CLINICAL STUDY

Removal of Caval and Right Atrial Thrombi and Masses Using the AngioVac Device: Initial Operative Experience

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ABSTRACT

Purpose: To describe initial single-center experience with a thrombectomy device in managing right atrial and caval thrombi, tumors, and vegetations.

Materials and Methods: A retrospective analysis of AngioVac thrombectomy performed in 16 patients (mean age 53 y ± 13; 8 men, 8 women) between August 2013 and August 2015 was performed. Indications included right atrial mass/thrombus (6/16; 37.5%) and iliocaval thrombus (10/16; 62.5%). Procedural success was defined as aspiration of > 70% volume of atrial mass/thrombus or restoration of antegrade caval flow.

Results: Procedural success was achieved in 4/6 (67%) right atrial masses/thrombi and 10/10 (100%) caval thrombi. All patients (8/8; 100%) with caval thrombus presenting with swelling/edema had improvement or resolution of symptoms. There were no procedural or periprocedural mortalities; complications included one major (6.3%; intraprocedural pulmonary embolus) and one minor (6.3%; access site hematoma not requiring transfusion) complication. Of 16 patients, 14 (87.5%) survived to discharge at a mean of 10 days ± 8 (range, 1–23 d), and 12 patients (75%) were alive at last known follow-up at a mean of 385 days ± 267 (range, 63–730 d). At a mean of 194 days ± 177 (range, 41–372 d), 4/16 (25%) patients were dead; no death was related to AngioVac thrombectomy. At a mean of 66 days ± 21 (range, 49–90 d) after intervention, 3/14 (21.4%) cases with procedural success had local recurrence of mass/thrombus.

Conclusions: AngioVac thrombectomy can be performed with high procedural success with clinical benefit in patients with right atrial and caval masses/thrombi.

In the United States, > 900,000 venous thromboembolism events occur annually (1,2). Iliocaval thrombi can cause morbidity in otherwise relatively healthy patients (3). Thrombolytic therapy has been shown to be successful for treating venous thromboembolism, but use of thrombolytic therapy may be complicated by the known hemorrhage risk (overall 22%, with up to 3% intracranial hemorrhage) (4). The AngioVac thrombectomy system (AngioDynamics, Inc, Latham, New York) is approved by the US Food and Drug Administration for removal of thrombi and emboli. The current literature on the AngioVac device is limited, primarily consisting of case reports; use of the device has been described for cardiac masses and thrombi, cardiac lead vegetations, iliocaval thrombi, intraprocedural embolic protection, and pulmonary emboli (5–18). The largest case series to date was reported by Donaldson et al (8) and comprised 14 consecutive patients treated for acute pulmonary embolism, intracardiac masses, and caval thrombus. In this series, 27% of patients were in shock before the procedure, there were no periprocedural mortalities, and 87% of patients survived to discharge. The present series evaluates the AngioVac device specifically for the treatment of atrial and caval bulk thrombi and masses.

MATERIALS AND METHODS

The medical center institutional review board approved this retrospective study. An analysis of patient demographics, procedural details, and outcomes was performed. All

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cases of AngioVac thrombectomy for nonpulmonary embolic indications, including right atrial masses and thrombi and iliocaval thrombi between August 2013 and January 2015 were reviewed. Contrast-enhanced computed tomography, contrast-enhanced magnetic resonance imaging, ultrasound, or echocardiography studies were obtained before the procedure in all patients. All procedures were performed under general anesthesia and transesophageal echocardiography guidance together with cardiac perfusionists and cardiothoracic anesthesiologists (Figs 1–3).

All patients were anticoagulated with heparin (Celsus, Cincinnati, Ohio) or argatroban (GlaxoSmithKline, Philadelphia, Pennsylvania) during the procedure with a target activated clotting time of > 300 seconds. Two percutaneous venous accesses were obtained in each patient under ultrasound and fluoroscopic guidance for the aspiration and reperfusion cannula, involving either the internal jugular or the common femoral vein. The aspiration venous access sites (femoral or internal jugular) were sequentially dilated to accommodate a 26-F Gore DrySeal sheath (W.L. Gore & Associates, Flagstaff, Arizona) over a 0.035-inch Amplatz (Boston Scientific, Marlborough, Massachusetts) or 0.035-inch Lunderquist (Cook, Inc, Bloomington, Indiana) guide wire passed into the inferior vena cava. The reperfusion access site (femoral or internal jugular) was sequentially dilated to accommodate an 18-F reperfusion catheter.

In all patients, the 22-F first-generation AngioVac cannula was passed over the Amplatz or Lunderquist wire to the site of pathology (atrial or caval) under fluoroscopic and transesophageal echocardiography guidance. The balloon-actuated, expandable funnel-shaped distal tip was inflated, and the extracorporeal circuit was slowly increased, over the course of several minutes, to a maximum rate of 3 L/min with active monitoring of hemodynamic parameters and transesophageal echocardiography.

The amount of luminal thrombus aspirated was estimated based on direct comparison of multioblique angiography of the cava performed before and after the intervention or comparison of echocardiographic findings for right atrial masses. Procedural success was defined as aspiration of > 70% volume of atrial lesions

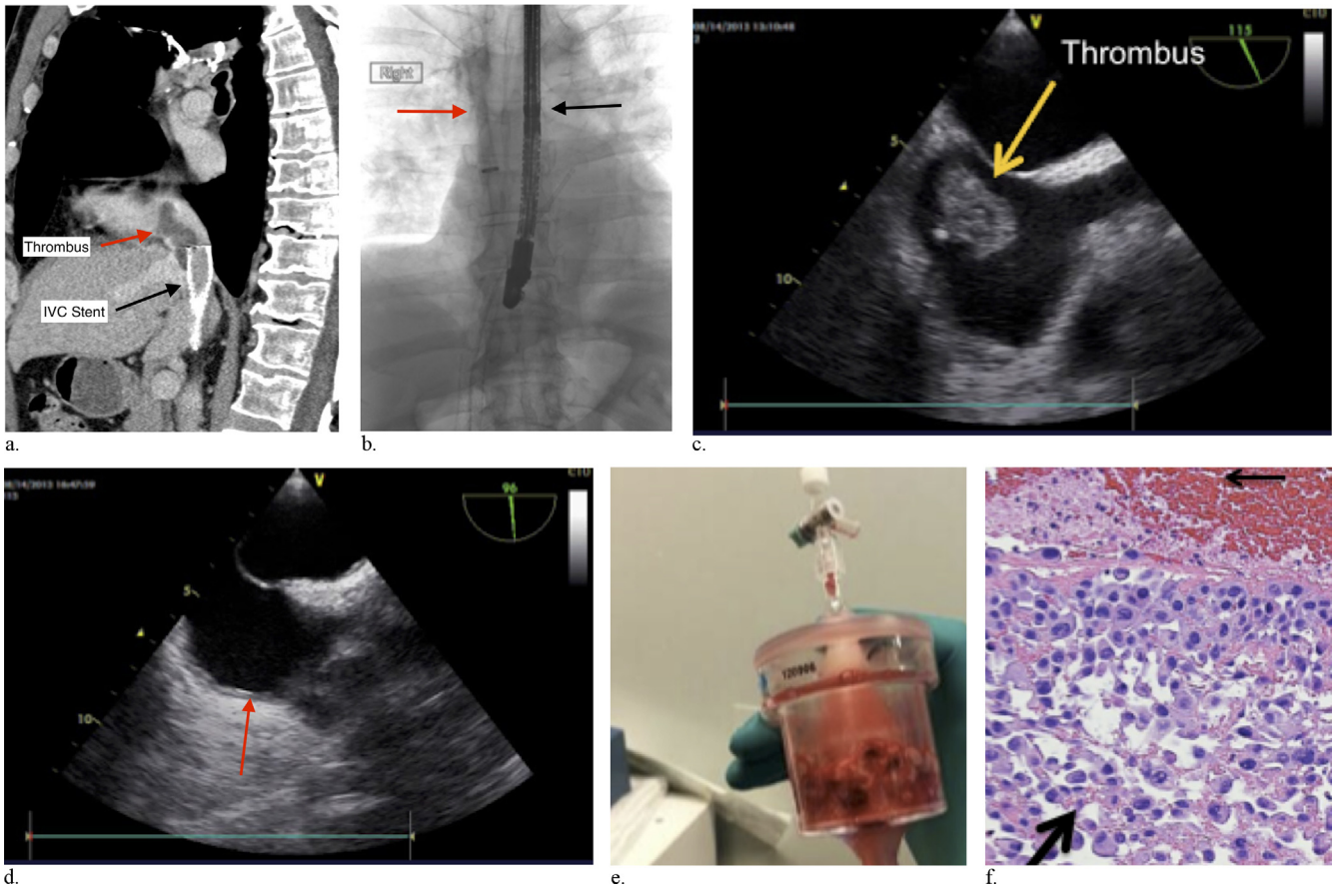
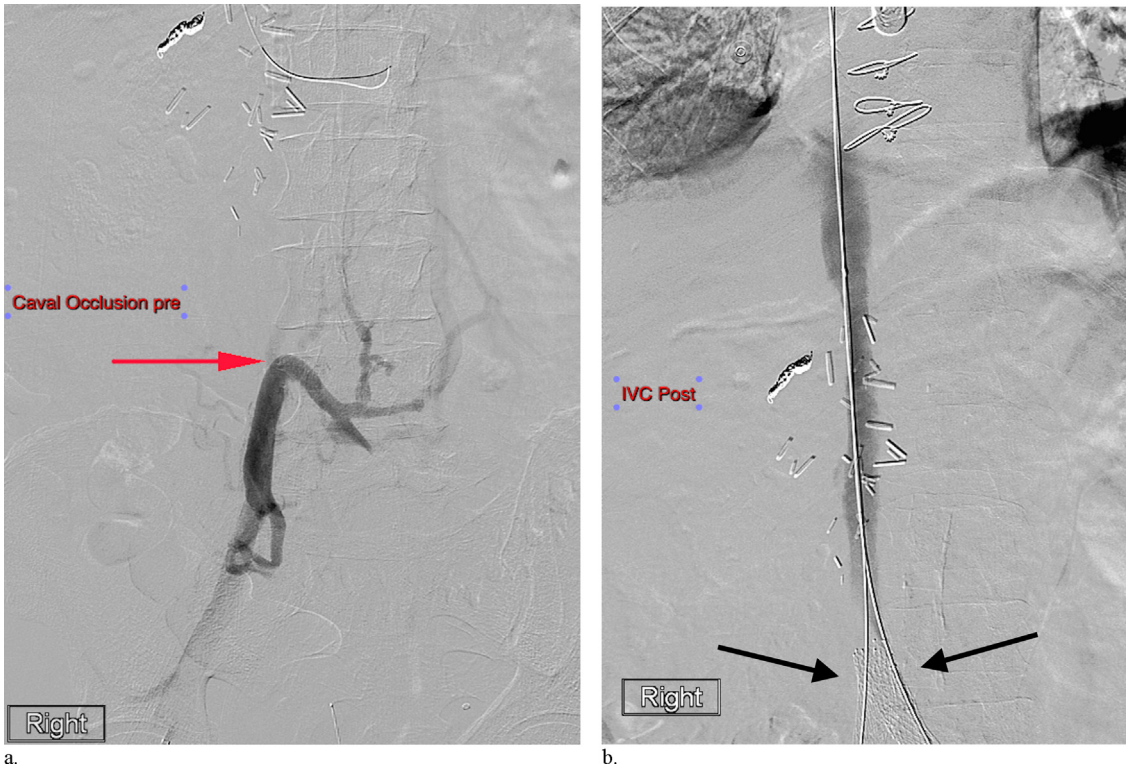
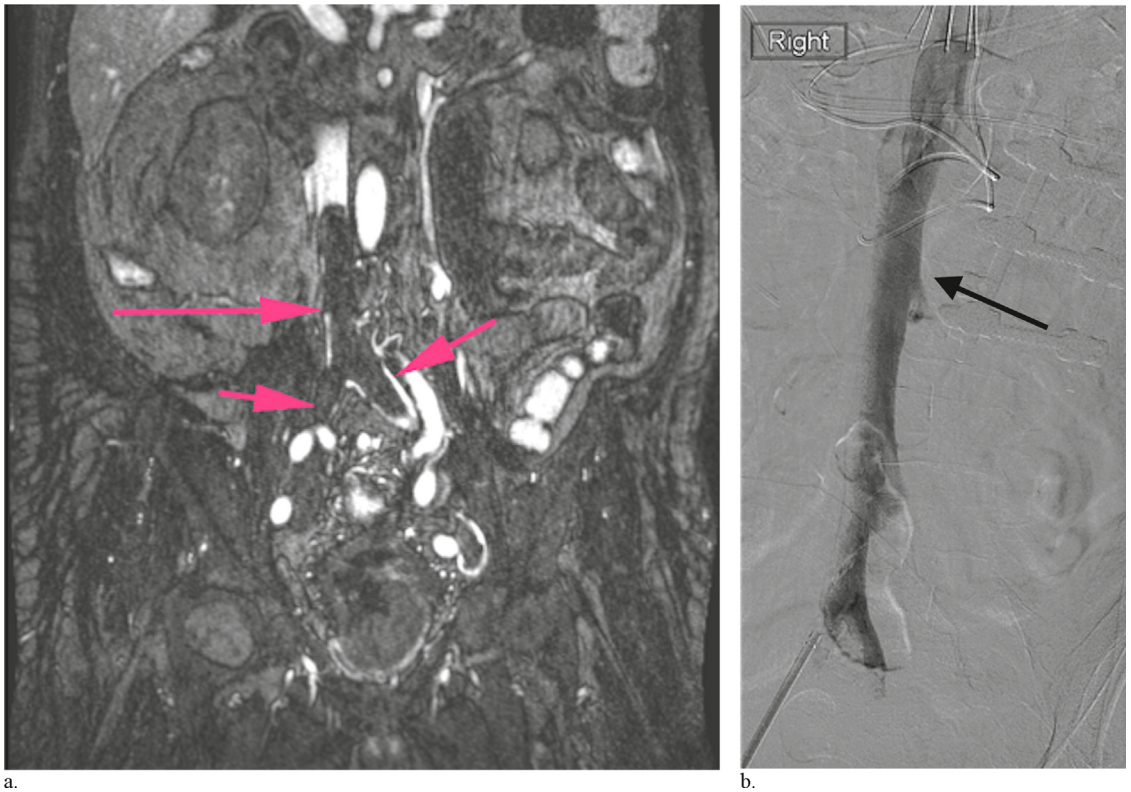


Figure 1. A 62-year-old man with metastatic melanoma to the heart and inferior vena cava. **(a)** Computed tomography image obtained before the procedure demonstrates extensive thrombus (red arrow) extending through an inferior vena cava stent (black arrow) into the right atrium. **(b)** Spot radiograph obtained during the procedure shows transesophageal echocardiographic probe (black arrow) and right internal jugular thrombectomy approach (red arrow). Echocardiograms obtained **(c)** before and **(d)** after AngioVac thrombectomy demonstrate complete removal of atrial thrombus (yellow arrow in **c**). Atrium is free of thrombus after removal (red arrow in **d**). **(e)** Suctioned thrombus and **(f)** pathology-proven melanoma (arrow). IVC = inferior vena cava.



a. b.

Figure 2. A 71-year-old man with metastatic renal cell carcinoma with extensive inferior vena cava tumor and bland thrombus. **(a)** Venogram obtained before the procedure demonstrates complete caval occlusion (arrow) with prominent collateral vessels. **(b)** Venogram obtained after the procedure demonstrates excellent antegrade flow restored in the inferior vena cava. Iliocaval stents (arrows) were also placed during the procedure. IVC = inferior vena cava.



a. b.

Figure 3. A 58-year-old man with a large intracranial hemorrhage and extensive bilateral leg swelling secondary to extensive iliocaval thrombosis. **(a)** Magnetic resonance venogram obtained before the procedure demonstrates occlusive iliocaval thrombus (arrows). **(b)** Venogram obtained after AngioVac thrombectomy demonstrates restoration of antegrade caval flow (arrow).

or restoration of antegrade flow in caval lesions. Major and minor complications were defined per clinical practice guidelines from the Society of Interventional Radiology (SIR) (19).

There were 16 consecutive patients who underwent AngioVac thrombectomy for nonpulmonary embolic indications, including right atrial masses and thrombi (six of 16; 37.5%) and iliocaval thrombi (10 of 16; 62.5%). Four patients (25%) failed catheter-directed thrombolysis (with tissue plasminogen activator) therapy before AngioVac thrombectomy, and four patients (25%) had absolute contraindications to thrombolysis. Mean patient age was 53 years ± 13, and there were eight men and eight women. Patient demographics are summarized in Table 1, and patient clinical characteristics are summarized in Table 2.

RESULTS

Percutaneous access was achieved in all cases. Procedural success was achieved in four of six (67%) cases of atrial masses and thrombi and 10 of 10 (100%) cases of caval thrombi. The two procedural failures were cases of right atrial sarcoma and tricuspid valve vegetation associated with a cardiac device lead. Average fluoroscopy time was 33.1 minutes ± 22.3 (range, 3.8–87.2 min). Adjunctive procedures were performed at the discretion of the proceduralist and included venoplasty (n = 4), closing a snare around the material to release smaller pieces toward the downstream suction cannula (n = 2), and rotational thrombectomy (n = 3) with the CLEANER device (Argon Medical Devices, Inc, Plano, Texas) (n = 2) or Arrow-Trerotola Percutaneous Thrombolytic Device (Teleflex Medical, Morrisville, North Carolina) (n = 1).

Clinical outcomes are outlined in Table 3. All patients (eight of eight; 100%) with caval thrombus who presented with swelling/edema had improvement or resolution of symptoms after procedural success with AngioVac thrombectomy. There were no procedural or periprocedural mortalities. There were 14 patients (14 of 16; 87.5%) who survived to discharge at a mean of 10 days ± 8 (range, 1–23 d) and 12 patients (12 of 16; 75%) who were alive at last known follow-up at a mean of 385 days ± 267 (range, 63–730 d). Four patients (4 of 16; 25%) were deceased at follow-up at a mean of 194 days ± 177 (range, 41–372 d), but no deaths were attributable to AngioVac thrombectomy. Of cases with procedural success, there were three cases of local recurrence of mass/thrombus (three of 14; 21.4%) at a mean of 66 days ± 21 (range, 49–90 d) after intervention.

Complications included one major (6.3%; intraprocedural pulmonary embolus) and one minor (6.3%; access site hematoma not requiring transfusion) complication. The major complication of intraprocedural pulmonary embolus occurred during AngioVac thrombectomy of iliocaval caval thrombus with subsequent pulseless electrical activity. After immediate cardiopulmonary resuscitative measures and establishment of extracorporeal membrane oxygenation circulation, angiography demonstrated bilateral pulmonary emboli, which were successfully treated with thrombectomy using maceration with balloon catheters and suction aspiration with the Penumbra Indigo System (Penumbra, Inc, Alameda, California). The patient's subsequent course after the intervention was uncomplicated, and the patient was discharged 13 days later with no adverse neurologic sequelae related to the temporary cardiac arrest.

DISCUSSION

Intravascular and cardiac thrombi and masses are traditionally managed medically or with open surgery, and most intracardiac masses still require surgical excision (17). However, intravascular masses may now be increasingly managed with endovascular techniques. Although catheter-directed thrombolysis has become a frequently used approach to thrombosis management, there are common clinical scenarios in which thrombolysis is not feasible and aspirational devices are a safe alternative. Donaldson et al (8) evaluated 14 patients with acute pulmonary embolism and intracardiac/caval masses and described the feasibility of using the AngioVac device in critically ill patients. However, most of the current literature on AngioVac thrombectomy primarily consists of case reports and small case series (11,20–22). In addition, the indications in these reports range from iliocaval thrombosis to cardiac lead vegetations, demonstrating the diverse spectrum of potential applications of the device and the lack of consensus on the indications for use.

Guidelines from the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the Heart Rhythm Society provide a class I recommendation for lead extraction in cases of device association with lead or valvular infection (23). The Heart Rhythm Society Guidelines on transvenous lead extraction suggest surgical extraction for vegetations > 3 cm (24). However, given that patients with implantable cardiac devices have depressed cardiac function, the risk of surgery is high, and percutaneous extraction is an alternative. AngioVac extraction of vegetations has been reported in the setting of infective endocarditis to debulk vegetations before lead explantation and was successfully performed in the case series presented here (13).

Our experience demonstrates that AngioVac aspiration, combined with other adjunctive measures such as mechanical maceration, balloon angioplasty, or stent placement, can be successful in single-session bulk removal of large volumes of caval thrombus with restoration of antegrade caval flow (10 of 10; 100%

Table 1. Patient Demographics

Patient No.	Diagnosis	Age, Sex	Days from Symptom Onset to Diagnosis	Current Smoking	Obesity*	Malignancy	Recent Surgery (< 4 wk)	Immobilization	Coagulopathy
1	Atrial melanoma	62, M	0	−	−	+	−	−	−
2	Atrial angiosarcoma	60, M	4	−	−	−	−	−	−
3	Tricuspid vegetation	62, M	30	−	−	−	−	−	−
4	SVC thrombus	62, M	1	−	+	−	+	+	−
5	IVC thrombus	51, F	0	−	−	−	+	+	−
6	Fontan thrombus	39, F	14	+	−	−	−	−	−
7	IVC thrombus	32, F	0	−	−	−	−	−	−
8	RA thrombus	28, F	14	−	−	−	−	−	−
9	SVC thrombus	41, F	2	−	−	+	−	−	+
10	IVC thrombus	42, M	17	−	−	+	−	−	−
11	IVC thrombus	58, M	0	−	−	−	−	−	−
12	IVC thrombus	63, F	3	−	−	−	−	−	+
13	IVC thrombus	70, M	90	+	−	+	−	−	−
14	Lead vegetation	49, F	0	−	−	−	−	−	−
15	IVC thrombus	67, M	0	−	−	+	−	−	−
16	IVC thrombus	71, M	0	−	−	+	+	−	−

Note–+ indicates yes, and − indicates no.
F = female; IVC = inferior vena cava; M = male; RA = right atrial; SVC = superior vena cava.
* Obesity was defined as body mass index > 25.

Table 2. Clinical Characteristics

Patient No.	Diagnosis	Dyspnea	Chest Pain	Syncope	Edema	Hypotension	D-Dimer > 500 ng/mL at Presentation	Systolic Pressure (mm Hg)	Heart Rate (beats/min)	Sao_2 (%)	FIo_2	ECHO Type	Right Ventricular Dilatation (RV/LV > 1)	Right Ventricular Hypokinesia	Abnormal Interventricular Septal Motion	Vena Cava Dilatation/ Occlusion	Tricuspid Regurgitation
1	Atrial melanoma	+	−	−	+	−	NA	129	81	98	21	TEE	+	−	−	−	Trace
2	Atrial angiosarcoma	+	+	−	−	−	NA	114	75	98	21	TEE	−	−	−	−	Mild
3	Tricuspid vegetation	+	−	−	−	−	NA	93	89	98	21	TEE	−	+	−	−	Mild
4	SVC thrombus	+	−	−	+	+	NA	88	104	100	80	TEE	+	+	−	−	None
5	IVC thrombus	+	−	−	+	−	+	136	82	100	21	TEE	−	−	−	−	Mild
6	Fontan thrombus	−	−	−	−	+	+	90	80	100	33	TEE	NA	NA	NA	+	NA
7	IVC thrombus	−	−	−	+	−	NA	102	100	98	21	TEE	+	−	−	+	Moderate
8	RA thrombus	−	−	−	−	+	NA	91	107	100	100	TEE	−	−	−	−	Moderate
9	SVC thrombus	+	+	−	+	−	NA	133	82	100	50	TEE	+	−	−	−	Trace
10	IVC thrombus	+	−	+	−	−	NA	114	61	100	21	TEE	−	−	−	−	None
11	IVC thrombus	−	−	−	+	−	NA	157	96	100	35	NA	NA	NA	NA	NA	NA
12	IVC thrombus	+	+	−	+	−	NA	127	71	97	21	NA	NA	NA	NA	NA	NA
13	IVC thrombus	−	−	−	+	−	+	126	52	94	28	NA	NA	NA	NA	NA	NA
14	Lead vegetation	+	−	−	−	−	NA	117	69	99	21	TEE	−	−	−	−	Trace
15	IVC thrombus	+	+	−	+	−	+	132	86	96	21	NA	NA	NA	NA	NA	NA
16	IVC thrombus	+	−	−	−	+	+	125	98	100	24	TEE	−	−	−	−	Trace

Note–+ indicates yes, and − indicates no.

ECHO = echocardiography; FIo_2 = fraction of inspired oxygen; IVC = inferior vena cava; LV = left ventricle; NA = not available; RA = right atrial; RV = right ventricle; Sao_2 = arterial oxygen saturation; SVC = superior vena cava; TEE = transesophageal echocardiography.

Table 3. Clinical Outcomes after AngioVac Thrombectomy

Patient No.	Clinical Benefit	Days to Discharge	Last Known Follow-up	Local Recurrence of Mass/Thrombus (d)	Additional Intervention
1	Improved lower extremity swelling	7	Deceased (372 d, metastatic melanoma)	60	None
2	NA	1	Alive (126 d)	NA	Surgical extraction of mass
3	NA	NA	Deceased (41 d, 4 d after heart transplant with arrhythmia)	NA	Heart transplant 37 d after intervention
4	Resolution of SVC syndrome	24	Alive (696 d)	None to last known follow-up	None
5	Improved lower extremity swelling	13	Alive (735 d)	None to last known follow-up	None
6	No paradoxical embolism with central venous catheter removal	9	Alive (730 d)	None to last known follow-up	None
7	Improved lower extremity swelling	17	Alive (502 d)	None to last known follow-up	Caval anastomotic stricture venoplasty at 25 d and 125 d after intervention
8	Thrombus (bland) debulking	NA	Deceased (43 d, chronic liver transplant rejection with sepsis)	None to last known follow-up	None
9	Resolution of SVC syndrome	3	Deceased (321 d, metastatic ovarian cancer)	None to last known follow-up	None
10	Thrombus (tumor) debulking	1	Alive (538 d)	None to last known follow-up	None
11	Improved lower extremity swelling	21	Alive (525 d)	49	None
12	Improved lower extremity swelling	2	Alive (82 d)	None to last known follow-up	None
13	Improved lower extremity swelling	7	Alive (63 d)	None to last known follow-up	None
14	Successful lead extraction without complication	23	Alive (176 d)	None to last known follow-up	None
15	Improved lower extremity swelling	1	Alive (336 d)	90	None
16	Thrombus (tumor) debulking	10	Alive (105 d)	None to last known follow-up	None

NA = not available; SVC = superior vena cava.

success). In addition, eight of eight (100%) patients with symptomatic swelling from caval thrombus with procedural success had immediate improvement or resolution of symptoms. However, symptomatic embolization to the pulmonary arteries with subsequent temporary cardiopulmonary collapse occurred in one patient undergoing iliocaval thrombectomy. A proposed mechanism was the aspiration of a large thrombus from the occluded iliac system superiorly into the cava, at which point it became nonadherent, and embolization of the thrombus past the AngioVac aspiration cannula to the pulmonary circulation occurred. Despite a severe immediate cardiopulmonary event, the patient was successfully managed and did not experience any notable resultant long-term adverse sequelae.

Procedural success was not achieved in two patients (12.5%), in one case of atrial sarcoma and one case of tricuspid valve lead vegetation. It is postulated that success was not achieved in these cases because of the adherence of pathology to cardiac structures and/or the firm nature of the underlying lesions themselves. Additional technical limitations of the device related to its physical characteristics warrant consideration. The large profile of the device precludes passage into leg veins, necessitating traditional pharmacologic or mechanical thrombolysis to create adequate inflow from the leg veins (16). In addition, the rigidity of the 22-F device renders manipulation difficult (16). Finally, in the setting of completely occlusive thrombus, flow rates may be lower than ideal for extraction, and adjunctive measures for recanalization may be required with angioplasty or thrombectomy to provide adequate flow (8). Future versions of the device could potentially be lower caliber, with superior flexibility and steerability (8).

Limitations to this study include the limitations inherent to the heterogeneous group of patients presented, with variable indications for use, clinical evaluation, and follow-up. Although efforts have been made to standardize the clinical and demographic parameters collected and presented, this is an issue that would be best served by a prospective data collection as part of a registry, which is currently ongoing. Furthermore, quantification of procedural success and complications (eg, the prevalence of clinically silent pulmonary emboli) is limited by the retrospective nature of the study and the lack of uniformity of clinical and imaging follow-up.

In conclusion, the present study demonstrates the safe applicability of the AngioVac device to intracardiac and iliocaval thrombi and masses. The AngioVac cannula, in association with other devices and techniques, was successful in achieving restoration of antegrade caval flow with thrombus removal in a single session and may prevent the need for open cardiac surgical removal of right atrial masses.

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