similarly, the association of other procedures to banding in two cases with CPB, did not interfere in mortality. Takayama et al. [7] analyzed the mortality of the PAB in their series since 1966, decade by decade. They noted progressive reduction in mortality, stabilized in the last two decades around 13.5%. No single variable such as gender, weight or diagnosis, represented a significant risk factor, as well as in our study. Patients who had undergone surgery in the last decade by Takayama et al. [7], presented mean

weight slightly lower than our study (3.2 ± 0.1 kg) and age much lower (3.69 ± 8.9 days), which represents the difficulty of access to tertiary medicine, still present in our state, which makes that many patients arrive late for specialized treatment.

Some authors report that the damage related to acute onset of a fixed overload to the ventricle may not be restricted to the hospital phase, being observed in experimental studies of late ventricular dysfunction and areas of necrosis [18-20]. All these aspects stimulate the experiences with adjustable banding devices, because, in addition to allow that the overload is established with the patient under physiologically normal conditions, they allow progressive or regressive adjustable, depending on the evolution of this patient. In Brazil, Dias et al. [12] and Assad et al. [21], aiming to prepare the subpulmonary ventricle for the Jatene's surgery, developed simple vascular adjustable banding device of hydraulic cuff type, which proved to be effective in other studies of Canêo et al. [13] and Valente et al. [22]. Indeed, the regular use of these devices greatly benefit patients who need to undergo this procedure. In any case, the PAB should be performed by experienced surgeons and patients monitored with attention, and the procedure should not be ignored or considered a simple technique without refinements.

Study limitations

The subgroups correlated in this study presented reduced number of patients, which limits the assessment of findings. Largest sample with comparisons between larger groups will allow a more valuable complementary assessment.

CONCLUSION

The study shows that the PAB can be performed with acceptable mortality rates, consistent with the literature. However, the intraoperative adjustments are difficult to control, making the procedure complex and justifying higher rates of complications, resulting in longer ICU stay. Weight, associated procedures and uni- or biventricular physiology of underlying heart disease did not affect the difficulty of adjusting the banding or incidence of death.

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