Case Series

Effect of Percutaneous Suction Thromboembolectomy

on Improved Right Ventricular Function

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Venous thromboembolism is a leading cause of cardiovascular death. Historically, surgical intervention has been associated with high morbidity rates. Pharmacologic therapy alone can be inadequate for patients with substantial hemodynamic compromise, so minimally invasive procedures are being developed to reduce clot burden. We describe our initial experience with using the AngioVac system to remove thromboemboli percutaneously.

We reviewed all suction thromboembolectomy procedures performed at our institution from March 2013 through August 2015. The main indications for the procedure were failed catheter-directed therapy, contraindication to thrombolysis, bleeding-related complications, and clot-in-transit phenomena. We collected details on patient characteristics, procedural indications, thrombus location, hemodynamic values, cardiac function, pharmacologic support, and survival to discharge from the hospital. The Wilcoxon signed-rank test was used for statistical analysis.

Thirteen patients (mean age, 56 ± 15 yr; 10 men) underwent suction thromboembolectomy; 10 (77%) survived to hospital discharge. The median follow-up time was 74 days (interquartile range [IQR], 23–221 d). Preprocedurally, 8 patients (62%) had severe right ventricular dysfunction; afterwards, 11 (85%) had normal function or mild-to-moderate dysfunction, and only 2 (17%) had severe dysfunction (P=0.031).

Percutaneous suction thromboembolectomy, a promising therapeutic option for patients, appears to be safe, and we found it to be associated with improved right ventricular function. ***(Tex Heart Inst J 2019;46(2):115-9)***

Key words: *Embolectomy/instrumentation/methods; equipment design; pulmonary embolism/prevention & control/surgery/therapy; retrospective studies; thrombectomy/instrumentation/methods/mortality; thromboembolism/complications; treatment outcome; vascular access devices; ventricular function, right*

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Venous thromboembolism, a major cause of cardiovascular morbidity and death, affects 300,000 to 600,000 people in the United States each year.[1] Approximately 20% of patients with pulmonary embolism (PE) die before the diagnosis is made or on the first day of diagnosis.[2] Among survivors, morbidity is compounded by sequelae, including symptomatic pulmonary hypertension (incidence, 3.8% at 2 yr).[3]

Anticoagulation is often the initial therapy in hemodynamically stable patients; thrombolytic therapy is reserved for more advanced disease. Although systemic or catheter-directed thrombolysis can be effective when thrombi are small, these methods may not clear a larger clot burden. Furthermore, approximately 40% of patients have at least one contraindication to systemic fibrinolysis.[4]

An alternative to thrombolytic therapy is surgical pulmonary embolectomy (SPE), which has similar early and long-term survival rates.[5] Indications for SPE include contraindication to fibrinolysis, active bleeding, failed fibrinolysis or catheter-based therapy, clots in transit, a large patent foramen ovale, and moderate-to-severe right ventricular (RV) dysfunction.[6-8] Given the morbidity associated with open surgery and cardiopulmonary bypass, alternative mechanical methods have emerged.

The AngioVac® system (AngioDynamics) enables percutaneous thromboembolectomy by means of a suction cannula, balloon-actuated funnel tip, venovenous bypass circuit, inline filter, and reinfusion cannula (Fig. 1). The system can aspirate material from the venae cavae, cardiac chambers, and pulmonary arteries (PAs).[9-12] We describe our initial experience with the AngioVac system, and we discuss the outcomes from its use.

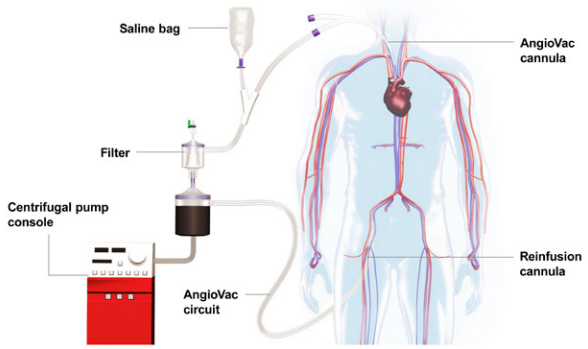

Fig. 1 *The AngioVac system consists of a suction cannula, balloon-actuated funnel tip, venovenous bypass circuit, inline filter, and reinfusion cannula. Diagram courtesy of AngioDynamics, Inc. (Latham, NY).*

Patients and Methods

Our institutional review board approved this retrospective study. We reviewed clinical use of the AngioVac system at Cedars-Sinai Medical Center from March 2013 through August 2015. We calculated data from an internally maintained institutional database, including patient characteristics, indications for the procedure, location of thrombus, hemodynamic variables, cardiac function, pharmacologic agents used in the periprocedural period, and survival to hospital discharge. Hemodynamic variables included systolic blood pressure, mean arterial pressure, and central venous pressure. Transthoracic echocardiography was used to evaluate cardiac function. We graded RV dysfunction as mild, moderate, or severe. The pharmacologic agents given patients were norepinephrine, epinephrine, vasopressin, dobutamine, fibrinolytic agents, and thrombin inhibitors.

Thromboembolectomy was performed with use of the AngioVac while patients were under general anesthesia; an anesthesiologist and perfusionist were always present. Heparin or argatroban was used for anticoagulation (targeted activated clotting time, >250 s). Under ultrasonographic guidance, the femoral or internal jugular veins were used for AngioVac aspiration and reinfusion cannula access. Aspiration venous sites were serially dilated to accommodate a 26F Gore® DrySeal Flex Introducer Sheath (W.L. Gore & Associates, Inc.), and a 22F AngioVac suction cannula was introduced over a 0.035-in Amplatz Super Stiff™ Guidewire (Boston Scientific Corporation). Reperfusion venous sites were serially dilated to accommodate an 18F AngioVac reinfusion cannula.

The venovenous bypass circuit was initiated at a flow rate of 3 L/min, and the AngioVac suction cannula was advanced to the lesion of interest. Direct contact with the thrombus was often necessary, and several passes were performed to ensure complete aspiration. Navigating the suction cannula into the pulmonary system was sometimes challenging and necessitated the use of a 7.5F, 110-cm pulmonary wedge catheter. The catheter was positioned in the left or right PA, and a guidewire was advanced. The catheter was then removed, and the AngioVac suction cannula was advanced over the guidewire. If steering was difficult through femoral access, access was gained through the jugular veins. Fluoroscopy and transesophageal echocardiography (TEE) were used for steering guidance and for evaluating thrombus retrieval. Successful thromboembolectomy was defined by complete removal of thrombus on fluoroscopy and TEE. Access sites were closed by using buttressed horizontal mattress sutures.

Statistical Analysis

Continuous variables are presented as mean ± SD or as median and interquartile range (IQR). Categorical variables are presented as number and percentage. We used the Wilcoxon signed-rank test and considered $P<0.05$ to be statistically significant. GraphPad Prism Version 7.0a (GraphPad Software) was used for all statistical analyses.

Results

During the study period, 13 patients (10 men; mean age, 56 ± 15 yr; body mass index, 28 ± 5 kg/m^2) underwent percutaneous suction thromboembolectomy with use of the AngioVac system. Six patients (46%) had undergone recent surgery (≤3 wk); 5 (38%) exhibited a clot-in-transit phenomenon; 2 (15%) had failed catheter-directed thrombolytic therapy; one (8%) had a bleeding complication, and one had a history of an intracranial neoplasm. Two patients (15%) had a cardiac arrest before the procedure.

In total, 26 thrombi were aspirated from the right PA (n=7), left PA (n=5), main PA (n=3), superior vena cava (n=4), inferior vena cava (n=3), right atrium (n=2), RV (n=1), and lower extremity (n=1). Figure 2 shows representative pathologic conditions. Eight patients had concurrent thrombi in multiple locations, and 5 had isolated clots in the superior vena cava or right PA. Ten patients (77%) survived to hospital discharge (Table I). The median follow-up time was 74 days (IQR, 23–221 d). Three patients had intraprocedural hemodynamic instability that necessitated conversion to standard cardiopulmonary bypass and median sternotomy. These cases were reviewed with use of an intention-to-treat analysis.

Preprocedurally, RV dysfunction was absent or mild-to-moderate in 5 patients (38%) and severe in 8 (62%); afterwards, 11 patients (85%) had absent or mild-to-moderate dysfunction, and only 2 (15%) had severe dysfunction (P=0.031) (Table II). The pre- and postprocedural values for central venous, mean arterial, and systolic blood pressures were not significantly different.

Ten patients needed pharmacologic support in the periprocedural period (Fig. 3 and Table III). The aver-

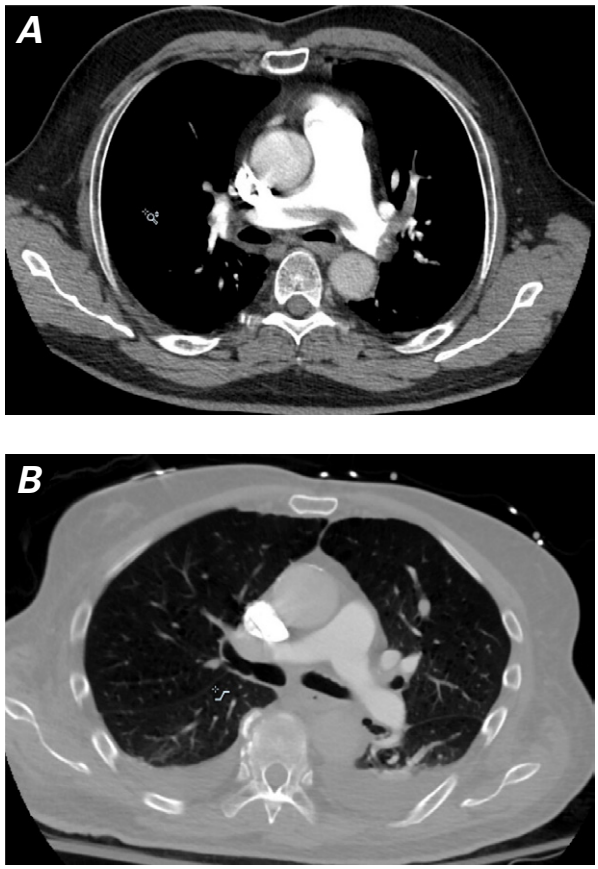

Fig. 2 *Computed tomographic angiograms show **A**) a saddle pulmonary embolism and **B**) a right pulmonary artery embolism.*

TABLE I. Baseline Characteristics of the 13 Patients and Results of Survival to Hospital Discharge

Variable	Value
Age (yr)	56 ± 15
Body mass index (kg/m^2)	28 ± 5
Male	10 (77)
Thrombus location	
Right pulmonary artery	7 (54)
Left pulmonary artery	5 (38)
Main pulmonary artery	3 (23)
Superior vena cava	4 (31)
Inferior vena cava	3 (23)
Right atrium	2 (15)
Right ventricle	1 (8)
Lower extremity	1 (8)
Discharged from hospital	10 (77)
Follow-up duration (d)	74 (23–221)

Data are presented as mean ± SD, as number and percentage (categorical variables), or as median and interquartile range (continuous variables).

TABLE II. Hemodynamic Values in the 13 Patients

Variable	Preprocedural	Postprocedural	*P* Value
SBP (mmHg)	114 (101–132)	105 (87–136)	0.985
MAP (mmHg)	78 (66–91)	77 (69–87)	0.8
CVP (mmHg)	16 (5–23)	13 (10–18)	0.719
RV dysfunction	—	—	0.031
Normal	3 (23)	4 (31)	—
Mild	1 (8)	2 (15)	—
Moderate	1 (8)	5 (38)	—
Severe	8 (62)	2 (15)	—

CVP = central venous pressure; MAP = mean arterial pressure; RV = right ventricular; SBP = systolic blood pressure

Data are presented as median and interquartile range or as number and percentage. *P* <0.05 was considered statistically significant.

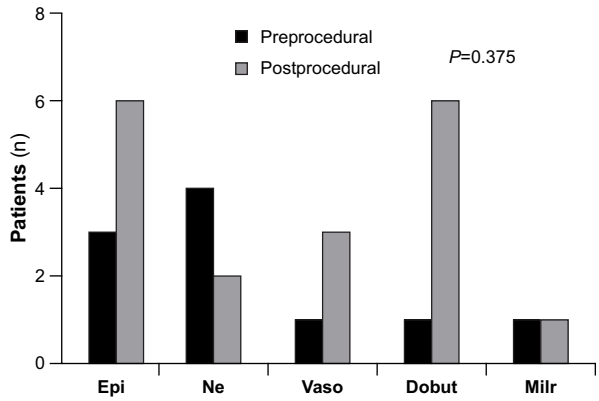

Fig. 3 *Graph shows no significant difference in how many patients needed pharmacologic support before and after the procedure.*

P *<0.05 was considered statistically significant.*

Dobut = dobutamine; Epi = epinephrine; Milr = milrinone; Ne = norepinephrine; Vaso = vasopressin

age dose for most agents decreased after the procedure (Fig. 4 and Table III). We noted statistically significant improvement in RV function in the postprocedural period (Fig. 5). Although more patients needed vasopressor and inotropic support after the procedure than before, the average dosage was lower. Three in-hospital deaths occurred, but these were unrelated to the AngioVac procedure.

Discussion

To our knowledge, these are the first reported data on periprocedural hemodynamic outcomes and cardiac function associated with use of the AngioVac system.

An important consequence of PE is elevated RV afterload and increased wall tension, which can lead to dysfunction.[13] In turn, RV dysfunction is associated with increased short-term mortality rates in patients

TABLE III. Comparison of Pharmacologic Support Before and After Treatment

	Preprocedural		Postprocedural	
Agent	**Patients** (%)	**Dose**	**Patients** (%)	**Dose**
Epinephrine (μg/min)	3 (23)	9.5 ± 9.3	6 (46)	3.5 ± 1.2
Norepinephrine (μg/min)	4 (31)	14.8 ± 16.9	2 (15)	5
Vasopressin (U/min)	1 (8)	0.04	3 (23)	0.04
Dobutamine (μg/kg/min)	1 (8)	20	6 (46)	5
Dopamine (μg/kg/min)	0	—	1 (8)	2
Milrinone (μg/kg/min)	1 (8)	0.125	1 (8)	0.125

Doses are presented as mean ± SD.

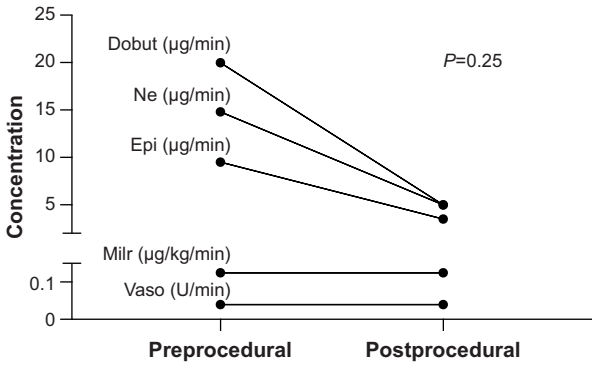

Fig. 4 *Graph shows a decrease in the average dose of most pharmacologic agents in the postprocedural period.*

P *<0.05 was considered statistically significant.*

Dobut = dobutamine; Epi = epinephrine; Milr = milrinone; Ne = norepinephrine; Vaso = vasopressin

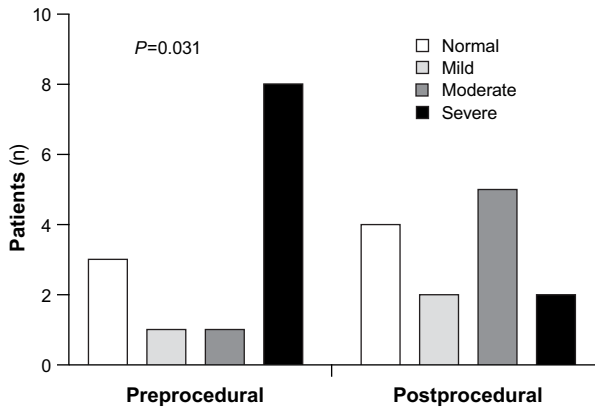

Fig. 5 *Graph shows that significantly fewer patients had severe right ventricular dysfunction postprocedurally.*

P *<0.05 was considered statistically significant.*

with PE.[14] Therefore, the improved RV function in this series, wherein most patients (62%) had thrombi in the pulmonary system, signifies an important outcome. A similar beneficial effect on RV function has been described in SPE patients.[15] In addition to RV functional improvement, PA pressures have been shown to decrease significantly after surgical treatment and catheter-directed thrombolytic therapies.[16-18] This series did not include direct measurement of PA pressure; however, given the significant decrease in RV depression, the PA pressure is hypothesized to have improved, as well.

Ten of the 13 patients (77%) survived to hospital discharge. Published outcomes on SPE vary but suggest similar in-hospital mortality rates. The Nationwide Inpatient Sample, which identified 2,709 patients who underwent SPE for acute PE (1999–2008), had an overall inpatient mortality rate of 27.2%.[19] Another cohort of 214 patients who underwent SPE at high-volume centers had a 23.7% mortality rate in patients with massive PEs.[20]

These results must be tempered by the relative difficulty in reaching the pulmonary system with the original AngioVac suction cannula. Iliocaval and right-sided heart thrombi are much more amenable to percutaneous retrieval and have higher success rates than does PE (>80% vs 12.5%).[21,22] New methods and techniques have been developed to circumvent this issue. AngioDynamics has recently created an angulated cannula for improved navigation and steering. In addition, a hybrid approach involves deploying the AngioVac directly into the RV through a subxiphoid incision or sternotomy.[23] Pending more experience and data, these newer methods represent promising innovation.

Limitations. This study is limited by its retrospective design, small sample size, and single-center nature. In addition, 3 patients needed conversion to open pulmonary embolectomy because of intraprocedural hemodynamic instability. Nevertheless, our data may aid directed research into hemodynamic outcomes associated with percutaneous therapy for PE.

Conclusion. We found that AngioVac embolectomy is associated with improvement in postprocedural RV function. Further studies are warranted to better define this technique's therapeutic role.

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