CASE REPORT

AngioVac Removal of a Saddle Pulmonary Embolus Using TEE Guidance and Venoarterial ECMO Support

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VENOUS THROMBOEMBOLIC disease is a significant cause of morbidity and mortality, and in patients with hemodynamic instability, intervention with thrombolysis or embolectomy is indicated.[1] In patients whose condition is otherwise stable, the use of thrombolysis or embolectomy has been advocated in the presence of right ventricular strain, patent foramen ovale, extensive clot burden, free-floating right heart thrombus, or severe hypoxemia.[1] When the risk of bleeding precludes the use of thrombolytics, either surgical or catheter-based embolectomy prevails as the most acceptable treatment option.

The Vortex AngioVac system (Vortex Medical, Inc; Marlborough, MA) is a catheter-based embolectomy system approved by the U.S. Food and Drug Administration for the percutaneous retrieval of unwanted intravascular material. The AngioVac cannula is paired with a thrombus filter, a centrifugal pump head, and a reinfusion cannula that returns blood to the patient's venous circulation. The authors present a case in which the AngioVac system was used to retrieve a saddle pulmonary embolus under transesophageal echocardiographic (TEE) guidance. Because of concern for cardiorespiratory collapse during the procedure, the reinfusion cannula was modified with the addition of a venoarterial extracorporeal membrane oxygenation (ECMO) circuit.

CASE REPORT

A 48-year-old man with no known comorbidities was admitted after a syncopal event from a saddle pulmonary embolus. The patient did not require any inotropes but did have mild hypoxia (oxygen saturation by pulse oximetry, 90%-94%) that corrected with supplemental oxygen. Preoperative transthoracic echocardiography demonstrated the deleterious effects of the embolus, with moderate right ventricular enlargment and a moderately severe decrease in right ventricular systolic function. Although the patient was normotensive, embolectomy was recommended to relieve right ventricular dysfunction, which can be a harbinger of hemodynamic compromise.[2] The decision was made to perform pulmonary embolectomy with the Vortex AngioVac system supported by venoarterial ECMO. While heparin therapy is required for both of these circuits, its rapid reversibility was felt to be more favorable than lytic therapy in this patient with craniofacial injuries related to a syncopal event.

After radial artery catheter placement, induction of general anesthesia proceeded smoothly with ketamine (1 mg/kg) and succinylcholine (1.5 mg/kg). Central access was obtained through 2 9F catheters that were placed in the left internal jugular vein, with 1 serving primarily as a resuscitative volume line and the other for infusing vasoactive medications. The right internal jugular vein was intentionally avoided to leave it available for the surgical team's percutaneous access. Analgesia was provided with fentanyl boluses, anesthesia was maintained with isoflurane, and muscle relaxation was accomplished with rocuronium.

A large-bore 22F coil-reinforced AngioVac cannula was deployed through a 26F Gore DrySeal Sheath (W.L. Gore and Associates, Inc; Flagstaff, AZ) placed percutaneously through the right internal jugular vein. Thrombus was aspirated from the AngioVac cannula into a Capiox BT15 bubble trap (Terumo Cardiovascular Systems Corp; Ann Arbor, MI) with a 170-μm filter screen. A 16F Edwards Fem-Flex II femoral cannula (Edwards Lifesciences Corp; Irvine, CA) was placed in the right femoral vein as the venous return limb of the AngioVac circuit. Because of concerns that AngioVac thrombectomy could lead to a "steal" phenomenon from the pulmonary artery, venoarterial ECMO was initiated before embolectomy through a 19F Medtronic Bio-Medicus cannula (Medtronic; Minneapolis, MN) percutaneously inserted into the left femoral artery (Fig 1). A 3/8-inch Y connector was placed on the AngioVac reinfusion tubing to provide venous inflow to the ECMO circuit. Both circuits were set up with 3/8 × 3/32-inch tubing and primed with isotonic solution. Two 3/8-inch Stockert flow probes (Tektronix, Inc; Beaverton, OR) were used, one proximal to the AngioVac pump and a second one on the venous side of the ECMO pump. Sorin centrifugal pumps (Sorin Group USA, Inc; Arvada, CO) were used for both the AngioVac and ECMO circuits. A Maquet Quadrox-iD adult oxygenator (Maquet Getinge Group; Wayne, NJ) was used with the ECMO circuit.

Baseline intraoperative TEE confirmed pulmonary arterial thrombus. Although the McConnell sign, or decreased right ventricular systolic function with apical sparing, was not present, the right ventricular systolic function was moderately decreased globally.[3] The midesophageal ascending aorta long-axis view showed a significant clot burden in the main

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1053-0770/2602-0033$36.00/0

http://dx.doi.org/10.1053/j.jvca.2015.10.013

Key words: embolectomy, extracorporeal membrane oxygenation, transesophageal echocardiography, venous thromboembolism

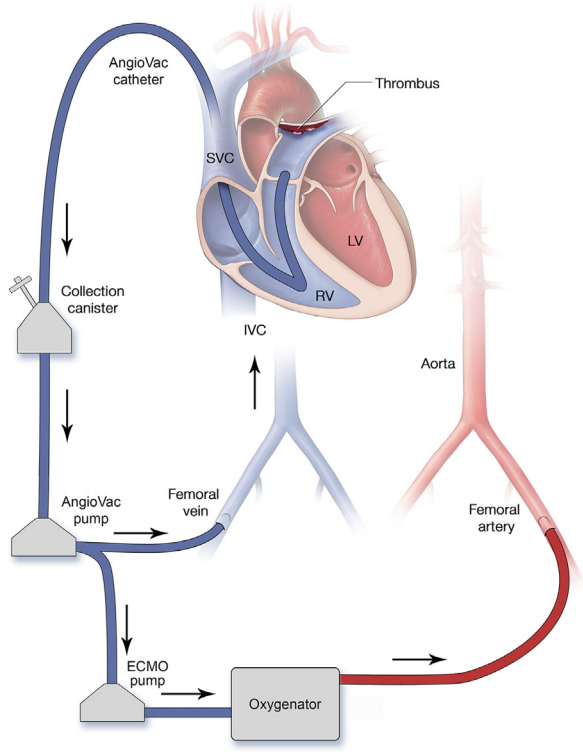

Fig 1. AngioVac system. Schematic shows AngioVac system (Vortex Medical, Inc; Marlborough, MA) with venoarterial extracorporeal membrane oxygenation (ECMO) circuit. IVC indicates inferior vena cava. LV, left ventricle; RV, right ventricle; SVC, superior vena cava.

pulmonary artery and a filling defect on color-flow Doppler imaging (Fig 2A). A midesophageal ascending aorta short-axis view allowed visualization of the long axis of the right pulmonary artery, with further delineation of the thrombus burden (Fig 2B). The interventricular septum was flattened and shifted leftward throughout the cardiac cycle, suggesting right ventricular pressure overload. Left ventricular function was preserved, and no other significant intracardiac pathologic changes were found.

The patient was heparinized to achieve an activated clotting time greater than 300 seconds, and venoarterial ECMO was initiated. Under direct echocardiographic visualization, the AngioVac suction device was placed through the introduction sheath into the right pulmonary artery, and the embolectomy was performed over the course of 5 passes (Videoclip 1). Upon simultaneous initiation of the AngioVac venovenous bypass system and venoarterial ECMO, AngioVac blood flow return was predominantly shunted to the inlet side of the venoarterial ECMO circuit. Consequently, nearly all blood drawn from the AngioVac circuit returned to the patient's femoral artery during use of the dual circuit. Partial venoarterial ECMO flows were maintained at 3-to-4 L/min to prevent decompression of the right side of the heart, which would further limit preload and optimal clot extraction via the AngioVac circuit. The AngioVac system flow was operated at 2-to-5 L/min with varying flows during clot capture dynamics.

Given that centrifugal pumps are preload and afterload dependent, flow variation was noted in the presence of hemodynamic changes or clot capture. Pressure transduced at the thrombus filter of the AngioVac varied from −60 to −150 mmHg. Excessive negative pressures, accompanied by venous line chatter or chug, were indicative of insufficient preload or intravascular thrombus trapped within the AngioVac cannula. To address the latter, the AngioVac cannula was removed periodically, flushed, and reinserted. At that time, the inlet and outlet of the AngioVac circuit were clamped in the presence of continuous ECMO flow. If hypovolemia was suspected, a fluid bolus was provided to the patient.

Postprocedural TEE images confirmed successful clot retrieval. Pulmonary angiography confirmed echocardiographic findings showing the clot burden in the right pulmonary artery significantly decreased and perfusion through the pulmonary vasculature improved (Fig 3). Gross thrombus was collected in the AngioVac collection canister (Fig 4).

At the conclusion of the procedure, the patient was weaned successfully from ECMO and was transported to the intensive care unit with propofol sedation. The right ventricular function

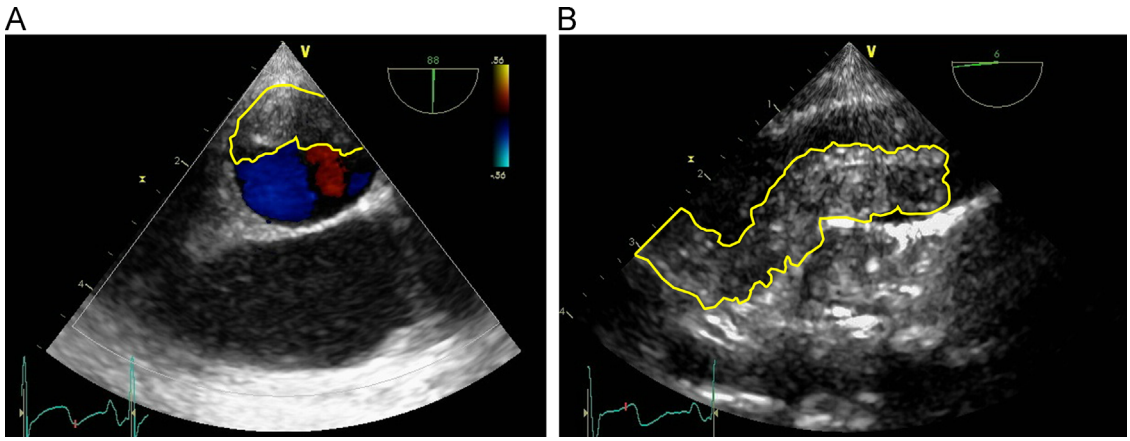

Fig 2. Transesophageal echocardiographic imaging of pulmonary arterial thrombi. (A) Midesophageal ascending aortic long-axis view shows clot (outlined in yellow) in the main pulmonary artery. (B) Midesophageal ascending aortic short-axis view shows clot (outlined in yellow) in the right pulmonary artery.

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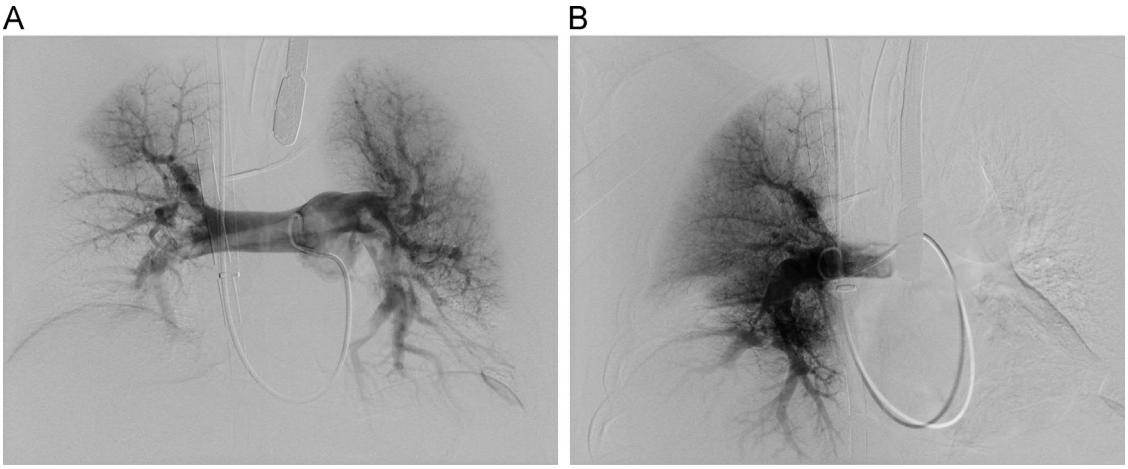

Fig 3. Pulmonary angiography. (A) Preprocedural angiogram shows a filling defect in the right pulmonary artery. (B) Postprocedural angiogram shows improved filling in the right pulmonary artery.

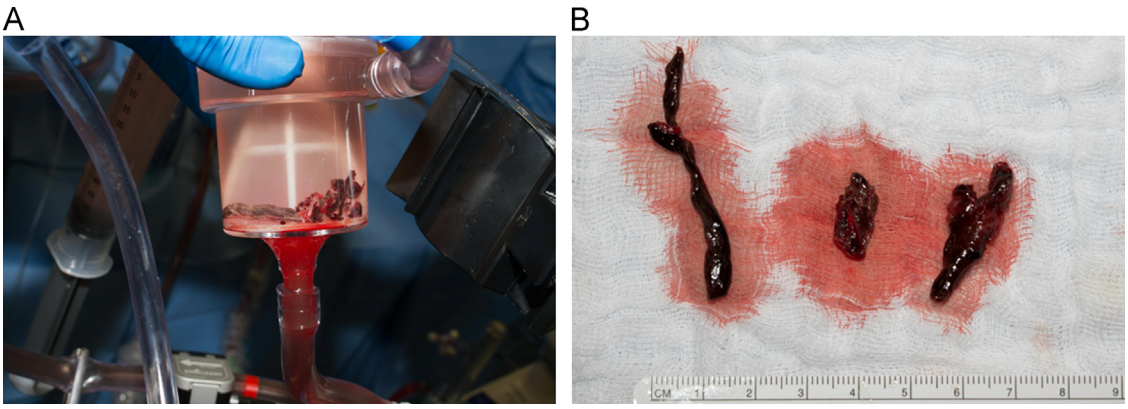

Fig 4. Gross views of thrombus. (A) Thrombus has been captured in the filter. (B) Thrombus has been removed.

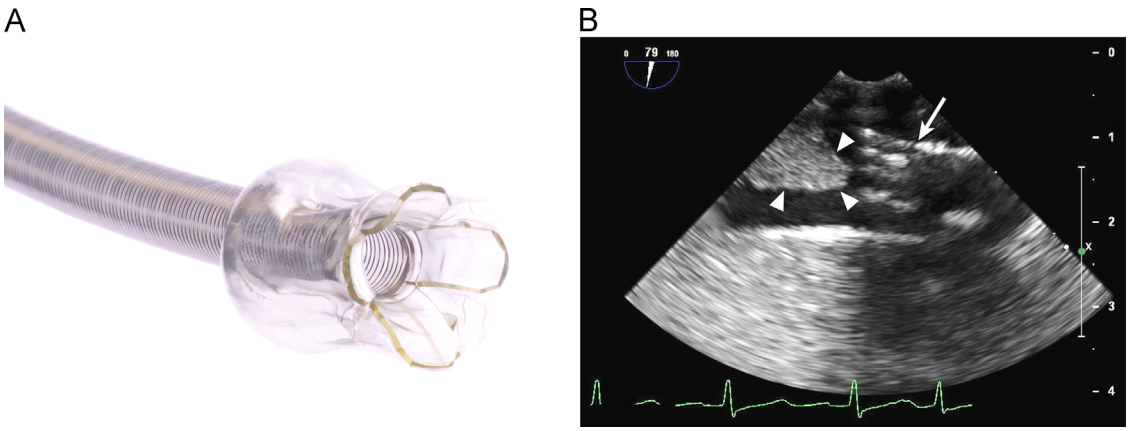

Fig 5. AngioVac device. (A) The tip of the AngioVac device (Vortex Medical, Inc; Marlborough, MA) resembles flower petals. (Courtesy of AngioDynamics, Latham, NY. Used with permission.) (B) The device (arrow) has a characteristic appearance on transesophageal echocardiography as it approaches a thrombus (arrowheads).

had nearly normalized, and the left ventricular function was preserved without inotropic support. Postoperatively the patient required a vasopressin infusion to maintain adequate blood pressure, likely because of the effects of sedation. He was extubated shortly after arrival, transferred to the general care unit the next day, and discharged on postoperative day 4. Thrombophilia screening showed that the patient was heterozygous for the factor V Leiden mutation.

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DISCUSSION

Since the introduction of the Vortex AngioVac system, few case reports have been published describing its use.[4–10] Todoran et al[4] first described the successful use of this aspiration system to remove bulky vegetations in the right atrium associated with an infected implantable cardioverter-defibrillator lead. Donaldson et al[10] reported the largest experience with this device in which 14 patients underwent 15 AngioVac thrombectomies without any periprocedural mortality. Although TEE has been used as an adjunct to AngioVac clot retrieval, its use has not been extensively discussed and reported. Furthermore, the modification to the reinfusion circuitry by adding an ECMO oxygenator and arterial reinfusion cannula has never been reported.

Echocardiographic findings associated with pulmonary embolism have been well described.[11] However, the use of TEE to guide catheter-based embolectomy devices for removal of thrombus from the right side of the heart has not been addressed. The tip of the AngioVac device, shaped like flower petals (Fig 5A), has a characteristic appearance on TEE (Fig 5B). In this patient, TEE proved invaluable in guiding the AngioVac suction device to contact thrombus, in assessing biventricular function, and in rapidly identifying pericardial fluid accumulation should intracardiac or pulmonary arterial perforation occur. Short-axis and long-axis views of the midesophageal ascending aorta provide visualization of the main pulmonary artery and right pulmonary artery. The short-axis view of the midesophageal ascending aorta may be modified by slightly rotating the probe to the right to further visualize the length of the right pulmonary artery. Unfortunately, the left pulmonary artery is poorly visualized with TEE because of shadowing from the left mainstem bronchus. While use of intraoperative TEE did not eliminate the need for angiography in the authors' patient, it did allow the proceduralist to continually assess the thrombus burden during the retrieval efforts without frequent administration of a contrast agent.

Venoarterial ECMO allowed for prophylactic support in the case of hemodynamic or respiratory instability owing to AngioVac thrombectomy. After embolectomy, patients' hemodynamic status and oxygenation typically improve. However, lung ischemia-reperfusion injury is a rare complication after embolectomy, and the ECMO circuit provides a safety net for ensuring oxygen delivery should this occur.[12] Not all AngioVac thrombectomies require the institution of venoarterial ECMO empirically; indeed, this case may have been conducted successfully in its absence. Nonetheless, it is prudent to perform these procedures with ECMO support and blood bank resources immediately available. The circuit components and configuration reported here have become the standard at this institution for these types of cases.

APPENDIX A. SUPPORTING INFORMATION

Supplementary data found in this article are available online at http://dx.doi.org/10.1053/j.jvca.2015.10.013.

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