CASE REPORT
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Pulmonary artery banding: An alternative treatment in heart failure. Case report

Bandaje de la arteria pulmonar: Un tratamiento alternativo en la insuficiencia cardíaca. Reporte de caso

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ABSTRACT

Terminal heart failure is a significant cause of morbidity and mortality in the pediatric age group. The definitive treatment is a heart transplant; the limited availability of organs in the pediatric age group necessitates exploring treatment alternatives as a bridge to transplant. Pulmonary artery banding with good right ventricular function becomes an option. We present the case of a 12-year-old female patient who, at the age of two, was admitted to our center with a diagnosis of dilated cardiomyopathy and good right ventricular function. It was decided to perform a pulmonary artery banding, which resulted in the recovery of biventricular function during a 10-year follow-up.

Keywords: congenital heart disease, heart failure, heart transplant, pulmonary artery banding.

RESUMEN

La insuficiencia cardíaca terminal es una causa significativa de morbilidad y mortalidad en el grupo de edad pediátrica. El tratamiento definitivo es un trasplante de corazón; la limitada disponibilidad de órganos en el grupo de edad pediátrica hace necesario explorar alternativas de tratamiento como puente al trasplante. El bandaje en la arteria pulmonar, con buena función del ventrículo derecho, se convierte en una opción. Presentamos el caso de una paciente de 12 años que, a los dos años, fue ingresada a nuestro centro con un diagnóstico de miocardiopatía dilatada y buena función del ventrículo derecho. Se decidió realizar un bandaje en la arteria pulmonar, lo que resultó en la recuperación de la función biventricular durante un seguimiento de 10 años.

Palabras clave: *cardiopatía congénita, insuficiencia cardíaca, trasplante de corazón, bandaje de la arteria pulmonar.*

Heart failure represents a cause of morbidity and mortality in the pediatric age group, with many causes, predominantly congenital and genetic. Treatment remains a challenge in this age group; however, we now know that heart transplantation is the definitive treatment.

In the course of managing end-stage heart failure, we have some treatment alternatives; however, the results are still uncertain. Only Ventricular Assist Devices (VADs) and heart transplantation have an optimal level of evidence.

In our setting, VADs have a high cost, and availability is still limited for many patients. Regarding heart transplantation, we

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are aware that donations are scarce in the pediatric population, so local statistics indicate that 50% of listed patients die while awaiting a heart.

Pulmonary artery banding (PAB) is a technique described over 60 years ago and is still used today to restrict blood flow in the pulmonary artery and balance systemic-pulmonary circulations in cases of complex ventricular shunts. This old surgical technique is also employed in patients with a morphological right ventricle (VD) in the systemic circulation who are candidates for a biventricular anatomical repair. PAB in corrected congenital transposition of the great arteries is used not only to retrain the subpulmonary left ventricle but also as an early prophylactic approach in newborns to prevent severe tricuspid insufficiency associated with the systemic position of the right ventricle.[1]

Some surgical management strategies for heart failure have been described, one of them being Pulmonary Artery Cerclage proposed in 2007 by the Giessen Working Group. Reversible CAP has been reinvented as an alternative surgical option for children affected by dilated cardiomyopathy (DCM) with preserved right ventricular (RV) function. Drawing lessons from the subpulmonary ventricle retraining in congenitally corrected transposition of the great arteries, the rationale for PAB in DCM is to promote positive ventricular-ventricular interactions and supposed molecular interference [activating the potential for myocardial repair]. As a result, PAB could represent a true "regenerative surgery" for children affected by terminal heart failure.[2]

CLINICAL CASE

We present here the case of a 12-year-old female patient with a diagnosis of non-compacted myocardium, which has been present since birth. She has a stay of two months in the neonatal intensive care unit before being transferred to our center at the age of 1-year and 4-months, where the diagnosis was confirmed. A study protocol for heart transplantation was conducted, and she was subsequently enlisted.

At two years of age, she was readmitted to the hospital due to decompensation of heart failure. Echocardiography revealed dilated cardiomyopathy, mild mitral insufficiency, and dilated left ventricle. MV E/A ratio > 200 mmHg, biplane LVEF 38%, synchrony index 36%, delayed septal contraction in relation to the free wall of 88 ms and 53 ms, RVP 38 mmHg. It was decided to perform pulmonary artery banding. She was discharged after nine days of the procedure due to improvement *(Figure 1)*.

At the age of six years, a new echocardiogram was performed, revealing mild tricuspid regurgitation, mild mitral regurgitation, preserved systolic and diastolic function of the right ventricle, preserved diastolic function of the left ventricle, systolic dysfunction of the left ventricle, and a global strain of -10. The patient continues to be monitored in Cardiology.

Currently, the patient has weight and height within percentiles, functional class I upon physical examination, with a grade III systolic murmur in the 4th intercostal space left parasternal line, accompanied by splitting of the second heart sound. Electrocardiogram showed a heart rate of 88 beats per minute, sinus rhythm, atrial conduction angle (aP) of 90º, intraventricular conduction angle (aQRS) of -30º, constant PR interval of 120 ms, QRS duration of 80 ms, QTm interval of 440 ms, QTc of 533 ms, sudden transition from V2 to V3, and a predominance of septal forces.

A 1-minute long Lead II strip revealed two QRS complexes, each lasting 140 ms (both with the same morphology), without ST segment elevation, followed by a positive T wave with a compensatory pause (consistent with isolated monomorphic ventricular extrasystoles). Chest X-ray showed levocardia, left apex ICT 0.5, and normal pulmonary flow.

Echocardiogram was reported as follows: right atrial volume 37.2 ml (z = +0.63), telediastolic area of the right atrium 14.7 cm2 (z = +1.28), TAPSE (Tricuspid annular plane systolic excursion) 16.1 mm (Z = -3.63), moderate tricuspid regurgitation, normal mitral valve, E/A ratio of

Prior to banding March 2017: LVEF BP 32.8%; 3D 27.9%

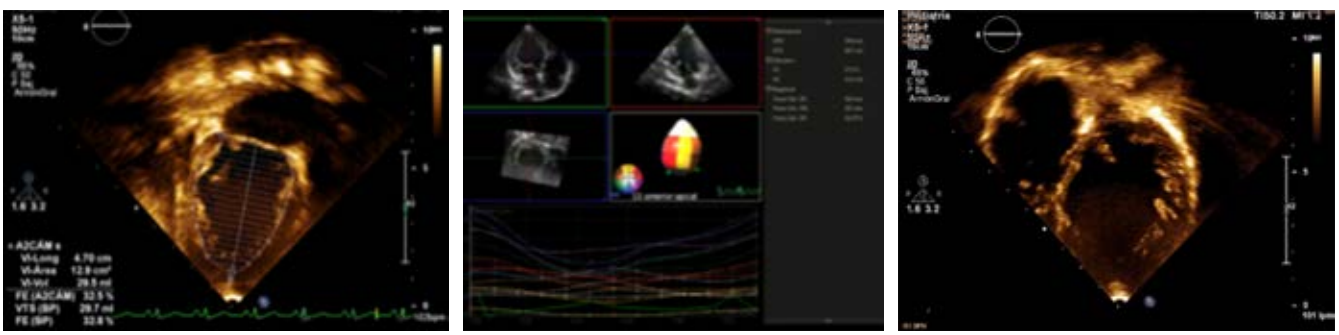

Figure 1: Echocardiogram performed before banding in March 2017: LVEF BP 32.8%; 3D 27.9%.

April 2021

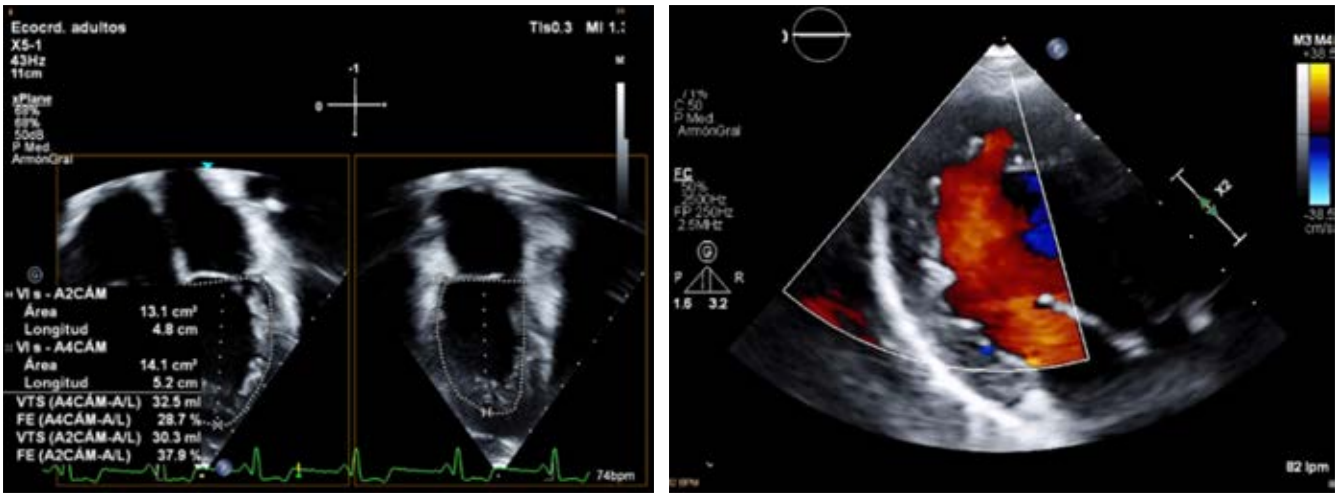

Figure 2: Postoperative echocardiogram showing improvement in left ventricular function after pulmonary artery banding. LVEF A/L 37.9%.

November 2021: LVEF BP 52%; 3D 57%

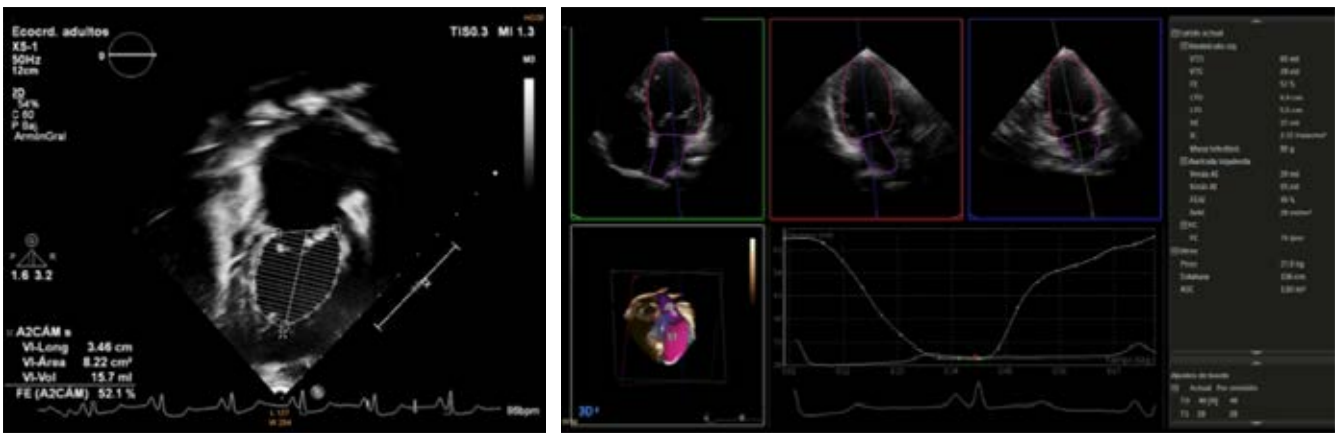

Figure 3: November 2021 Echocardiography with a significant improvement in left ventricular function: Left Ventricular Ejection Fraction (LVEF) increased to 52%.

the mitral valve 1.5, septal E/E' ratio 12.0. Both ventricles exhibited myocardium with a hyper trabeculated appearance, predominantly affecting the left ventricle. Tabulations were present in the apical and mid portions of the free wall of the left ventricle, along with intertrabecular recesses, yielding a non-compacted/compacted (NC/C) ratio of 2.22. The proximal ascending aorta with a diameter of 7.25 mm, generating a gradient of 55 mmHg. Left ventricular mass is 95 grams (Z = 0.45), with a normal left ventricular geometry (GRP 0.45). Right ventricular strain by speckle tracking -21%, Left ventricular longitudinal strain by speckle tracking: 4C - 13.4%, 3C - 27.8%, 2C -16%, Global -19.1%. Aortic insufficiency strain reservoir 34.4%, conduit -21.3%, pump -13.2% *(Figures 2 to 4)*. The study concluded as non-compacted myocardium, operated on the proximal ascending aorta with a gradient of 55 mmHg, moderate tricuspid regurgitation, diastolic dysfunction of the right ventricle, adequate systolic function of the right ventricle, borderline systolic function of the left ventricle.

COMMENT

The first reported case of a 2-month-old infant with progressive idiopathic dilated cardiomyopathy, who was on the heart transplant list, made a dramatic recovery from terminal heart failure after the placement of a pulmonary artery band by Schranz et al. in 2007.[1]

They describe the surprising mechanism of concentric remodeling with improved left ventricular function in response to chronic pressure load on the right ventricle. This led to a shift in decision-making, focusing on unloading the right ventricle through balloon dilation of the pulmonary band. However, the precise mechanism of left ventricular remodeling still needs further clarification.[2]

In 2013, Schranz et al. presented the first study from one center, in which 12 cases of patients with dilated cardiomyopathy affecting the left ventricle were treated. Clinical functional status improved in all patients. The pressure gradient across the PAB increased from 28 ± 7 to 43 ± 15 mmHg in 20 days. Left ventricular ejection fraction increased from 14.5% ± 5% before PAB to 27% ± 13% at hospital discharge and to 47% ± 10% at three to six months. The telediastolic diameter of the left ventricle (z-score) decreased ($p > 0.001$) from 46 ± 6.1 (+7.0 ± 1.3) to 35 ± 15 mm (+3.0 ± 1.3) after three to six months and to 34 ± 15 mm (+1.3 ± 1.14) after a median age of two years (maximum 6.6 years), respectively. Plasma levels of B-type natriuretic peptide decreased from 3,431 ± 2,610 to 288 ± 321 pg/ml at discharge and to 102 ± 96 pg/ml 22 months later. They conclude that in young children with left ventricular dilated cardiomyopathy and preserved right ventricular function, PAB led to an improvement in LV function and mitral valve function through ventricular interaction.[1]

In 2007, Schranz et al. published a multicenter study, reporting worldwide experience, including three cases from our center.[3] The study describes 15 centers in 11 different cities and presents a flowchart of 70 patients who underwent PAB between 2006 and 2017. Among them, nine patients (mean age 159 ± 101 days) received PAB after complex open-chest procedures, including mitral valve repair (n = 4), mitral valve replacement (n = 1), repair of anomalous left coronary artery arising from the pulmonary artery (n = 1), epicardial pacemaker placement (n = 1), fenestrated atrial septal defect closure (n = 1), and repair of a left-sided partial anomalous pulmonary venous return (n = 1). All patients, except the latter, recovered following a mean intensive care stay of 25 ± 33 days and 54 ± 32 days to discharge. The child with partial anomalous pulmonary venous return died eight months after corrective surgery, as left ventricular dilated cardiomyopathy did not respond to PAB, and heart transplantation listing was declined. The experience with these nine patients supports the use of PAB as a recovery strategy to wean patients with left ventricular dilated cardiomyopathy after open-heart surgery.

Spigel et al. reported the first North American series, comparing their results to those by the German group. They included 14 patients, and ultimately, 4 (29%) experienced cardiac recovery, 8 (57%) were bridged to heart transplantation (6 with ventricular assist device placement), and 2 (14%) died. Although the U.S. and German series

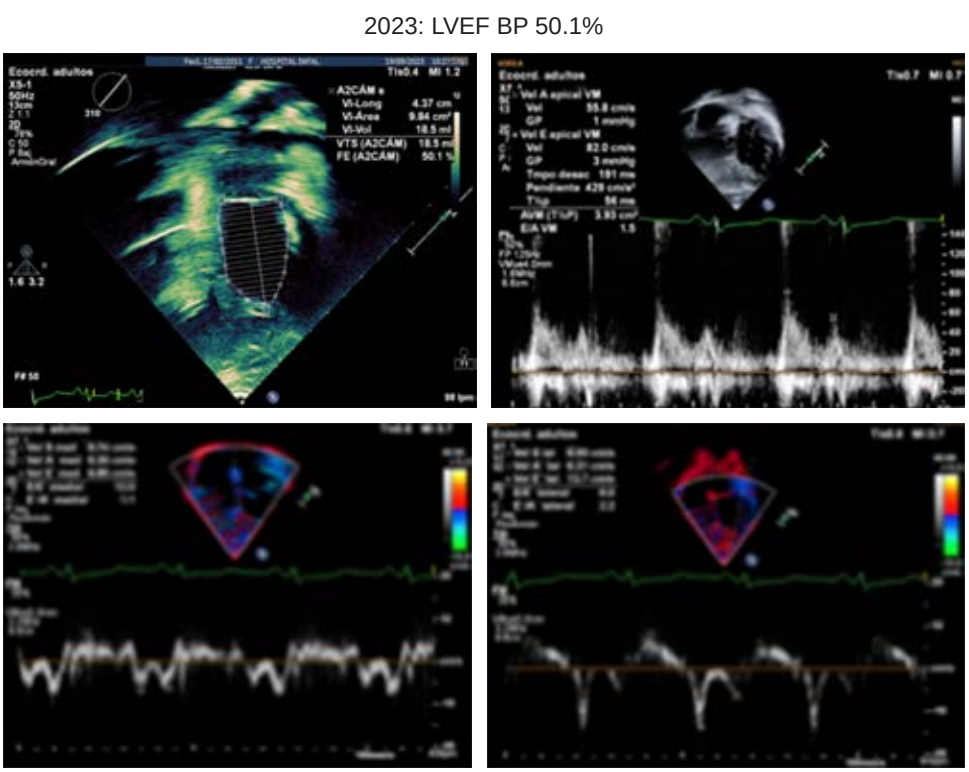

Figure 4:

Latest echocardiographic study in 2023: Left ventricular function is maintained, with a Left Ventricular Ejection Fraction (LVEF) of 50.1%.

demonstrated a high prevalence of achieving the individual patients' goals (either cardiac recovery or transplantation), the mode of success differed (recovery rate: < 1/3 in the U.S. and > 2/3 in Germany). A lower recovery rate may reflect a sicker preoperative state and, therefore, a more advanced stage of heart failure (preoperative intubation: > 2/3 in the U.S. vs. < 1/3 in Germany).[4]

In 2020, an Italian group reported their series of four patients. Out of them, three showed favorable outcomes. All underwent elective percutaneous band removal, 18.5 months, 4.8 months, and 10.7 months after PAB, respectively. The ejection fraction increased from 17.7 ± 8.5% to 63.3 ± 7.6% (p = 0.03), and all were subsequently removed from the transplant list. They concluded that better outcomes seem to be achieved in patients under 12-months old.[4]

In clinical practice, PAB has shown tangible potential to restore left ventricular function in one out of two children affected by end-stage dilated cardiomyopathy. By restoring appropriate left ventricular preload, ellipsoidal shape, and biventricular synchrony, PAB improves myocardial contractility and promotes positive ventricular-ventricular interactions in selected patients. However, several surgical centers remain hesitant to adopt this technique because the precise biological pathways recruited by PAB and the final clinical outcomes are still unknown. To date, only speculative hypotheses derived from ongoing animal experiments on myocardial healing after injury and human data in similar clinical settings, such as morphological retraining of the left ventricle in congenitally corrected transposition of the great arteries, can be proposed. Understanding the cellular and molecular mechanisms of PAB is mandatory to provide an evidence-based explanation supporting this approach. Experimental and specific research is expected to expand the implementation of PAB into the surgical toolkit for pediatric heart failure treatment and refine its effectiveness.[5]

CONCLUSIONS

As a conclusion, PAB has emerged as a potential therapeutic alternative to mechanical circulatory support or heart transplantation in infants with severe heart failure due to dilated cardiomyopathy.

Further studies are still needed to standardize its indication, although everything indicates that the best results will be achieved in patients under 1-year of age.

In the ultimate treatment of patients with end-stage heart failure and preserved right ventricular function, PAB becomes a viable alternative in the absence of donations in this age group.

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