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ORIGINAL ARTICLE / ÖZGÜN MAKALE

Transcatheter pulmonary artery debanding: Is it effective in every patient?

Transkateter pulmoner arter debanding: Her hastada etkili midir?

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ABSTRACT

Background: This study aimed to present our experience with transcatheter pulmonary debanding, focusing on patient outcomes.

Methods: The retrospective study was conducted with 32 patients (17 males, 15 females; mean age: 3.6±2 years; range, 0.5 to 8.8 years) who underwent transcatheter pulmonary debanding between January 2010 and January 2024. The patients were evaluated in two groups. In Group 1 (n=24), total debanding was targeted for patients with spontaneously closed or restrictive ventricular septal defects or those suitable for transcatheter ventricular septal defect closure. In Group 2 (n=8), palliative debanding was utilized in children with ongoing band requirement.

Results: The median body weight was 15 kg. In Group 1, the mean right ventricle-to-aortic pressure ratio (RVp/Aop) was 0.91±0.21 before the procedure, which decreased to a mean of 0.33±0.20 after the procedure. In Group 2, the mean RVp/Aop was 1.31±0.47, which decreased to 0.77±0.13 after transcatheter palliative debanding. The mean peripheral oxygen saturation was 80±6% before the procedure and 94±2.5% after the procedure. Transcatheter debanding was successful in all patients when surgical pulmonary banding was performed with 6-0 Prolene and polytetrafluoroethylene band material.

Conclusion: Transcatheter banding is a safe and effective procedure that minimizes the need for reoperation.

Keywords: Balloon dilation, banding, debanding, pulmonary artery, transcatheter.

ÖZ

Amaç: Bu çalışmada transkateter pulmoner debanding deneyimimizin hasta sonuçlarına odaklanarak sunulması hedeflendi.

Çalışma planı: Bu retrospektif çalışma Ocak 2010-Ocak 2024 tarihleri arasında transkateter pulmoner arter debanding uygulanan 32 hasta (17 erkek, 15 kadın; ort. yaş: 3.6±2 yıl; dağılım, 0.5-8.8 yıl) ile yürütüldü. Hastalar iki grupta değerlendirildi. Grup 1'de (n=24), spontan olarak kapanmış veya restriktif ventriküler septal defektleri olan veya transkateter ventriküler septal defekt kapatma için uygun olan hastalarda total debanding hedeflendi. Grup 2'de (n=8), devam eden band gereksinimi olan çocuklarda palyatif debanding uygulandı.

Bulgular: Medyan vücut ağırlığı 15 kg idi. Grup 1'de, işlem öncesi ortalama sağ ventrikül/aortik basınç oranı (RVp/Aop) 0.91±0.21 idi ve işlem sonrasında bu ortalama 0.33±0.20'ye azaldı. Grup 2'de, ortalama RVp/Aop 1.31±0.47 idi ve transkateter palyatif debanding sonrası 0.77±0.13'e azaldı. Ortalama periferik oksijen satürasyonu işlem öncesi %80±6 ve işlem sonrası %94±2.5 idi. Cerrahi pulmoner banding işlemi 6-0 Prolen ve politetrafloroetilen band malzemesi ile yapıldığında tüm hastalarda transkateter debanding başarılı oldu.

Sonuç: Transkateter debanding tekrar ameliyat gereksinimini minimize eden güvenli ve etkili bir girişimdir.

Anahtar sözcükler: Balon dilatasyon, band, debanding, pulmoner arter, transkateter.

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Pulmonary artery banding (PAB) is a palliative procedure that reduces pulmonary blood overflow to prevent heart failure, provide long-term protection against irreversible pulmonary hypertension, and maintain optimal systemic output in cases of large left-to-right shunting or univentricular heart defects.[1,2] Although the use of PAB has markedly decreased due to the increasing popularity of early complete intracardiac repair, it remains an important intervention to serve as a bridging technique to advance the patient to an older age and facilitate subsequent biventricular repair.[3]

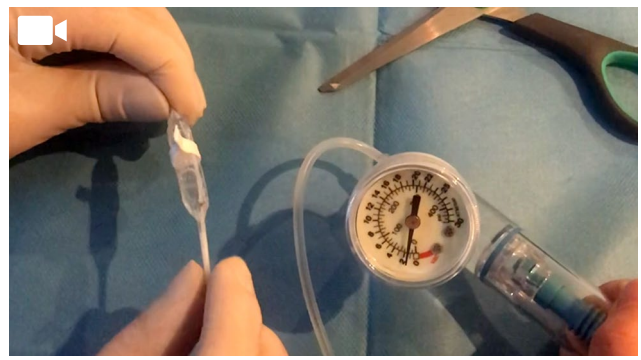
Surgical debanding is inevitable when the pulmonary band is no longer needed due to spontaneously closed or restrictive ventricular septal defects (VSDs) or when hemodynamic deterioration (cyanosis, ventricular dysfunction) occurs before the time of desired corrective surgery. However, surgical debanding is not a simple, risk-free procedure.[4]

Transcatheter methods for total debanding or band loosening have been reported in a limited number of studies.[5,6] In this study, we aimed to present our experience with the transcatheter pulmonary debanding technique and provide patient outcomes.

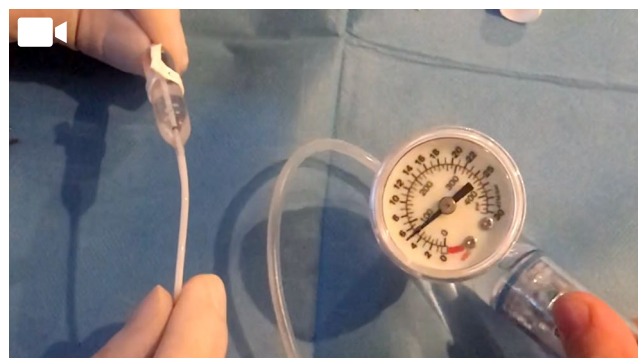
PATIENTS AND METHODS

The retrospective study was conducted with 32 patients (17 males, 15 females; mean age: 3.6±2 years; range, 0.5 to 8.8 years) who underwent transcatheter pulmonary debanding at Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital between January 2010 and January 2024. Demographic information, indications, interval after pulmonary banding for transcatheter debanding, pre- and postintervention echocardiographic pressure measurements, and pre- and postcatheterization pressure values, and final balloon diameter were extracted from the hospital database. Surgical pulmonary banding was performed in patients who had the following indications for biventricular repair: *(i)* a large apical VSD or multiple muscular VSDs; *(ii)* accompanying prematurity or chromosomal anomalies; *(iii)* cases where surgical correction was performed but residual or additional multiple muscular defects were present; *(iv)* residual or additional defects following perventricular VSD closure. A written informed consent was obtained from the parents of the patients. Ethical approval was obtained from the Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital Ethical Committee (decision date 23.10.2023 and number: E-28001928-604 01.01-227447248). This study was conducted in accordance with the principles of the Declaration of Helsinki.

In our clinic, pulmonary banding was performed via sternotomy. During the surgical procedure, the adventitia between the aorta and the pulmonary artery was dissected only in the segment where the band was to be placed. Care was taken to ensure that the band placement site was equidistant from the pulmonary valve and the level of the bifurcation to avoid deformation of the pulmonary valve and the pulmonary artery. Previously, Dacron tape and metal hemoclips were used for pulmonary banding. However, due to partial dilation or failure to dilate the bands with balloon catheters in the transcatheter method, we changed the method of surgical pulmonary banding in our clinic. After observing that polytetrafluoroethylene (PTFE) strips, which were fixed with 6-0 Prolene suture in vitro, were easily opened, PTFE strips and 6-0 Prolene suture were started to be used in patients with biventricular circulation (Videos 1, 2).



Video 1. In the *in vitro* setting, the artificial band made using a polytetrafluoroethylene strip and 5-0 Prolene failed to open when inflated with a 10-mm Z-Med balloon to pressures above the burst pressure.



Video 2. The band made with 6-0 Prolene opened successfully when inflated with a 10-mm Z-Med balloon.

The 3- to 5-mm thick PTFE strip was first passed under the pulmonary artery and aorta using a transfer groove. Distal pulmonary artery pressure (PAP), systemic arterial pressure, pulse oximetry, and arterial blood gas were monitored to determine the length and tightness of the pulmonary band. Before the band tightening began, it was ensured that the lungs were not atelectatic, hemoglobin level was not low, and hypovolemia was not present. Band tightness was initially adjusted stepwise with metal clips. Care was taken to ensure that the ratio of distal PAP to systemic arterial pressure was 50%. In addition, arterial oxygen saturation was aimed at 95% and above, while the fraction of inspired oxygen was 21% (room air). After the band was tightened, it was ensured that hypotension, arrhythmia, and ischemic electrocardiogram changes were absent. After adjusting the length and tightness of the PTFE band with clips, the PTFE band was fixed in length and tightness with 6-0 Prolene suture from the lowest hemoclip level, and all hemoclips were removed. Thus, the PTFE band was fixed with 6-0 Prolene suture only.

Patients were divided into two groups: Group 1 included patients suitable for transcatheter VSD closure who underwent total transcatheter debanding, while Group 2 included patients with spontaneously closed or restrictive VSD (without severe cyanosis despite suprasystemic right ventricle pressure). On transthoracic echocardiography, defects with a color flow diameter <4 mm were considered restrictive.[7] In addition, those with sufficient apical rim and defects in the muscular region with a color flow diameter up to 14 mm were considered suitable for transcatheter closure.[8]

In addition, in infants and young children with ongoing banding requirements, partial (palliative) transcatheter debanding was performed in Group 2 to correct significant desaturation (peripheral oxygen saturation [SpO_2] <88%) associated with a hemodynamically significant VSD causing right-to-left shunting or ventricular dysfunction to the reduce right ventricle pressure to infrasystemic levels. Patients with single ventricle physiology, bilateral pulmonary banding for the hybrid procedure, or in need of additional surgical repair were excluded.

Femoral venous access was used for all procedures, and femoral arterial access was also used for monitoring. Ventricular, systemic arterial, and PAPs were assessed. Ventricular angiograms were performed to evaluate VSDs and right ventricular outflow tract anatomy. Main pulmonary artery injection was also used to evaluate pulmonary annulus diameter, pulmonary banding zone, and main pulmonary artery diameter distal to the pulmonary banding.

In patients in Group 1, balloon diameter was selected according to pulmonary valve and normal pulmonary artery diameters. High-pressure Z-Med (Numed, Hopkinton, NY, USA) and VACS III (OSYPKA, Rheinfelden, Baden, Germany) balloons were used, with a diameter not exceeding the pulmonary valve annulus, and 110 to 120% of adjacent normal pulmonary artery diameter gradual dilation was performed to avoid dissection. Initially, the procedure was started with the annulus at 75 to 80% (Figure 1).

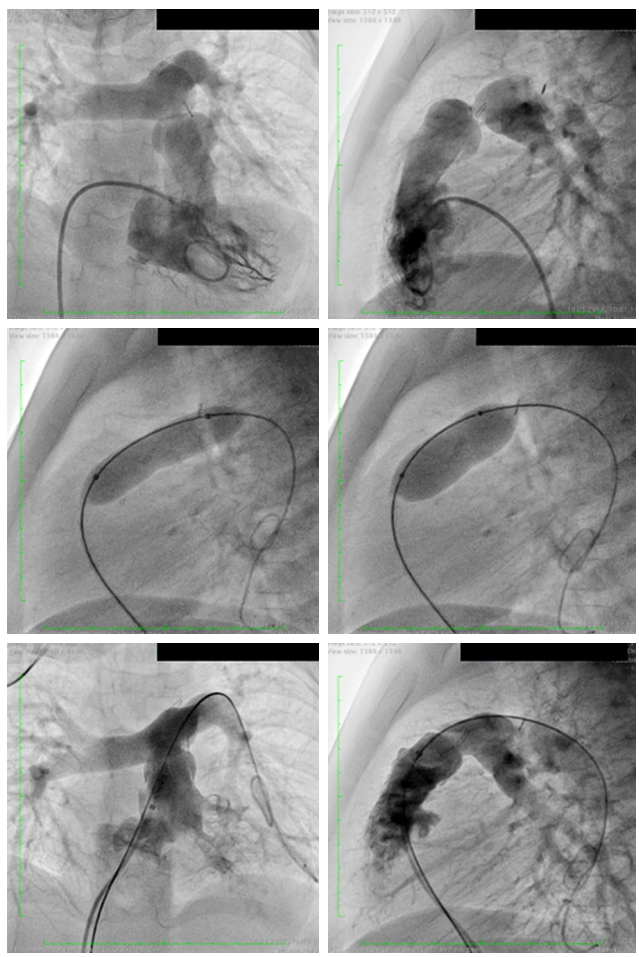


Figure 1. A total pulmonary artery debanding procedure was performed on a three-year-old patient due to spontaneous closure of VSDs. The patient had a pulmonary annulus diameter of 14.1 mm, and balloons with diameters of 10 mm and 14 mm (Z-Med) were used for debanding.
VSDs: Ventricular septal defects.

In Group 1, the goal was to reduce the right ventricle pressure to one-third of systemic pressure. Control pressure measurements were performed, and after contrast injection into the pulmonary artery, the balloon diameter was gradually increased until this goal was achieved. After the debanding procedure, the right ventricle to pulmonary artery pressure gradient (RV-PA) was assessed using a multitrack catheter. In addition, the VSDs were reevaluated, and the left ventricular injection was repeated. If there was contrast passage through the interventricular septum, hemodynamic assessment was performed to evaluate PAP and Qp/Qs (the ratio between pulmonary and systemic flow). If the Qp/Qs was <1.5, the VSD was considered hemodynamically insignificant, and the procedure was terminated. If Qp/Qs was >1.5 or PAP was >25 mmHg, the VSDs were considered hemodynamically significant and were closed.

In Group 1, the procedure was considered successful if the right ventricle-to-aortic pressure ratio (RVp/Aop) was less than one-third, if spontaneously closed or hemodynamically insignificant VSDs were present, or if significant VSDs could be closed by transcatheter methods (Figure 2).

In Group 2, sequential dilatations were performed with balloons of increasing diameter, with hemodynamic control in between (pressure or Qp/Qs evaluation), to obtain as high an increase in oxygen saturation as possible. The procedure was initiated with dimensions not exceeding twice the narrowest segment. The pulmonary annulus was not traversed beyond 80% for balloon diameter selection.

After stepwise dilatations, the hemodynamic study and angiograms were repeated. After each stepwise dilatation, hemodynamic assessments were performed and the PAP was reassessed. The procedure was performed to maintain a PAP <25 mmHg and to increase SpO_2 as much as possible. Postprocedure success was defined as achieving an SpO_2 >92% and ensuring that PAP remained <25 mmHg.

Statistical analysis

Data were analyzed using IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was used for the analysis of compliance with normal distribution. Normally distributed continuous data were presented as mean ± standard deviation (SD), and nominal variables were presented as frequency and percentage. Nonnormally distributed continuous data were presented as median with the 25th and 75th percentiles (interquartile range, IQR). For comparison of groups, Student's t-test was used for continuous normally distributed variables, and the Mann-Whitney U test was used for nonnormally distributed variables. Comparisons between paired groups were performed using a paired t-test or the Wilcoxon signed-rank test, as appropriate. A p value <0.05 was considered statistically significant.

RESULTS

The median body weight was 15 kg (IQR, 5-16 kg). The median time from pulmonary banding to transcatheter debanding was 34 months (IQR, 17-54 months). Among the cases, 14 patients had isolated apical or Swiss cheese VSDs. Others had associated anomalies in addition to VSDs, such as coarctation of the aorta, aortic arch hypoplasia, or aortic interruption in 10 patients, post-Jatene pulmonary banding in five (transposition of the great arteries in three, Taussig-Bing in two), atrioventricular septal defect in one, and corrected transposition of the great arteries in two. Transcatheter balloon angioplasty was performed in 24 patients for total debanding (Group 1) and in eight patients for palliation due to hypoxia or ventricular dysfunction (Group 2).

In Group 1, VSD closed spontaneously or became restrictive in 17 patients, while in seven patients, the VSD was large. Patients in Group 1 had a median age of 3.4 years (IQR, 1.8-5.5 years) and a median weight of 15 kg (IQR, 5-16.5 kg). Preprocedural echocardiographic assessment revealed a mean peak RV-PA of 92±18 mmHg (range, 65 to 120 mmHg). During catheter angiography, the mean preprocedure RV-PA was 67±15 mmHg (range, 35 to 119 mmHg), and the mean RVp/Aop was 0.91±0.21. After balloon dilatation, the mean RV-PA decreased to 13±2.7 mmHg (range, 4 to 40 mmHg; p<0.05), and the RVp/Aop decreased to a mean of 0.33±0.20 (p<0.05).

The median value of the final balloon diameter used for pulmonary artery band dilation was 16 mm (IQR, 12-16.5 mm). The median pulmonary valve annulus diameter was 15.8 mm (IQR, 12.0-16.1 mm), and the median ratio of final balloon diameter to pulmonary valve annulus diameter was 1.05 (IQR, 0.96-1.1) (Table 1).

Debanding was successful in 21 of 24 patients in Group 1. Hemodynamically significant VSDs were detected in seven patients. Five patients underwent transcatheter closure of muscular VSDs via the jugular vein for hemodynamically significant VSDs. Six devices were deployed in five patients. All were Amplatzer muscular devices (AGA Medical Corp., Golden Valley, Minnesota, USA) (10 mm in two and

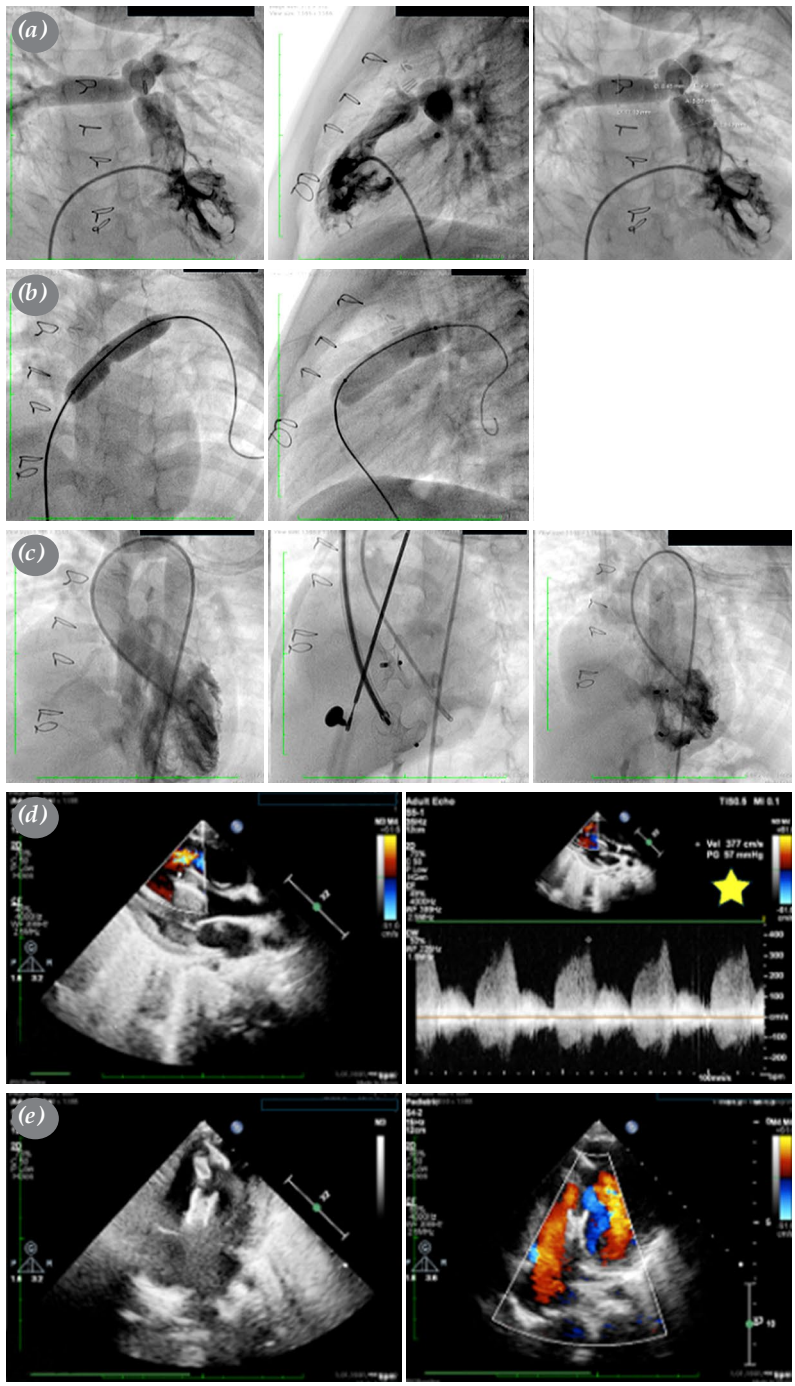


Figure 2. Catheter angiography was performed on a two-year-old girl weighing 12 kg due to hypoxia. **(a)** Tight PAB was shown during right ventricular injection after hemodynamic studies. **(b)** Pulmonary artery debanding was performed by applying dilation with 10- and 12-mm Z-Med balloons. **(c)** After visualizing muscular and apical VSDs during left ventricular injection, two 12-mm Amplatzer muscular devices were used to close them through the jugular vein. **(d)** Residual VSD was observed on echocardiographic examination after the procedure. It was a restrictive defect and a continuous wave Doppler gradient of 52 mmHg was obtained (yellow star). **(e)** On the echocardiographic examination at the last follow-up, the residual VSD was observed to have spontaneously closed.

PAB: Pulmonary artery banding; VSDs: Ventricular septal defects.

Table 1. Patients' characteristics

	Group 1 (n=24)			Group 2 (n=8)		
	Mean±SD	Median	IQR	Mean±SD	Median	IQR
Age (year)		3.4	1.8-5.5		2.1	1.2-4.6
Weight (kg)		15	5-16.5		9	5-39
RVp/Aop (pre)	0.91±0.21			1.31±0.47		
RVp/Aop (post)	0.33±0.20			0.77±0.13		
PV annulus (mm)		15.8	12-16.1		15.3	13.9-16.3
Final balloon/PV annulus		1.05	0.96-1.1		0.71	0.68-0.74

SD: Standard deviation; IQR: Interquartile range; RVp: Right ventricular pressure; Aop: Aortic pressure; PV: Pulmonary valve.

12 mm in four). One patient required two muscular devices. Complete spontaneous closure of the muscular VSDs was observed in the remaining 12 patients, while the VSDs became hemodynamically insignificant in five patients. Transcatheter pulmonary debanding was ineffective in three patients. Three patients were referred for surgery, two patients underwent surgical closure of the VSDs and debanding, and one underwent surgical debanding only. A patient diagnosed with transposition of the great arteries (TGA) and VSD with a history of pulmonary banding underwent pulmonary balloon angioplasty after restenosis following the first procedure. Additionally, VSD closed spontaneously in one patient. At the last follow-up, the mean peak RV-PA measured by transthoracic echocardiography was 27±11 mmHg. No patient had more than mild pulmonary regurgitation (Figure 3).

In Group 2, the median age was 2.1 years (IQR, 1.2-4.6 years), and the median body weight was 9 kg (IQR, 5-39 kg). The median time between surgical pulmonary banding and transcatheter debanding was 14 months (IQR, 7-26 months). At the echocardiographic evaluation before transcatheter debanding, the mean RV-PA was 103±23 mmHg (range, 65 to 148 mmHg), and the mean SpO_2 was 80±6% (range, 70 to 88%) before the procedure. The median final balloon diameter used for inflation was 10 mm (IQR, 10-13 mm). Before the procedure, the mean RVp/Aop was 1.31±0.47, while after palliative debanding, the mean RVp/Aop was 0.77±0.13. The median pulmonary artery annulus diameter was 15.3 mm (IQR, 13.9-16.3 mm), and the median ratio of final balloon diameter to pulmonary artery annulus diameter was 0.71 (IQR, 0.68-0.74). The mean postprocedure SpO_2 was 94±2.5% ($p<0.05$). Table 2 summarizes all palliative debanding patients in detail.

DISCUSSION

To mitigate the risks inherent in palliative surgeries and minimize the enduring impact of untreated cardiac anomalies on cardiac function, contemporary approaches in pediatric cardiac surgery prioritize achieving definitive repair of complex heart defects shortly after birth.[9,10] However, certain corrective procedures pose significant challenges and may carry a high risk when performed during the neonatal or infantile period, particularly those involving large apical or multiple VSDs. In such cases, PAB has emerged as a valuable palliative strategy.[2] This is applicable in cases where residual shunts persist after total corrective surgery and in patients deemed candidates for biventricular repair, with prematurity and other accompanying comorbidities.[1,10] It is well known that multiple muscular VSDs have the potential to become restrictive or close over time.[4,9] In such cases, pulmonary debanding alone may be sufficient at a later stage. Pulmonary banding in patients who are candidates for other biventricular repair allows patients to undergo corrective surgery with debanding at a later time and in a safer manner. However, surgical pulmonary debanding is not a straightforward procedure.[11,12] Some patients may require pulmonary artery reconstruction and the use of a patch to treat the stenosis. In addition to the inherent risks of redo surgery, there is the potential for reoperation due to residual stenosis and pulmonary insufficiency.[12] An alternative to surgical debanding, the transcatheter pulmonary debanding procedure, has been reported in a limited number of studies.[13-15] In our study, we sought to evaluate the outcomes of patients who underwent transcatheter pulmonary debanding. The total debanding procedure was successful in 21 (87.5%) patients in Group 1.

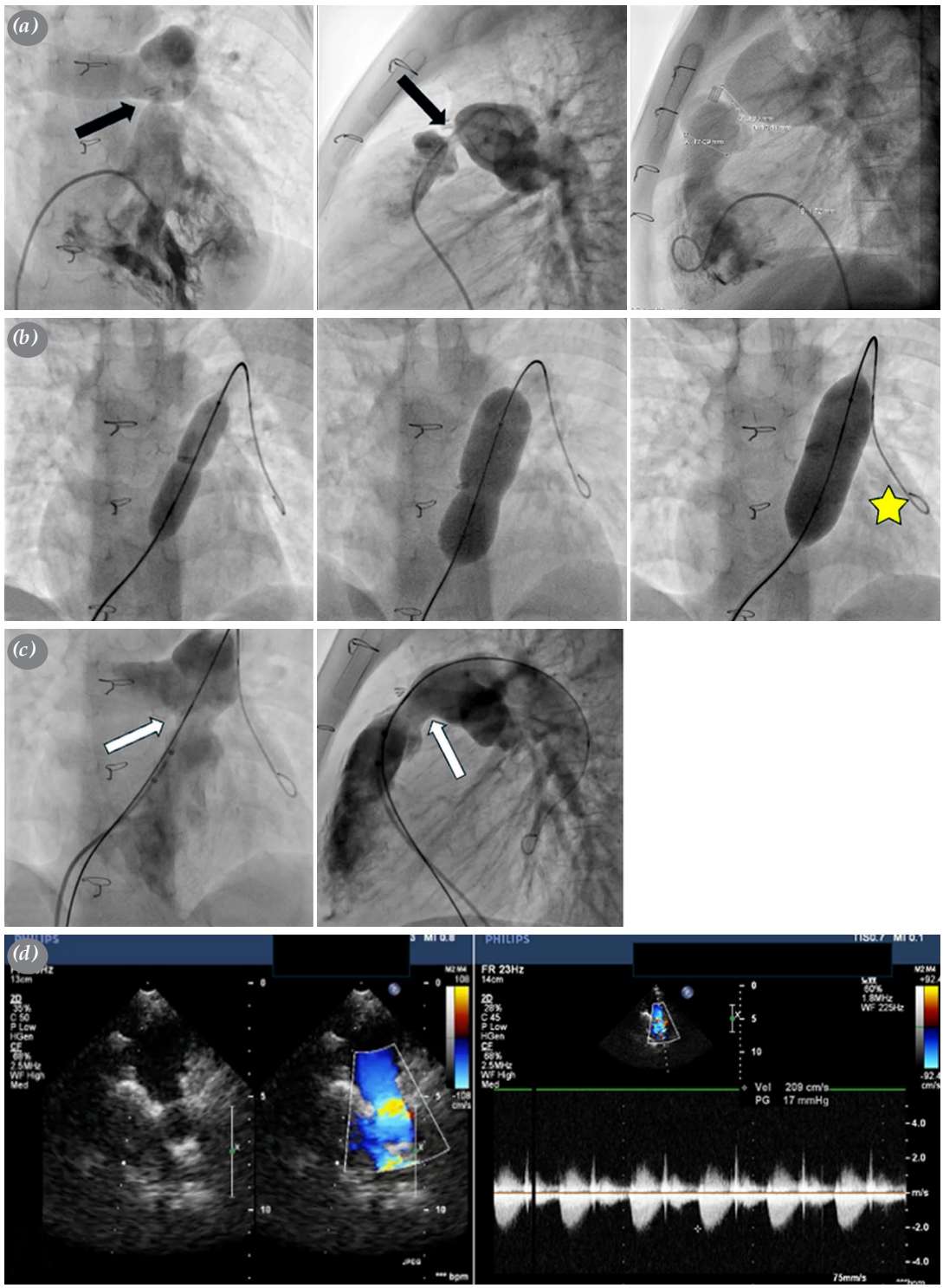


Figure 3. Catheter angiography was performed on a five-year-old girl weighing 16 kg due to the restrictive VSDs. **(a)** Black arrows show the narrowed pulmonary artery due to surgical banding. **(b)** Gradual dilation was performed with 11-, 14-, and 18-mm Z-Med balloons. Dilation with an 18-mm Z-Med balloon resulted in the loss of indentation (yellow star). **(c)** Total debanding was observed during control injections, and pressure measurements showed a peak RV-PA of 7 mmHg. **(d)** Echocardiographic examination revealed no anatomical narrowing of the pulmonary artery due to banding, and a peak gradient of 17 mmHg was observed on continuous wave Doppler, with no pulmonary regurgitation.

VSDs: Ventricular septal defects; RV: Right ventricular; PA: Pulmonary artery.

Table 2. List of patients who underwent palliative pulmonary artery debanding

No	Age (month)	Main diagnosis	Comorbidity	Indication	SpO_2 (before)	SpO_2 (after)	RV/Ao (after)	RV/Ao	Final balloon diameter	PV annulus	Balloon diameter ratio	Follow-up
1	5	AVSD + Coarctation	Prematurity	Hypoxia	78	94	1.25	0.77	10	14.2mm	0.7	AVSD repair + debanding 1 year
2	9	VSD + Coarctation	Chromosomal anomalies	Hypoxia	83	97	0.95	0.68	10	16.4 mm	0.61	VSD closure + deban -28 mo
3	5	IAA + VSD (postoperative residual VSD)	No	Hypoxia	85	95	1.01	0.82	9	13.8	0.65	VSD closure + PA reconstruction at 15 mo of age
4	84	ccTGA	No	Hypoxia + morphological LV dysfunction	89	97	1.9	0.77	16	20.1	0.79	In follow-up
5	25	Post Jaten, Swiss cheese VSD	No	Hypoxia	70	95	1.6	0.91	12	16.1	0.74	Surgical PA reconstruction with VSD cosure, 6 year old
6	13	Arcus repair + band + multiple VSDs	No	Hypoxia	80	94	1.4	0.85	10	14.5	0.69	Inlet VSD closure + total debanding at 5 year old
7	46	ccTGA; VSD closure	No	Lv dysfunction	92	99	1.2	0.74	12	16.4	0.73	In follow-up
8	22	Swiss cheese VSD + apical VSD	No	Hypoxia	82	96	1.2	0.8	10	13.4	0.74	In follow-up

RV: Right ventricular; Ao: Aorta; PV: Pulmonary valve; AVSD: Atrioventricular septal defect; VSD: Ventricular septal defect; mo: Month; IAA: Interruption of aortic arcus; PA: Pulmonary artery; ccTGA: Congenitally corrected transposition of the great arteries.

The median age of these patients at the time of the procedure was 3.4 years. In 12 patients, the VSDs closed spontaneously, and in five patients, the VSDs were considered hemodynamically insignificant. Patients were followed for this duration, and no further surgical intervention was required in the total debanding group. In addition, one patient experienced spontaneous closure of another muscular VSD after the procedure.

Percutaneous transcatheter closure of muscular VSDs was performed and reported as a safe and less invasive alternative with encouraging results following the development of devices specifically designed for muscular VSDs.[16] Our institutional policy in the management of patients with muscular VSDs with a body weight >6 kg and defects distant from the tricuspid valve has been percutaneous transcatheter closure since 2007. In our study, transcatheter muscular VSD closure was performed in conjunction with total pulmonary artery debanding in five patients via the jugular approach. One patient required two devices. No residual defect was observed in four patients, while a small defect of no hemodynamic significance remained in one patient. Assessment of the feasibility of closing VSDs by both transcatheter and surgical methods prior to the total pulmonary artery debanding procedure is critical. Planning based on the clinic's experience in this regard is crucial. Surgical closure can be challenging in infants with muscular VSDs since the visualization of these defects can be difficult due to coarse trabeculations of the right ventricle and associated with a high incidence of residual shunts.[17] Left ventriculotomy may provide better surgical exposure but is detrimental in infants in the short and long term.[18] Therefore, a poorly timed total pulmonary artery debanding procedure may result in the need for surgical rebanding.[14]

In our clinic, pulmonary banding surgery is not the primary choice for patients with muscular VSDs younger than six months of age who do not respond to medical therapy and develop congestive heart failure or pulmonary hypertension in the absence of comorbidities. If surgical closure of the defect is not feasible during this period, the patient weighs <6 kg, and the defect is at a distance of >4 mm from the atrioventricular valve and the aortic rim, our first preference is perventricular VSD closure. After perventricular VSD closure, other small defects that were initially considered hemodynamically insignificant may become significant and require a second device. However, due to the anatomy of

the right ventricle, implantation of a second device may not always be feasible, resulting in the potential need for banding in these patients. In our study, transcatheter pulmonary debanding was performed in two patients who underwent banding after the closure of a perventricular VSD. In one of these patients, an additional VSD was closed percutaneously during the same session. In the other, the additional defect closed spontaneously.

In our study, pulmonary banding was performed in five patients after arterial switch surgery. One of the surgical alternatives in TGA patients with multiple VSDs is pulmonary banding in the first stage.[19] However, pulmonary banding is one of the risk factors for neoaortic valve regurgitation after arterial switch.[20] Therefore, in our clinic, pulmonary banding is performed with arterial switch in such patients. One of the most common complications after arterial switch is right ventricular outflow tract stenosis, which may recur despite both surgical and transcatheter interventions.[19,21] In our study, among the four patients who underwent total debanding, no additional intervention for right ventricular outflow tract stenosis was required during follow-up. However, in one patient, a second transcatheter intervention was later performed due to stenosis in the valvular and supravalvular regions after the debanding procedure.

The transcatheter pulmonary debanding procedure is not without risks. Pulmonary artery rupture, dissection, and temporary complete atrioventricular block requiring a pacemaker have been reported in the literature after transcatheter pulmonary debanding.[6,13,22] In our study, semicompliant balloons (Z-Med and VACS III) were used for the total pulmonary debanding procedure, and a stepwise dilatation was performed. The final balloon size was selected to be no more than 110 to 120% of the pulmonary annulus diameter and adjacent normal pulmonary artery diameter. In this way, oversizing was avoided, gradient reduction was effectively achieved, and complications such as pulmonary artery rupture and dissection were prevented. During follow-up, none of our patients developed moderate to severe pulmonary insufficiency. In our study, only one patient developed a temporary complete atrioventricular block during the procedure, but the rhythm returned to sinus after medical treatment without the need for intervention.

In pulmonary banding surgery, various techniques exist with differing band tightness.[1,23] Inadequate tightening of the band may result in increased volume overload and high PAP. On the other hand, excessive tightening or rapid constriction of the band at unpredictable times can lead to suprasystemic pulmonary ventricular pressure, resulting in hypoxia or ventricular dysfunction.[6,23] In cases where the need for banding persists, partial debanding of the band eliminates the need for early surgical intervention and ensures continuity of palliation. In our study, partial debanding was performed in eight patients due to hypoxia and ventricular dysfunction after pulmonary banding. In this group, the interval between pulmonary banding and palliative debanding was 14 months. After the procedure, hypoxia was eliminated in all patients, and in two patients who underwent debanding due to ventricular dysfunction, an improvement in contractility was observed. In five cases, corrective surgery was performed after palliative pulmonary artery debanding with a median duration of 20 months. One of the most critical points in palliative debanding is that the effect of the band should not be completely eliminated. In the study by Malekzadeh-Milani et al.,[6] VSD closure was performed after the procedure in a patient who underwent transcatheter debanding for right ventricular dysfunction after pulmonary banding. However, rebanding was performed due to significant residual shunt after surgical VSD closure, but the patient died. We also used stepwise dilatation for partial debanding. In the initial balloon selection, we started the debanding procedure with a balloon size that did not exceed twice the pulmonary band indentation, and we carefully maintained the balloon-to-pulmonary annulus ratio below 0.8 in the final balloon diameter. If an adequate increase in saturation could not be achieved after the first balloon dilatation procedure and the procedure was to be continued with a larger balloon, we made sure to repeat the hemodynamic evaluation and confirmed that the mean PAP remained below 25 mmHg.

The suture used during banding, the material, the clip, the strength of the suture, the scar tissue formed in the surrounding tissue, and the compliance of the balloon used can all affect the success of transcatheter debanding.[6,9,14,22] In our study, transcatheter pulmonary banding was ineffective in three patients, and these patients required surgical debanding. Our surgical team initially used Dacron tape and clips for pulmonary banding. Due to the inability to expand the bands with balloon catheters in some patients, we decided to change our surgical banding method in our clinic. Therefore, we tested in vitro whether the PTFE band material could be opened by inflating a high-pressure balloon (Z-Med) with 5-0 and 6-0 Prolene. When 6-0

Prolen was used, we found that the band easily opened when the balloon pressure reached 6 to 8 atm. When 5-0 Prolene was used, we noticed that the balloon did not open even at values well above the burst pressure (14 to 16 atm). After this test, we started using PTFE strips and 6-0 Prolene in the surgical banding procedure for biventricular circulation. The procedure was successful in our last 18 patients who underwent transcatheter debanding after we modified our surgical banding method.

This study had some limitations. The retrospective design was one limitation. Furthermore, due to the single-center nature of the study and the consistent use of a particular surgical technique for PAB, comparisons with alternative techniques for transcatheter debanding were not possible. Additionally, the number of patients undergoing surgical debanding was limited, precluding a direct comparison with those undergoing transcatheter debanding.

In conclusion, transcatheter debanding is an effective and safe procedure that eliminates the need for redo surgery in the majority of patients. It also eliminates the need for early reoperation in patients undergoing corrective surgery. In patients who are candidates for biventricular repair, banding with 6-0 Prolene and PTFE band material increases the effectiveness of transcatheter debanding.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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