Recanalization of a Discrete Atretic Right Pulmonary Artery Segment With a New Radiofrequency System

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We describe a case in which a discrete atretic segment of the right pulmonary artery (due to a Blalock-Taussig shunt) was reconstructed using a new radiofrequency system, balloon dilation, and stent implantation in an 18-month-old patient. The shunt was coil-occluded. The technique and applications of this novel approach are discussed. Catheter Cardiovasc Interv 2003;60:82–87. © 2003 Wiley-Liss, Inc.

Key words: pulmonary atresia and intact ventricular septum; vessel perforation

INTRODUCTION

Radiofrequency (RF) catheter perforation has been employed in the last decade to reestablish continuity between the right ventricle and the main pulmonary artery in selected patients with pulmonary atresia (PA) and intact ventricular septum (IVS) with satisfactory outcomes [1–5]. Recently, this technique has also been used for recanalization of atretic vessels in the pulmonary circulation [6] and transeptal access [7,8]. In this report, we describe a case in which a new RF system (Baylis Medical, Montreal, Quebec, Canada) was employed to restore patency of an acquired discrete atretic segment of the right pulmonary artery in an 18-month-old patient with pulmonary atresia and intact ventricular septum status post-neonatal RF perforation of the pulmonary valve and placement of a right modified Blalock-Taussig shunt.

CASE REPORT

This patient was an 18-month-old boy with PA and IVS who underwent successful RF perforation of the pulmonary valve according to a previously described technique [4] at the age of 3 days. In the neonatal period, there was a well-developed infundibulum, a tripartite right ventricle, and confluent, good-sized pulmonary arteries. The Z-score of the tricuspid valve was −2.0. Due to inadequate right ventricular compliance [9,10], an additional source of pulmonary blood flow was required after a week. Right diaphragmatic paralysis and staphylococcal sepsis followed placement of a right modified Blalock-Taussig (BT) shunt, requiring 45 days in hospital. Because development of the right ventricle was considered appropriate on serial echocardiography [9,10], the child was brought back for hemodynamic assessment in the catheterization laboratory and possible coil occlusion of the BT shunt at the age of 13 months. He was receiving digoxin and furosemide (2 mg/kg/day) and his weight was 8 kg. There was qualitatively mild to moderate right ventricular dysfunction, moderate tricuspid regurgitation, and free pulmonary insufficiency (PI) on echocardiographic evaluation. In the catheterization laboratory, the right and left femoral veins were found occluded due to previous line insertions in the intensive care unit. Venous access was then obtained with placement of a 6 Fr sheath in the right internal jugular vein (RIJV). A 4 Fr sheath was placed in the right femoral artery and heparin sulfate was given (150 IU/kg). Hemodynamics showed the following pressures (in mm Hg): right atrium, 7; right ventricle, 42/7; main pulmonary artery, 42/7 (19); right pulmonary artery, 30/7 (17); aorta, 90/50 (65). A right ventricular angiogram demonstrated occlusion of the right pulmonary artery at its origin. An angiogram at the origin of the BT shunt revealed distal right pulmonary artery stenoses and diffuse narrowing within the shunt (Fig. 1A). Simultaneous contrast media injection in the main pulmonary artery (MPA) and in the distal right pulmonary artery revealed a short (1–2 mm) discrete atretic segment presumably secondary to the previous BT shunt insertion. A “nipple” was seen on both sides of the atretic segment (Fig. 1B). In order to preserve...
flow to the right lung and access for a future attempt at RF perforation of the atretic segment, a decision was made to stent the BT shunt after balloon dilation of the distal right pulmonary artery branches. Over an extra-support, 183 cm, 0.014” percutaneous transcatheter angioplasty (PTCA) wire (Choice, Boston Scientific Scimed, Matick, MA), the distal branches were dilated through the shunt using a mini Tyshak balloon (6 mm × 20 mm; 4 atm; Numed, Cornwall, Ontario, Canada). This was followed by placement of a coronary stent (4.5 mm × 12 mm, 14 atm; Express I, Boston Scientific Scimed) within the shunt. Significant increase in the size of the BT shunt and the distal right pulmonary arteries along with improvement in local blood flow were seen on control angiography (Fig. 1C). Procedure and fluoroscopy times were 110 and 25 min, respectively. Two doses of enoxiparin (0.5 mg/kg/dose) and cefazolin were administered overnight. Recovery was uneventful and the child was discharged home the following morning on a low dose of aspirin. After 4 months, the child was brought back to the catheterization laboratory for an attempt at RF restoration of right pulmonary artery patency. His weight was unchanged. The same vascular accesses were obtained as in the previous catherization and heparin sulfate was given (150 IU/kg) after sheath insertion. Hemodynamics were unchanged. An angiogram at the origin of the BT shunt demonstrated maintenance of the previous result with no significant neointimal proliferation within the stent. Satisfactory catheter stabilization in the MPA was not achieved because of free PI and conspicuous enlargement of the MPA. Therefore, a decision was made to perforate the atretic segment in a retrograde fashion. A Berman angiographic catheter (Arrow, Reading, PA) was left in the MPA for landmark and angiography purposes. The distal right pulmonary artery was entered through the BT shunt with the aid of a 7 Fr right coronary Judkins catheter (Infinity, Cordis, Miami, FL) and a 0.035” hydrophilic guidewire (Glide wire, Terumo Cardiovascular Systems, Ann Arbor, MI). The tip of the Judkins catheter was kept pointing toward the MPA by seating it in the distal RPA nipple. A soft and flexible RF catheter (Nykanen RF perforation catheter; active tip diameter, 0.016”; body diameter, 0.024”; length, 260 cm; Baylis Medical) was advanced through the Judkins catheter to the distal RPA nipple. Contrast media injections through a Y-connector (Touhey-Borst) confirmed an adequate position of the RF catheter (Fig. 2A), which was then connected to an RF current generator (Baylis Medical). Perforation of the atretic segment was achieved after two applications of 10 W of energy delivered for 10 sec keeping a gentle push on the RF catheter. After perforation, the RF catheter was advanced freely and manipulated to form a loop in the enlarged MPA. An injectable catheter (Baylis Medical coaxial injectable catheter; inner diameter, 0.027”; outer diameter, 0.038”; length, 245 cm) was advanced retrograde over the RF catheter through the Judkins catheter to the MPA. The RF catheter was withdrawn and exchanged for an extra-support, 300 cm, 0.014” PTCA wire (Choice, Boston Scientific Scimed). This wire was snared in the MPA and withdrawn via the RIJV with the aid of a 6 Fr right coronary Judkins catheter (Cordis) and a 25 mm gooseneck snare (Microvena, White Bear Lake, MN), forming an arterial-venous loop. The injectable catheter was taken out and progressive anterograde dilation of the atretic segment was performed from the RIJV using a 2 mm × 15 mm coronary angioplasty balloon (Maverick; 12 atm; Boston Scientific Scimed) followed by a 6 mm × 20 mm peripheral angioplasty balloon (Rx ViaTrac; 14 atm; Guidant Advanced Cardiovascular Systems, Temecula, CA; Fig. 2B). Recanalization of the vessel was achieved successfully with no aneurysm formation or contrast leak seen on control angiography through the BT shunt (Fig. 2C). Nevertheless, as had been anticipated, there was an area of significant residual stenosis requiring stent implantation. A 4 Fr Judkins catheter (Infinity, Cordis) was advanced from the RIJV to the MPA in parallel with the PTCA guidewire used for balloon dilation. Through this catheter, a 0.035” hydrophilic wire (Terumo) was advanced to a distal right pulmonary artery branch (Fig. 2C). Unfortunately, it was not possible to proceed with the intervention due to technical problems with the X-ray generator. The child was awakened and transferred to the recovery room with no complications. Procedure and fluoroscopy times were 185 and 45 min, respectively. After a week, the child was brought again to the catheterization laboratory, the same vascular access was obtained, and heparin sulfate was given (150 IU/kg) after sheath insertion. As planned, a 4 Fr right coronary Judkins catheter (Infinity, Cordis) was advanced over a 0.035” hydrophilic wire (Terumo) to a distal right pulmonary artery branch from the RIJV. However, due to the free PI, significant enlargement of the MPA, and the tight curve coming from the RIJV, this maneuver required a 7 Fr, hand-shaped, braided long sheath (Shuttle, Cook Cardiology, Bloomington, IN) that had been placed in the MPA for optimization of catheter and wire manipulation/support. The hydrophilic wire was then exchanged for a 260 cm, 0.035”, super-stiff wire (Whisker, Cook). Using the front-loading technique [11], a P188 Palmaz stent (Cordis) was mounted over a 7 mm × 20 mm catheter balloon (Powerflex, Cordis) that was passed through an 8 Fr long sheath (Balkin curve, Cook). In order to have optimal support to advance the stent-balloon-sheath assembly, a cut-off, hand-shaped, 10 Fr long sheath (Cook) was left in the MPA. In this way, the whole stent-sheath assembly progressed smoothly from the RIJV over the wire through the 10 Fr
sheath to the desired location. The balloon was manually inflated and a mild residual waist was seen on cine (Fig. 3A). After removal of the catheter balloon, control angiography using a 6 Fr Multi-Track catheter (Numed) over the wire demonstrated satisfactory opening of the RPA without any complications (Fig. 3B). Adequate flow to all distal pulmonary branches was observed. The BT shunt was then closed in a retrograde fashion using a 35-5-5 standard Gianturco coil (Cook) deployed through a 4 Fr right coronary Judkins catheter (Infinity, Cordis; Fig. 3C). For coil deployment, care was taken to avoid possible dislodgment of the stent. The child was awakened in the catheterization laboratory and transferred to the recovery room after hemostasis was achieved by manual compression. Procedure and fluoroscopy times were 140 and 35 min, respectively. Two doses of enoxaparin (0.5 mg/kg/dose) and cefazolin were administered overnight. The following morning, an echocardiogram with color Doppler interrogation revealed good stent position in the RPA, laminar flow through it, and no residual flow through the shunt. No significant change in right ventricular function and the degree of tricuspid and pulmonary regurgitation was observed. The child was discharged home on low-dose aspirin for 3 months and on the same doses of digoxin and furosemide as before. Diminished distal pulse amplitude was noted in the leg in which the arterial sheath was placed.

DISCUSSION

Although mechanical, laser, and RF perforation of the pulmonary valve has been performed safely and effectively in selected patients with PA and IVS [1–5], some patients may still need an additional source of pulmonary blood flow to achieve adequate oxygenation in the first weeks after perforation [9,10]. It is well known that pulmonary artery distortions are commonly seen after placement of Blalock-Taussig shunts as a result of tenting, local scar formation, or vessel compression [12]. These may require balloon dilation/stent implantation for stenosis relief. Complete occlusion of the pulmonary

Fig. 1. A: Angiogram at the origin of the Blalock-Taussig shunt demonstrating diffuse narrowing within the shunt and distal stenoses in the right pulmonary arterial tree. B: Simultaneous angiograms in the main pulmonary artery and through the shunt clearly demonstrating a localized atretic segment within the right pulmonary artery due to the previous shunt insertion. The distance between the two pulmonary ends was 1–2 mm. A 10 mm metallic sphere was left on the chest for calibration purposes. C: Angiogram at the origin of the Blalock-Taussig shunt after balloon dilation of the distal pulmonary artery branches and stent implantation in the shunt. Significant improvement in local flow and sizes of the vascular structures is observed.
artery, as observed in our patient, is the most severe form of this complication, although its incidence has not been clearly defined. Also, some patients with PA and IVS will need further interventional procedures in the follow-up management strategy such as atrial septal defect and shunt occlusion [10].

Radiofrequency technology has already been reported for blind recanalization of an occluded left pulmonary artery using a technique similar to that described here, albeit with another system [6]. In our case, some modifications were required because of the underlying anatomy and limited vascular access. Also, due to some of the advantageous features of the Baylis Medical RF system [4], the procedure could be completed in a relatively straightforward manner. In our case, perforation was not performed in a blind fashion. The discrete area of atresia was clearly demonstrated by simultaneous injection in the MPA and distal RPA. The presence of nipples on each side of the occluded vessel was considered a marker of continuity between the two vascular ends. A similar concept had already been employed for balloon dilation and stent recanalization of peripheral vessels [13]. The possibility of having two sources of contrast injections, one on each side of the atretic segment, made the procedure easier and safer from the technical standpoint. Since stabilization of catheters was not possible in the MPA, the RF perforation could only be performed in a retrograde fashion. This proved to be a better strategy because optimal positioning and stabilization of the 4 Fr Judkins catheter was achieved within the distal RPA nipple via the BT shunt. In addition, the low-profile and flexible Nykanen RF perforation catheter did not distort the Judkins catheter course. The amount of energy and time used for vessel perforation was determined arbitrarily, being a little more than that previously used for pulmonary valve perforation [4].

Because the Nykanen RF catheter has steerable features, it was easily manipulated and advanced to the MPA to form a loop. Although the risk of significant

Fig. 2. A: Manual contrast media injection through a Tohey-Borst connector confirming adequate position of the Nykanen RF perforation catheter. After the application of RF energy to the atretic segment, the catheter was freely advanced to the main pulmonary artery. B: After multiple wire exchanges and snaring maneuvers, anterograde progressive balloon dilation of the atretic segment was performed. No residual waist was seen in a 6 mm × 20 mm angioplasty balloon inflated to 14 atm. C: Control angiography through the Blalock-Taussig shunt revealing complete recanalization of the atretic segment in spite of significant residual stenosis due to elastic recoil. A hydrophilic wire is seen in a distal right pulmonary arterial branch. It had been advanced from the main pulmonary artery through a 4 Fr right coronary Judkins catheter in parallel with the 0.014" wire used for dilation.
bleeding with a 0.024" catheter is probably very low in case of malperforation, subsequent balloon dilation may aggravate the problem. Therefore, free progression and assurance of correct positioning of the RF catheter in the MPA were mandatory before the atretic segment was dilated. Progression of the injectable catheter over the RF catheter was crucial for subsequent exchange for a PTCA wire and the snaring maneuver. In this regard, formation of an arterial-venous loop was employed to optimize support for anterograde progressive balloon dilation of the atretic segment, also minimizing local trauma to the femoral artery and to the BT shunt. Furthermore, maintenance of this wire loop could have been critical for optimal support for covered stent implantation if malperforation and pulmonary artery disruption had happened. Coil occlusion of the affected pulmonary artery could also have been employed to control local bleeding [6,14]. Given the small stent placed (7 mm), future redilation of the right pulmonary artery will probably be required because of somatic growth. In this regard, redilation of stents in the pulmonary circulation has been performed safely and effectively [15].

Due to the cumbersome access (RIJV) for catheter manipulation and the tight curve across the right ventricular outflow tract to reach the RPA, we believe that the application of a coaxial sheath system played an important role in catheter and stent-balloon-sheath assembly progression. Hand-shaping the long sheaths and using the Balkin curve for the front-loading technique were also helpful in this regard. Although not done in our case, the same catheter balloon employed for stent implantation could have been utilized to reduce flow through the BT shunt and stabilize the stent position for safer coil deployment within the shunt.

Finally, one might argue that transcatheter recanalization of the atretic segment could have been performed in the first catheterization session minimizing risks, X-ray exposure, and costs. Because this approach had not been considered standard practice and entailed obvious inherent risks, our group adopted a more conservative initial approach ensuring adequate flow to the affected lung with distal RPA angioplasty and stent implantation in the BT shunt. Local surgical reconstruction of the affected segment would have remained an option if RF perfora-

Fig. 3. A: Stent implantation in the atretic segment. A mild residual waist was observed after manual inflation of the catheter balloon. B: Control angiogram in the right pulmonary artery after stent implantation showing optimal stent position with satisfactory improvement in local flow and vessel size. Flow to all distal branches was preserved. Retrograde flow within the Blalock-Taussig shunt is also seen. C: Control angiogram in the innominate artery showing complete shunt occlusion after coil deployment.
tion had failed. However, the staged strategy proved to be effective on the basis of the good final result.

In summary, this report shows that reconstruction of a discrete atretic segment in the pulmonary circulation is feasible and safe using RF technology followed by balloon dilation and stent implantation. This novel approach has potential application in selected cases of “atretic congenital coarctation of the aorta” [16] and acquired occlusion of peripheral vessels due to previous catheterization. The new Baylis/Nykanen RF system may facilitate perforation procedures due to several advantageous features: the system is easy and simple to use, the RF catheter has a low profile, is soft, flexible, and steerable, and the whole system allows for maintenance of catheter position and further wire exchanges due its coaxial design.

REFERENCES