

Complications Associated With Transcatheter Therapy of Acute Vascular Thrombosis

A series of four children with congenital heart disease.

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Thrombotic occlusion of vascular structures and shunts in patients with congenital heart disease, while rare, is often associated with significant morbidity and mortality.¹ Several therapeutic management options are available, which include surgical thrombectomy, along with medical treatment options, such as the use of systemic anticoagulation and thrombolytic therapy,² with the majority of current antithrombotic treatment protocols in pediatrics being derived from guidelines set forth by the American College of Chest Physicians.³ Catheter-directed thrombolysis and mechanical thrombus disruption has emerged as an important treatment strategy in both adult and pediatric patients.⁴⁻⁶ For acute vascular occlusions especially, the use of rheolytic thrombectomy using the over-the-wire AngioJet system (Medrad Interventional/Possis, Indianola, PA) has been reported in patients with congenital heart disease, with very good results.⁷⁻⁹ However, these promising results seen in individual case reports often fail to highlight the challenges and potential complications that can be encountered when treating these patients in the catheterization laboratory. We report a short series of four patients with congenital heart disease who had a somewhat complicated course associated with transcatheter treatment of acute vascular thrombosis/occlusion.

CASE 1

A 6-month-old infant with hypoplastic left heart syndrome underwent hybrid palliation with bilateral pul-

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monary artery (PA) banding and stenting of the ductus arteriosus at 4 days of age. He subsequently underwent comprehensive stage II palliation, which included aortic arch reconstruction and a bidirectional Glenn procedure. Eight days after surgery, he became hypotensive and hypoxic, with progressively worsening saturations to as low as 40%. He was taken to the catheterization laboratory based on echocardiographic evidence of stenosis of the right pulmonary artery (RPA) and nonvisualization of the left pulmonary artery (LPA) in an attempt to recanalize these vessels. An initial angiogram obtained in the superior vena cava (SVC) revealed complete obstruction of the LPA and significant stenosis of the RPA origin (Figure 1A). Reverse wedge angiography was performed in the left lower pulmonary vein, documenting a long-segment LPA occlusion with clot being visualized from its proximal origin to the left of the Glenn (native RPA) all the way toward the LPA hilum (Figure 1B). Using these images as a roadmap, attempts were made to manipulate a 0.014-inch coronary wire distal to the clot, which were

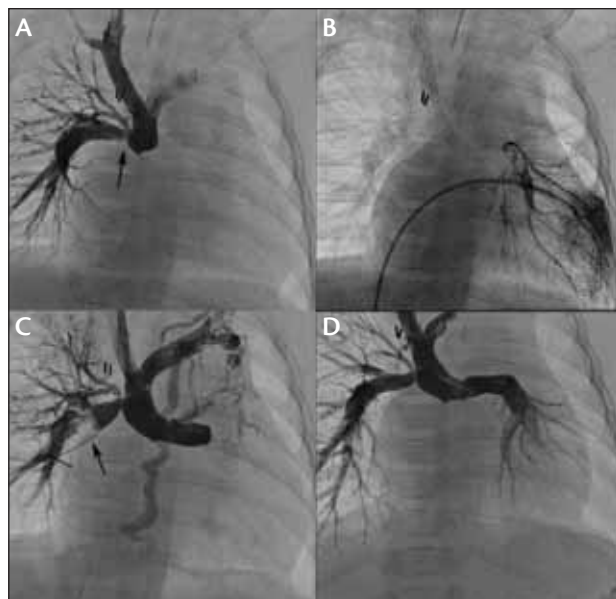


Figure 1. LPA thrombosis in a 6-month-old infant with hypoplastic left heart syndrome, after comprehensive stage II palliation. Initial angiography in the SVC showed complete obstruction of the LPA and significant RPA stenosis (A; arrow). Reverse wedge angiography in the left lower pulmonary vein showed long-segment LPA occlusion with a large thrombus (B). Hand injections after resuscitation and rescue balloon angioplasty of the RPA revealed a large clot that had migrated into the right lower lobe branch (arrow) in addition to the occluded LPA, with some false tract created by catheter manipulation (C). Improved LPA patency after placement of a 19-mm Genesis XD stent (Cordis Corporation, Bridgewater, NJ) in a subsequent procedure (D).

initially unsuccessful. However, during these attempts, the patient desaturated profoundly with cardiopulmonary arrest necessitating epinephrine and chest compressions. Brief hand injections during resuscitation demonstrated clot having migrated proximally, nearly completely occluding the RPA in addition to the occluded LPA. A 0.014-inch coronary wire was quickly advanced into the RPA and balloon angioplasty was performed at the proximal/mid-RPA to crumble the clot, which led to significant improvement in oxygen saturations to 70%, with residual clot being seen on angiography in the right lower lobe branch (Figure 1C).

Once the patient was stabilized, a wire was eventually manipulated into the distal LPA. However, to avoid recurrent clot migration/embolism, it was decided not to perform LPA angioplasty to disintegrate the clot. Instead, a cut-off pigtail catheter was manipulated into the mid-LPA, and recombinant tissue plasminogen activator (rtPA) was administered locally through the pigtail



Figure 2. A 13-year-old adolescent girl with late fenestrated Fontan completion and thrombotic occlusion of the fenestration. Initial angiography showed no evidence of fenestration in the Fontan circuit (A). Transesophageal echocardiography revealed a large clot sitting directly on the left atrial side of the fenestration, entangled around the guidewire (B). Cerebral angiography documented no evidence of cerebral embolism (C). Final angiography after placement of a 7-X 15-mm Palmaz Blue stent (Cordis Corporation) showed swift flow through the reopened fenestration (D).

catheter, as well as through the short sheath positioned in the SVC, at infusion rates of 0.025 $\mu\text{g/kg/min}$. The patient was transferred to the Cardiac Intensive Care Unit (CICU) where angiography performed the next day showed improvement of RPA flow, with persistence of some LPA clot. The dose of rtPA was gradually increased to aid dissolution of the clot, complemented by daily angiography performed to evaluate patency of the LPA. However, after 3 days, the patient developed an intraventricular hemorrhage, necessitating discontinuation of rtPA. Therefore, the patient was taken to the catheterization laboratory to undergo placement of a 19-mm Genesis XD stent to the LPA, which resulted in improved LPA vasculature (Figure 1D). Residual clots were still present, and heparin was continued. Eventually, the LPA reoccluded, and ultimately the patient underwent orthotopic heart transplantation 2 years later.

CASE 2

A 13-year-old adolescent girl with hypoplastic left heart syndrome (mitral atresia, aortic atresia type) underwent a late high-risk lateral tunnel fenestrated

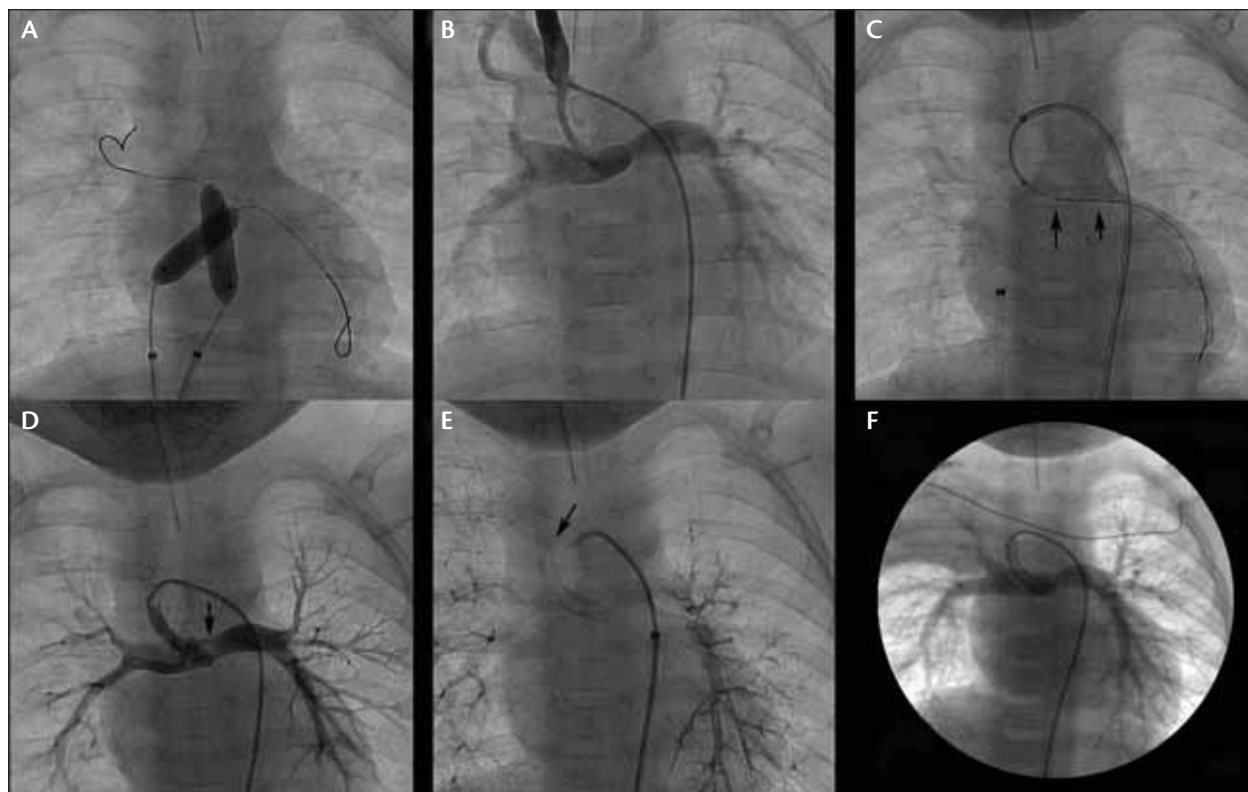


Figure 3. An 8-month-old infant with a history of Norwood palliation and total anomalous pulmonary venous return repair presented with stenosis of the pulmonary venous confluence and BTS stenosis. Double-balloon angioplasty performed at the pulmonary venous confluence (A). Angiography performed at the mouth of the BTS showed a curved, elongated shunt with uniform narrowing (B). While advancing a second stent through the shunt, the previously placed stent embolized to the LPA (C; arrow). Thrombotic material at the distal end of the stent and within the pulmonary arteries (D). Attempts to remove clot with the AngioJet resulted in a small dent in the proximal stent (E; arrow). Final angiography obtained the next day after rtPA showed virtually complete clot resolution (F).

Fontan completion. She was brought to the cardiac catheterization laboratory 2 weeks after surgery with echocardiographic evidence of absent shunting across the fenestration (without visible clot). Clinical symptoms included SVC syndrome, ascites, pleural effusions, and low cardiac output. Hemodynamic evaluation documented mean pressures in the Fontan circuit of 26 to 27 mm Hg, with a right ventricular end diastolic pressure of 16. Angiography of the SVC and inferior vena cava documented no evidence of any obstruction in the Fontan circuit. However, there was no residual fenestration visible on angiography (Figure 2A). Using a Judkins right coronary catheter and a V18 wire (Boston Scientific Corporation, Natick, MA), attempts were made to probe for the previously placed fenestration, which was eventually crossed successfully.

It was believed that the patient would likely require stent placement across the reopened fenestration. To aid positioning, transesophageal echocardiography evalua-

tion was performed, which documented a very large clot sitting directly at the left atrial side of the fenestration, entangled around the guidewire (Figure 2B). It was believed that wire removal and local administration of rtPA had an associated risk of systemic/cerebral thromboembolism. For this reason, the patient was positioned in the Trendelenburg position, and an Export aspiration catheter (Medtronic, Inc., Minneapolis, MN) was used to try to remove as much of the clot as possible. Furthermore, guide catheters and large long sheaths were advanced over the wire to the mouth of the fenestration with continuous suction applied to aid in clot removal. Eventually, the clot was removed. In order to be certain that no cerebral embolism had occurred, cerebral angiography was performed and interpreted by colleagues from interventional radiology, which documented no evidence of any filling defects (Figure 2C). At this point, it was decided to stent the fenestration, which was accomplished using a 7-mm X 2-cm cutting balloon, followed

by implantation of a 7- X 15-mm Palmaz Blue stent, with excellent angiographic result (Figure 2D). The patient was transferred to the CICU (extubated and in stable condition) where she had continued to have hemodynamic improvement and was further evaluated for systemic embolization. There was no evidence of ischemia on a cranial CT scan, but a small renal infarct was noted with preserved renal function. The stent remained patent at 2 years after the procedure.

CASE 3

An 8-month-old infant with hypoplastic left heart syndrome and supracardiac total anomalous pulmonary venous drainage underwent Norwood palliation with a 3.5-mm, modified Blalock-Taussig shunt (BTS), as well as repair of total anomalous pulmonary venous return (TAPVR) at an outside institution. He presented acutely with profound desaturations into the 60s. Echocardiography was suspicious for shunt stenosis, as well as stenosis at the pulmonary venous confluence. In the catheterization laboratory, initial hemodynamic evaluation documented a gradient at the junction of the left atrium and the pulmonary venous confluence of approximately 10 mm. Double-balloon angioplasty using a kissing technique was performed, which reduced the gradient to 3 to 4 mm Hg (Figure 3A). Subsequently, angiography performed at the mouth of the BTS showed uniform narrowing of the shunt to less than 2 to 2.5 mm, with the shunt appearing curved and somewhat elongated (Figure 3B). Due to its elongated nature, two coronary stents (4-mm diameter) were required to cover the entire length of the shunt.

After deployment of the first of two stents, the second stent was advanced through the 5-F guide catheter positioned at the mouth of the BTS. However, while advancing the stent through the shunt, the initial stent embolized to the LPA (Figure 3C). At this point, a 4-mm coronary balloon was advanced over the wire and inflated halfway within the embolized stent. The balloon was then pulled back gently into the shunt, allowing the stent to wedge within the distal portion of the BTS. After this, another 4-mm coronary stent was placed coaxial to the initial stent within the BTS. An angiographic result looked satisfactory, and saturations improved into the 80s. The procedure was terminated, and protamine was administered by the anesthesiologist. Within 10 minutes, saturations decreased to the low 60s. Vascular access was achieved again, and an angiography documented clots at the distal end of the stent within the pulmonary arteries (Figure 3D).

With the intent to break the clots using a 4-F AngioJet catheter, multiple attempts were made to advance the

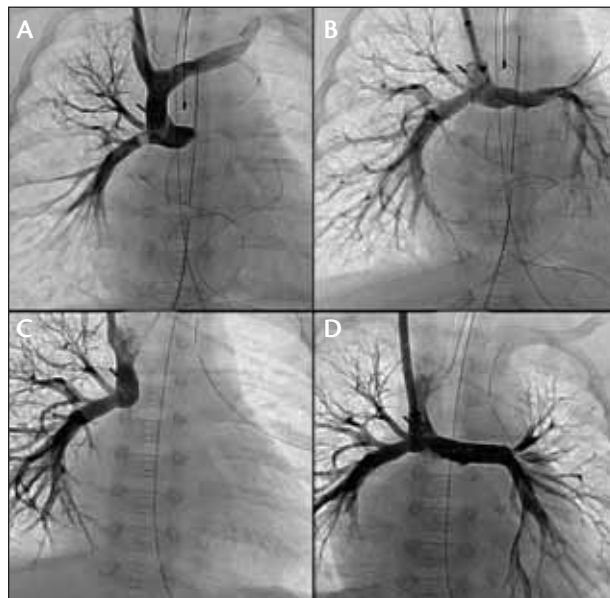


Figure 4. LPA thrombosis in a 4-month-old infant with hypoplastic left heart syndrome after comprehensive stage II palliation. Initial angiography in the SVC showed clot at the origin of the proximal RPA and a completely occluded LPA (A). After multilevel AngioJet use, there was significantly improved flow through the branch pulmonary arteries (B). Five days later, there was recurrence of the LPA thrombosis (C). After repeat AngioJet use, a 19-mm Genesis XD stent was placed in the LPA, with excellent results and no residual narrowing (D).

catheter through the BTS shunt, without success. Difficulties arose primarily due to the sharp angulation and rough surface within the stented segments of the shunt. Unfortunately, these attempts resulted in a small dent in the proximal stent that had been previously placed (Figure 3E). At this point, rtPA was administered locally, at a dose of 50 µg/kg given over 20 minutes.

Saturations improved to the mid-70s, and therefore the patient was transferred back to the CICU where rtPA was systemically administered for 24 hours. Angiography performed the next day documented virtually complete clot resolution (Figure 3F), with saturations now improved to the 80s.

CASE 4

A 4-month-old infant with a history of hybrid stage I palliation of hypoplastic left heart syndrome during the neonatal period underwent comprehensive stage II palliation at 4 months of age. On postoperative day 6, he developed progressive desaturations to 30% to 40% and hemodynamic instability. Echocardiography was unable to show flow to the left pulmonary artery. He was taken to

the catheterization laboratory with extracorporeal membrane oxygenation support on standby as a precaution. Initial angiography of the SVC showed a moderate clot at the origin of the proximal RPA and a completely occluded LPA (Figure 4A). A 0.014-inch coronary wire was advanced into the distal RPA, and a 4-F AngioJet catheter was used for clot removal. After the RPA clot had been largely removed, a 0.014-inch coronary wire was manipulated through the LPA clot into the distal LPA. Again, a 4-F AngioJet catheter was used, with wires being intermittently repositioned into different pulmonary side branches. The final angiographic result showed significantly improved flow with some small residual clots in distal pulmonary arterial branches (Figure 4B). There was a mild nipping in the neo-LPA, which was not dissimilar to what is frequently seen after comprehensive stage II palliation, and therefore it was believed that stent implantation was not required. However, due to the distal clots, rtPA was slowly administered locally at a dose of 50 µg/kg and was subsequently continued systemically for 24 hours after the procedure. rtPA was stopped shortly thereafter after the occurrence of an intracranial bleed.

Five days later, the patient deteriorated again clinically, with evidence of renewed LPA obstruction on echocardiographic evaluation. He was taken back to the catheterization laboratory where angiography documented a recurrent complete occlusion of the LPA (Figure 4C). Again, the AngioJet was used for clot removal, but this time, it was followed by implanting a 19-mm Genesis XD stent in the LPA, which was expanded to 6 mm. The angiographic result was excellent with no residual narrowing; however, some proximal and distal clots were still visible (Figure 4D). Despite the intracranial bleed, the patient was placed on low-dose heparin to prevent clot formation inside the stent. The patient died approximately 1 week later due to multisystem organ failure.

DISCUSSION

The use of catheter-based interventions for treatment of acute vascular thrombosis is increasing and often involves the use of thrombolytics and mechanical disruption of clots along with use of balloon angioplasty and stenting of the occluded vessels, as well as use of special techniques such as the AngioJet device.

Even though successful outcomes can be achieved, these procedures are often challenging because many patients are frequently significantly hemodynamically compromised. The appropriate method selection is essential for procedural success. The chosen approach not only depends on the individual patient but also on operator experience and the equipment that is available at each individual institution. In case 1 in this series, angiography

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documented a large clot extension into the more distal LPA, which was only clearly delineated through reverse pulmonary venous wedge angiography. Although attempts at advancing a wire directly through an acute thrombotic lesion are often successful, obtaining some imaging of the distal end of the occlusion can serve as a very useful roadmap during the procedure.

The AngioJet rheolytic thrombectomy system uses high-velocity saline jets to create a Bernoulli effect for entrainment, dissociation, and evacuation of thrombus.¹⁰ It has been shown to be an effective treatment for life-threatening postoperative thrombosis involving pulmonary or systemic veins and shunts in infants after cardiac surgery.⁹ It would have been the preferred treatment option in case 1 if it had been available at that time.

In absence of such equipment, the options for successful clot removal are more limited. Disintegrating clots through serial balloon angioplasty may restore some distal flow at the expense of distal thromboembolism of fragmented thrombotic material. However, an interventionist has to be very careful to avoid critically occluding nearby branches, as seen in case 1. In fact, it is often more beneficial to treat any nearby vascular stenosis before engaging in the clot removal of the main lesion. If thrombotic material cannot be removed through the use of the AngioJet, continuous infusion of rtPA directly into the thrombus over 24 hours may be required to reduce clot burden,³ even though this may not work well for long-segment occlusions in which rtPA may not reach the distal clot. For those long-segment lesions, using rtPA as an adjunct to clot fragmentation, along with balloon angioplasty, may achieve good results. However, postprocedural anticoagulation with tight monitoring of the coagulation status is crucial, especially during the transitioning from rtPA to heparin. In case 4, the recurrent occlusion may have occurred while transitioning from rtPA to heparin.

The majority of patients with acute vascular thrombosis have some underlying risk factors, most of which are usually nonmodifiable. However, when removing thrombus in the catheterization laboratory, careful evaluation of the vascular structure should be performed to identify any lesion that requires further treatment. Leaving a stenosis untreated in the background of a vascular occlusion only sets the stage for reocclusion, as occurred in case 4 in this

series. However, placing stents too early may not be beneficial either; stents themselves are thrombogenic and placing a stent over only partially removed fresh clot leads to clot protrusion through the cell meshwork of the stent into the vascular lumen, which is an even higher risk factor for reocclusion. This may have been the cause for reocclusion in case 1, in which a stent had to be placed prematurely after rtPA was stopped due to intracranial bleed, with significant residual clot around the stented area.

Again, the choice of appropriate equipment, as well as flexibility to improvise, are essential ingredients for procedural success with these challenging cases. In case 3, protamine was given after having placed two stents in a narrowed BTS. This highlights the need for clear communication with the cardiac anesthesiologist because protamine is not an ideal choice in these patients. This patient remained somewhat stable due to residual pulmonary flow, but if systemic-to-pulmonary artery shunts become completely occluded, time is an important factor. In this situation, rapid wire manipulation and forceful injection of heparinized saline may be used to dislodge the clot, especially in the acute phase when the clot is soft and gelatinous.¹¹ Although the AngioJet device is often very effective for acute vascular occlusions, it was less helpful in this particular patient. The thrombotic material was dispersed all around the stent, and as such, would have been less likely to be removed adequately using the AngioJet, which would have been confined to the in-stent area. Furthermore, even though the 4-F AngioJet catheter is not large, it is fairly stiff, and advancing through a stent can be difficult at times. When advancing around sharp corners, care should be taken not to bend any freshly implanted stent, as occurred in this patient.

In case 2, the operator was faced with the unexpected finding of a clot sitting on the guidewire in the systemic side of the Fontan baffle. In hindsight, performing transesophageal echocardiography evaluation before attempting to cross the occluded fenestration would have been advisable. However, whether visualization of a small clot may have changed the therapeutic approach is difficult to predict. Administration of rtPA in this situation may in fact lead to thromboembolism, especially in pedunculated clots in which the pedicle is resolved first. Equally, surgical clot removal using cardiopulmonary bypass would have been a high-risk procedure given the instability of the patient. Ultimately, clot removal attempts were successful, even though the Export aspiration catheter was found to be less well suited for larger clots. To some degree, the patient was lucky not to sustain a cerebral infarct and "only" a small renal infarct. The need for cerebral angiography in the catheterization laboratory should hopefully remain a rare occurrence. The most important component

of procedural success is multidisciplinary communication. All cases were discussed among cardiothoracic surgical colleagues, and extracorporeal membrane oxygenation support on standby in the catheterization laboratory was believed necessary in one patient (case 4). Again, when patients are very unstable, small changes especially in pulmonary blood flow can have a dramatic impact on the patient (as seen in case 1).

CONCLUSION

Recanalization of acute vascular thrombosis in patients with congenital heart disease is challenging. Operators need to have a wide variety of equipment available and need to be flexible in the chosen approach to achieve a successful outcome for each individual patient. Communication with surgical colleagues and the use of periprocedural anticoagulation is integral to procedural success. ■

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