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AngioVac Aspiration Thrombectomy of Right Atrial Thrombus is Safe and Effective in Cancer Patients

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Objectives: The aim of this study was to test the hypothesis that endovascular aspiration thrombectomy of right atrial thrombus (RAT) using the AngioVac device is as safe and effective in patients with cancer as those without cancer.

Background: RAT is a uniquely challenging clinical presentation of venous thromboembolism due to its low incidence and historically high-risk of mortality due to thrombus propagation into the pulmonary arteries. There is a lack of consensus regarding management, particularly in high-risk cancer patients. Endovascular aspiration thrombectomy utilizing the AngioVac device is effective in removal of right atrial thrombus and may be a safer option for patients with cancer in whom avoidance of higher-risk intervention is preferred.

Methods: This was an institutional review board-approved retrospective single-center case control study of patients with RAT who underwent AngioVac aspiration thrombectomy between August 2013 and July 2020. Analysis of patient demographics and clinical characteristics, thrombus-related factors, and operative details was performed. Primary endpoints included survival, safety, and technical success.

Results: A total of 44 patients met inclusion criteria, 20 of whom with active malignancy. The oncology group had a significantly higher Charlson comorbidity index ($P = 0.01$). Comparative outcomes between the oncology and non-oncology group showed no difference in survival ($P = 0.8$) or technical success (OR 3, 95% CI 0.83–10.9). There were 9 complications, including 6 minor, 1 moderate, 1 severe, and 1 death.

Conclusions: AngioVac aspiration thrombectomy of RAT is as safe and effective in patients with cancer as those without cancer.

INTRODUCTION

Right atrial thrombus (RAT) is a uniquely challenging clinical presentation of venous thromboembolism (VTE) due to its low incidence and historically high-risk of mortality due to thrombus propagation into the pulmonary arteries (Fig. 1).[1] Successful treatment requires rapid intervention, however, there is a lack of consensus regarding optimal management, particularly in high-risk cancer patients.

VTE occurs in up to 15% of cancer patients throughout their disease course and is associated with increased risk of fatal pulmonary embolism, recurrent VTE, and anticoagulation-associated complications.[2]

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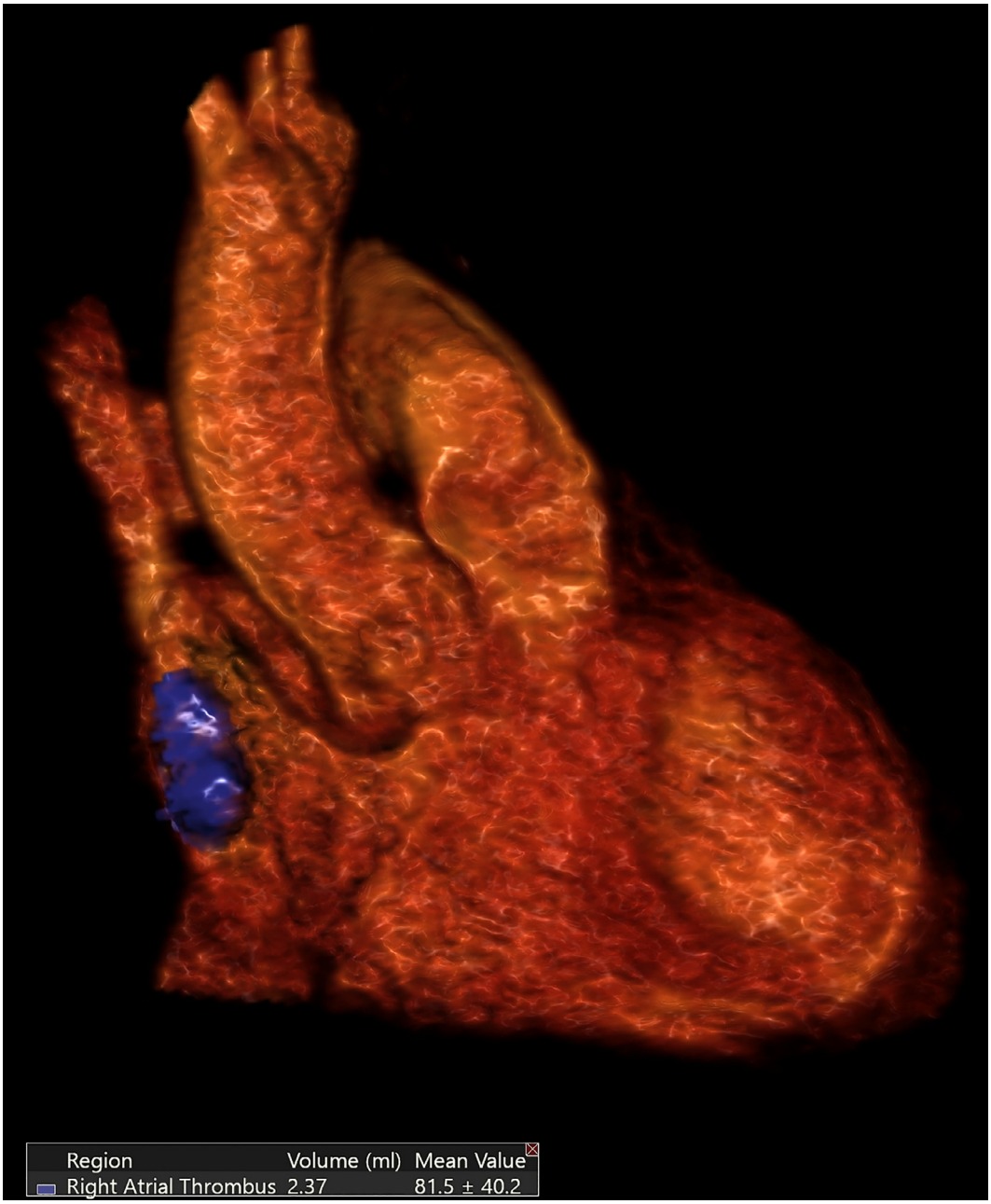

Fig. 1. Three-dimensional reconstruction of the heart in a frontal view with volume rendering from a cardiac-gated contrast-enhanced venous phase coronal magnetic resonance angiogram demonstrates thrombus (blue) within the right atrium (color version of figure is available online).

RAT treatment options include anticoagulation alone, catheter-directed and systemic thrombolysis, and open atrial embolectomy. Each of these is associated with limited efficacy and/or significant morbidity and mortality, particularly in the high-risk cancer population.

In recent years, endovascular aspiration thrombectomy utilizing the AngioVac device (AngioDynamics, Inc, Queensbury, New York) with veno-venous bypass has been shown to be an effective and safe treatment for RAT,[3,4] however, there is a lack of literature guidance on patient selection and risk stratification. The aim of this study was to test the hypothesis that endovascular thrombectomy for right atrial thrombus using the AngioVac system is as safe and effective in patients with and without cancer.

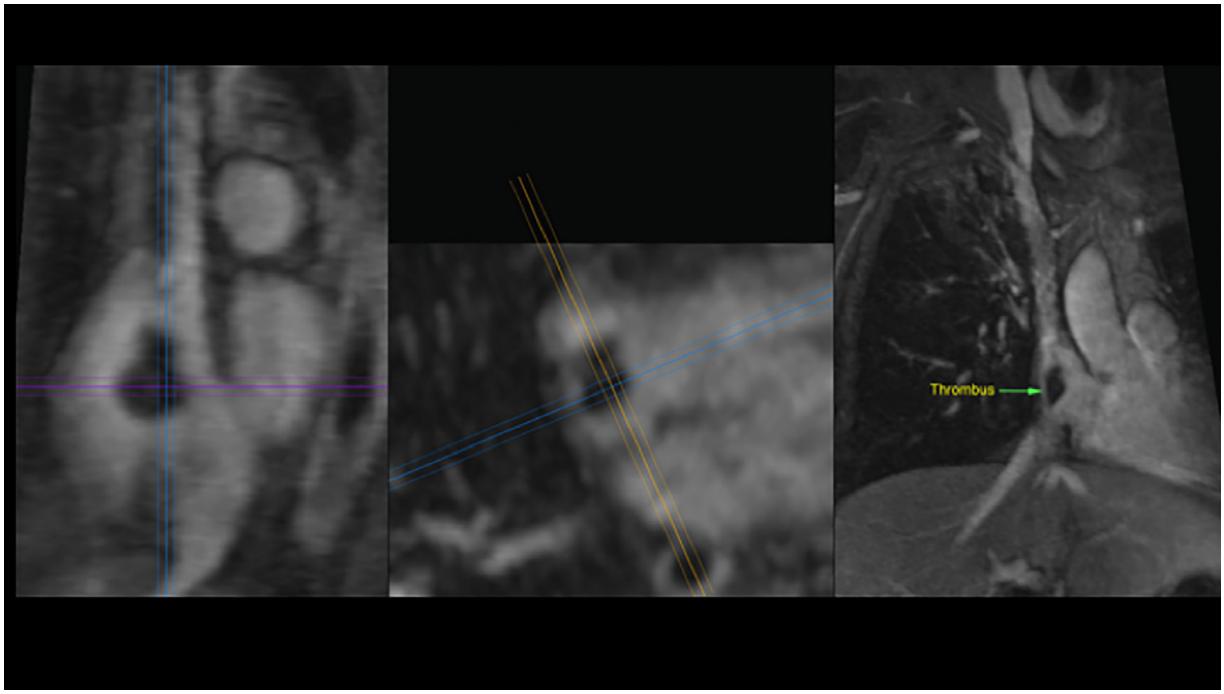

Fig. 2. Multi-planar reconstruction of a cardiac-gated contrast-enhanced venous phase coronal magnetic resonance reveals a non-enhancing filling defect within the right atrium suspicious for thrombus. There is a broad base of attachment to the right atrial wall.

MATERIALS AND METHODS

Study Population

This retrospective single-center case-control study was approved by the medical center institutional review board. Patients with right atrial thrombus who underwent AngioVac aspiration thrombectomy between August 2013 and July 2020 at a single academic medical center were included.

Active malignancy was defined as a pathologic diagnosis of cancer for which the patient was undergoing treatment at the time of intervention. Patients with primary right atrial malignancy or less than 18 years of age were excluded. All cases were performed by a single operator with a high-volume of experience (80 AngioVac cases). This study population includes 28 patients previously reported by the same authors.

Operative Details

All patients underwent contrast-enhanced computed tomography, contrast-enhanced magnetic resonance imaging, or echocardiography (transesophageal and/or transthoracic) prior to the procedure (Fig. 2). The decision to proceed with AngioVac aspiration thrombectomy was determined via multidisciplinary discussion between the interventional radiologists, cardiologists, pulmonologists, and critical care and cardiac surgeons, as indicated. All procedures were performed under general anesthesia with cardiac perfusionists, cardiac anesthesiologists, and intraoperative transesophageal echocardiography (TEE) guidance (Fig. 3).

All patients were anticoagulated with heparin (Celsus, Cincinnati, Ohio) or argatroban (GlaxoSmithKline, Philadelphia, Pennsylvania) intraoperatively with activated clotting time targets of 250–300 sec. Two percutaneous venous accesses were obtained in each patient under fluoroscopic and ultrasound guidance. The left common femoral vein was most commonly accessed (70.5%) for the reperfusion cannula and the right common femoral (47.7%) and internal jugular (47.7%) veins were most commonly accessed for the aspiration cannula.

The aspiration site was serially dilated to accommodate a 26-Fr 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) guidewire and passed into the superior or inferior vena cava. The reperfusion site was serially dilated to accommodate an 18-Fr Fem-Flex reperfusion catheter (Edwards

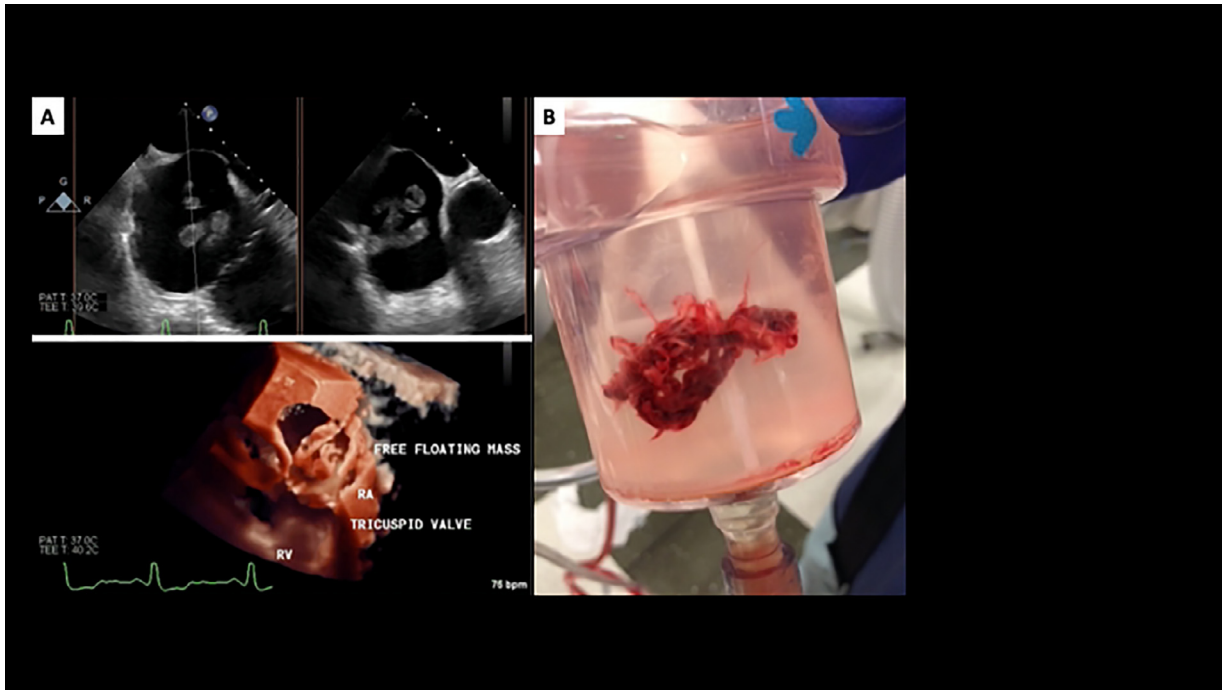

Fig. 3. Intraoperative transesophageal echocardiographic (TEE) 3-dimensional volume-rendered reconstructed images pre AngioVac thrombectomy. (A) Pre AngioVac thrombectomy TEE demonstrates a large free-floating mobile thrombus in the right atrium. (B) Thrombus gross specimen collected from the AngioVac veno-venous bypass circuit. RA, right atrium; RV, right ventricle.

Lifesciences, Irvine, California). Additional accesses were obtained at operator's discretion.

In all patients, the 22-Fr AngioVac aspiration cannula was passed over the Amplatz or Lunderquist guidewire through the inferior or superior vena cava into the site of pathology in the right atrium under fluoroscopic and transesophageal echocardiographic guidance. After inflating the balloon-actuated, funnel-shaped distal tip, the extracorporeal circuit was initiated and rate increased over several minutes to a maximum of 3.5 L/min. Careful contact was initiated with the mass under constant transesophageal guidance. Hemodynamic parameters and transesophageal echocardiography were actively monitored throughout. Hemostasis was accomplished using a combination of purses-string suture and manual compression.

Adjuvant devices and procedures were used and performed at the discretion of the operating physician and included snare manipulation ($n = 8$), forceps ($n = 1$), venoplasty ($n = 3$), catheter-directed thrombolysis ($n = 1$) and AngioVac thrombectomy of pulmonary emboli ($n = 1$). Snare manipulation typically involved either maneuvering the tip of the AngioVac cannula through traction with a snare, or more, commonly, using a snare to cut or drag the mass or thrombus into close position to the cannula. Patent foramen ovale closure was performed intraoperatively prethrombectomy in a patient with paradoxical embolic stroke secondary to right atrial thrombus. Inferior vena cava filters were placed in 2 patients.

Study Endpoints

The primary endpoints of this study were comparative survival, safety, and technical success. Survival was evaluated in technically successful cases using Kaplan-Meier estimates with censoring events including loss to follow-up and death.

Safety was investigated through analysis of procedural complications. All complications were defined per clinical practice guidelines from the Society of Interventional Radiology.[5]

Technical success was defined as >70% thrombus aspiration, in keeping with previous publications, as estimated based on pre and postintervention echocardiography.[6]

Secondary endpoints included comparative technical and thrombus-related factors. Thrombi were evaluated by an independent TEE reader pre and postoperatively for size and mobility, categorized as mobile or adherent.

Statistical Analysis

Patient demographics and clinical characteristics, thrombus-related factors, and operative details were summarized by whether the patient had a malignancy using means and standard deviations for continuous variables and frequencies and percentages for categorical variables. Fisher's exact test and the Wilcoxon rank-sum test were used to determine if there were any significant differences in any of the factors between the 2 groups. The Kaplan-Meier method was used to estimate survival and the log-rank test was used to determine if overall survival differed between the groups.

Logistic regression was used to determine whether there were differences in the odds of technical success for gender, body mass index, age, malignancy status, Eastern Cooperative Oncology Group (ECOG) status, American Society of Anesthesiologists (ASA) Score, Charlson Comorbidity Index (CCI) Score, thrombus size, thrombus mobility, catheter-associated thrombus, cardiac lead-associated thrombus and pulmonary embolism. Odds ratios and 95% confidences intervals were estimated from the models.

SAS Version 9.4 (Cary, NC USA) was used for all statistical analyses. A P value <0.05 is considered statistically significant.

RESULTS

Study Population

A total of 44 patients met inclusion criteria and were included in analysis. Of these, 20 (45.4%) had an active malignancy at the time of intervention (Table I). Primary malignancy type was highly variable with breast cancer as the most common ($n = 5$, 25%) followed by pancreatic, prostate, sarcoma, renal cell, lymphoproliferative, hepatocellular, melanoma, endometrial, and gallbladder. Comparative analysis revealed no difference in gender, age, body mass index, ECOG functional status, and ASA classification. There was no difference in preoperative vasopressor or inotropic support. The oncology group had a significantly higher CCI score due the presence of malignancy ($P = 0.01$). Moderate-to-severe kidney disease was more common in the non-oncology group ($P = 0.01$).

Thrombi were limited to the right atrium in 44% of patients with 40% demonstrating some degree of caval extension. There was no significant difference in thrombus size, thrombus mobility, catheter- or cardiac lead-association between the 2 groups (Table II). 15 (34%) patients presented with concurrent pulmonary embolism with the majority stratified as low-risk (80%) with no difference between groups.

Operative Details

There was no significant difference in fluoroscopy time, contrast, adjuvant device use or blood loss between the 2 groups (Table III).

Technical Success

Percutaneous access was achieved in all cases. There was no significant difference in technical success between the oncologic and non-oncologic groups (OR, 3; 95% CI, 0.8–10.9; Fig. 4). Technical success was not associated with thrombus size or patient clinical status (ECOG, ASA, CCI; Fig. 4). Thrombus mobility was predictive of success (OR, 16.3; 95% CI, 3.5–76.3; Fig. 1). Catheter-associated thrombus was associated with increased technical success (OR, 5.5; 95% CI, 1.4–21.7; Fig. 4). Cardiac lead-associated thrombus was not associated with technical success (OR, 0.13; 95% CI, 0.01–1.23; Fig. 4).

Survival

There was no significant difference in survival between the 2 groups ($P = 0.88$; Fig. 5).

Complications

There was a total of 9 complications. There were 6 mild (SIR Class I) complications including: 4 access site hematomas managed conservatively, an episode of asymptomatic atrial tachycardia captured on telemetry overnight and managed conservatively and 1 occurrence of intraoperative thrombus propagation into the pulmonary artery successfully managed with intraop catheter maceration.

There was 1 moderate (SIR Class II) complication of acute occlusive deep venous thrombosis in the right common femoral vein access site on postoperative day 1. Subsequently, the patient underwent mechanical thrombectomy and balloon angioplasty with an unremarkable remaining postoperative course.

There was 1 severe (SIR Class III) complication of intraoperative right atrial perforation. The patient developed a pericardial effusion with tamponade physiology which was immediately seen on transesophageal echocardiography and managed with pericardial drain placement. The postoperative course was uncomplicated. Drain output continued to decrease and the drain was

Table I. Descriptive summary of patient factors - by Oncology Group

Variable statistic or category	Overall	Malignancy	No malignancy	*P* value
Gender				.
Male	19 (43.2%)	10 (50.0%)	9 (37.5%)	0.5430
Female	25 (56.8%)	10 (50.0%)	15 (62.5%)	.
Body Mass Index				.
N	44	20	24	0.8689
Mean (SD)	25.570 (6.0121)	25.815 (5.5065)	25.366 (6.5141)	.
Median	25.450	25.750	24.600	.
Min, Max	13.70, 38.90	13.70, 35.80	13.80, 38.90	.
Age				.
n	44	20	24	0.0643
Mean (SD)	47.933 (18.2541)	53.945 (17.0310)	42.923 (18.0479)	.
Median	48.366	56.493	41.774	.
Min, Max	14.27, 86.84	14.27, 86.84	15.18, 74.85	.
ECOG Status				.
0	8 (18.2%)	5 (25.0%)	3 (12.5%)	0.5606
1	16 (36.4%)	8 (40.0%)	8 (33.3%)	.
2	5 (11.4%)	1 (5.0%)	4 (16.7%)	.
3	8 (18.2%)	4 (20.0%)	4 (16.7%)	.
4	7 (15.9%)	2 (10.0%)	5 (20.8%)	.
ASA Classification				.
N	38	15	23	0.7687
Mean (SD)	3.4 (0.55)	3.4 (0.51)	3.5 (0.59)	.
Median	3.0	3.0	3.0	.
Min, Max	3, 5	3, 4	3, 5	.
Preoperative Vasopressor or Inotropic Support				.
No	27 (61.4%)	9 (45.0%)	18 (75.0%)	0.0633
Yes	17 (38.6%)	11 (55.0%)	6 (25.0%)	.
CCI Index				.
N	44	20	24	0.0184
Mean (SD)	5.1 (3.54)	6.5 (3.80)	3.9 (2.89)	.
Median	5.0	7.0	4.0	.
Min, Max	0, 15	0, 15	0, 10	.
CCI Age				.
<50 years (0)	24 (54.5%)	8 (40.0%)	16 (66.7%)	0.3621
50–59 years (+1)	7 (15.9%)	4 (20.0%)	3 (12.5%)	.
60–69 years (+2)	6 (13.6%)	4 (20.0%)	2 (8.3%)	.
70–79 years (+3)	6 (13.6%)	3 (15.0%)	3 (12.5%)	.
≥80 years (+4)	1 (2.3%)	1 (5.0%)	0 (0.0%)	.
CCI Myocardial infarction				.
No	39 (88.6%)	19 (95.0%)	20 (83.3%)	0.3562
Yes (+1)	5 (11.4%)	1 (5.0%)	4 (16.7%)	.
CCI Congestive Heart Failure				.
No	35 (79.5%)	17 (85.0%)	18 (75.0%)	0.4771
Yes (+1)	9 (20.5%)	3 (15.0%)	6 (25.0%)	.
CCI Peripheral Vascular Disease				.
No	43 (97.7%)	20 (100.0%)	23 (95.8%)	1.0000
Yes (+1)	1 (2.3%)	0 (0.0%)	1 (4.2%)	.

(*continued on next page*)

Table I (*continued*)

Variable statistic or category	Overall	Malignancy	No malignancy	*P* value
CCI Cerebrovascular Accident				.
No	39 (88.6%)	18 (90.0%)	21 (87.5%)	1.0000
Yes (+1)	5 (11.4%)	2 (10.0%)	3 (12.5%)	.
CCI Dementia				.
No	44 (100.0%)	20 (100.0%)	24 (100.0%)	.
CCI Chronic Obstructive Pulmonary Disease)				.
No	34 (77.3%)	17 (85.0%)	17 (70.8%)	0.3056
Yes (+1)	10 (22.7%)	3 (15.0%)	7 (29.2%)	.
CCI Connective Tissue Disease)				.
No	41 (93.2%)	20 (100.0%)	21 (87.5%)	0.2389
Yes (+1)	3 (6.8%)	0 (0.0%)	3 (12.5%)	.
CCI Peptic Ulcer Disease				.
No	44 (100.0%)	20 (100.0%)	24 (100.0%)	.
CCI Liver Disease				.
None	37 (84.1%)	18 (90.0%)	19 (79.2%)	0.8194
Mild, chronic hepatitis, or cirrhosis without portal hypertension (+1)	1 (2.3%)	0 (0.0%)	1 (4.2%)	.
Moderate/Severe, cirrhosis with portal hypertension, variceal bleeding (+3)	6 (13.6%)	2 (10.0%)	4 (16.7%)	.
CCI Diabetes Mellitus				.
None or diet-controlled (+0)	32 (72.7%)	15 (75.0%)	17 (70.8%)	0.5902
Uncomplicated (+1)	3 (6.8%)	2 (10.0%)	1 (4.2%)	.
End-organ damage (+1)	9 (20.5%)	3 (15.0%)	6 (25.0%)	.
CCI Hemiplegia				.
No	42 (95.5%)	20 (100.0%)	22 (91.7%)	0.4926
Yes (+2)	2 (4.5%)	0 (0.0%)	2 (8.3%)	.
CCI Moderate-to-Severe Kidney Disease				.
No	30 (68.2%)	18 (90.0%)	12 (50.0%)	0.0082
Yes (+2)	14 (31.8%)	2 (10.0%)	12 (50.0%)	.
CCI Solid Tumor				.
None	25 (56.8%)	1 (5.0%)	24 (100.0%)	<0.0001
Localized (+2)	9 (20.5%)	9 (45.0%)	0 (0.0%)	.
Metastatic (+6)	10 (22.7%)	10 (50.0%)	0 (0.0%)	.
CCI Leukemia				.
No	43 (97.7%)	19 (95.0%)	24 (100.0%)	0.4545
Yes	1 (2.3%)	1 (5.0%)	0 (0.0%)	.
CCI Lymphoma				.
No	44 (100.0%)	20 (100.0%)	24 (100.0%)	.
CCI Aids				.
No	44 (100.0%)	20 (100.0%)	24 (100.0%)	.

Note: *P* values obtained through Fisher's test for categorical variables and Wilcoxon Rank-Sum for continuous variables.

Table II. Thrombus-related factors - by Oncology Group

Variable statistic or category	Overall	Malignancy	No malignancy	*P* value
Thrombus Size				.
n	41	20	21	0.2147
Mean (SD)	3.784 (3.0160)	3.893 (1.8182)	3.681 (3.8767)	.
Median	2.900	3.250	2.800	.
Min, Max	0.60, 20.00	1.70, 7.50	0.60, 20.00	.
Thrombus Mobility				.
Mobile	24 (54.5%)	14 (70.0%)	10 (41.7%)	0.0755
Adherent	20 (45.5%)	6 (30.0%)	14 (58.3%)	.
Catheter-Associated Thrombus				.
No	23 (52.3%)	11 (55.0%)	12 (50.0%)	0.7709
Yes	21 (47.7%)	9 (45.0%)	12 (50.0%)	.
Cardiac Lead-Associated Thrombus				.
No	39 (88.6%)	20 (100.0%)	19 (79.2%)	0.0534
Yes	5 (11.4%)	0 (0.0%)	5 (20.8%)	.
Pulmonary Embolism				.
No	29 (65.9%)	15 (75.0%)	14 (58.3%)	0.3420
Yes	15 (34.1%)	5 (25.0%)	10 (41.7%)	.
Pulmonary Embolism Risk Stratification				.
None	29 (65.9%)	15 (75.0%)	14 (58.3%)	0.3271
Low-Risk	12 (27.3%)	5 (25.0%)	7 (29.2%)	.
Sub-Massive	3 (6.8%)	0 (0.0%)	3 (12.5%)	.

Note: *P* values obtained through Fisher's test for categorical variables and Wilcoxon Rank-Sum for continuous variables.

removed on postoperative day 2 and the patient was discharged home on postoperative day 4.

There was 1 death (SIR Class V). The patient was an 87-year-old male with prostate cancer and hepatocellular carcinoma and poor functional status (ECOG 3) who underwent AngioVac thrombectomy with removal of approximately 25% of the thrombus complicated by distal embolization of the remaining thrombus into the pulmonary arteries causing immediate hemodynamic collapse and cardiac arrest. A stable perfusing rhythm was unable to be attained despite resuscitation efforts and multiple attempts at thrombus removal, including mechanical thrombectomy, catheter-directed thrombolysis, and angioplasty.

DISCUSSION

We report on the safety and efficacy of endovascular aspiration thrombectomy of right atrial thrombus (RAT) using the AngioVac device in 44 patients with and without cancer. Despite the increased comorbidities associated with active cancer, there was no difference in safety, technical success, or survival compared to patients without cancer. These data indicate that in cancer patients who develop the challenging and rare diagnosis of RAT, an endovascular approach utilizing the AngioVac aspiration thrombectomy device is a safe and effective option.

RAT is a life-threatening condition with a high rate of mortality due to the risk of thrombus propagation.[7,8] Patients with cancer are at increased risk for fatal pulmonary embolism, recurrent VTE, anticoagulation-associated complications, and perioperative morbidity and mortality.[2]

RAT treatment options include anticoagulation alone, catheter-directed and systemic thrombolysis, and open atrial embolectomy. There is no consensus in the literature regarding optimal management as the existing options are associated with limited efficacy and/or significant complications.

Anticoagulation alone and systemic thrombolysis represent the least invasive treatment options but are associated with significant complications. Anticoagulation alone does not promote thrombus dissolution and is associated with 37% mortality when performed without another intervention.[1] Systemic thrombolysis has the benefit of potentially dissolving thrombus in multiple locations, however carries an increased risk of hemorrhage compared to catheter-directed thrombolysis and the risk of recurrent embolism following partial thrombus dissolution.[9,10] Catheter-directed thrombolysis is contraindicated in patients at increased risk for hemorrhage (i.e., active malignancy) and may be poorly tolerated in hemodynamically unstable

Table III. Operative details - by Oncology Group

Variable statistic or category	Overall	Malignancy	No malignancy	*P* value
Fluoroscopy Time				.
n	43	20	23	0.6611
Mean (SD)	14.47 (12.222)	12.76 (8.518)	15.96 (14.750)	.
Median	11.50	11.70	11.30	.
Min, Max	3.2, 75.8	3.2, 31.8	3.2, 75.8	.
Contrast				.
n	42	19	23	0.2841
Mean (SD)	22.4 (30.57)	30.5 (41.76)	15.7 (14.48)	.
Median	20.0	20.0	20.0	.
Min, Max	0, 180	0, 180	0, 60	.
Blood Loss				.
n	34	16	18	0.9704
Mean (SD)	79.4 (111.48)	72.2 (82.22)	85.8 (134.42)	.
Median	25.0	37.5	25.0	.
Min, Max	20, 600	25, 355	20, 600	.
Aspiration Cannula				.
Right Common Femoral Vein	21 (47.7%)	11 (55.0%)	10 (41.7%)	0.9294
Right Internal Jugular Vein	21 (47.7%)	9 (45.0%)	12 (50.0%)	.
Left Common Femoral Vein	1 (2.3%)	0 (0.0%)	1 (4.2%)	.
Right Atrium	1 (2.3%)	0 (0.0%)	1 (4.2%)	.
Reperfusion Cannula				.
Right Common Femoral Vein	11 (25.0%)	2 (10.0%)	9 (37.5%)	0.0936
Right Internal Jugular Vein	2 (4.5%)	1 (5.0%)	1 (4.2%)	.
Left Common Femoral Vein	31 (70.5%)	17 (85.0%)	14 (58.3%)	.
Adjuvant Device/Procedure				.
No	29 (65.9%)	12 (60.0%)	17 (70.8%)	0.5316
Yes	15 (34.1%)	8 (40.0%)	7 (29.2%)	.
Snare Manipulation				.
No	36 (81.8%)	17 (85.0%)	19 (79.2%)	0.7095
Yes	8 (18.2%)	3 (15.0%)	5 (20.8%)	.
Endovascular Forceps				.
No	43 (97.7%)	19 (95.0%)	24 (100.0%)	0.4545
Yes	1 (2.3%)	1 (5.0%)	0 (0.0%)	.
Other				.
Cerebral protection device	1 (16.7%)	1 (25.0%)	0 (0.0%)	1.0000
Inferior Vena Cava Angioplasty	1 (16.7%)	1 (25.0%)	0 (0.0%)	.
Pulmonary Embolism Catheter-Directed Thrombolysis	2 (33.3%)	1 (25.0%)	1 (50.0%)	.
Patent Foramen Ovale Closure	1 (16.7%)	1 (25.0%)	0 (0.0%)	.
Superior Vena Cava Angioplasty	1 (16.7%)	0 (0.0%)	1 (50.0%)	.
Inferior Vena Cava Filter Placement				.
No	42 (95.5%)	19 (95.0%)	23 (95.8%)	1.0000
Yes	2 (4.5%)	1 (5.0%)	1 (4.2%)	.

Note: *P* values obtained through Fisher's test for categorical variables and Wilcoxon Rank-Sum for continuous variables.

patients requiring rapid treatment.[11,12] Open pulmonary embolectomy in the setting of RAT propagation into the pulmonary arteries is the most invasive option requiring midline sternotomy, cardiopulmonary bypass with or without cross clamping of the aorta and is associated with as much as 7% intraoperative mortality[13] and 2% mortality at 1 year.[13]

In recent years, an endovascular approach using the AngioVac device has shown to be a safe and effective treatment option for removal of right atrial thrombi.[3] However, there is a lack of literature guidance on patient selection and risk stratification, particularly in the high-risk cancer population.

In this single-center, retrospective case-control study of 44 patients with RAT, 20 of whom had active malignancy at the time of intervention, there was no difference in survival, technical success, or safety between groups.

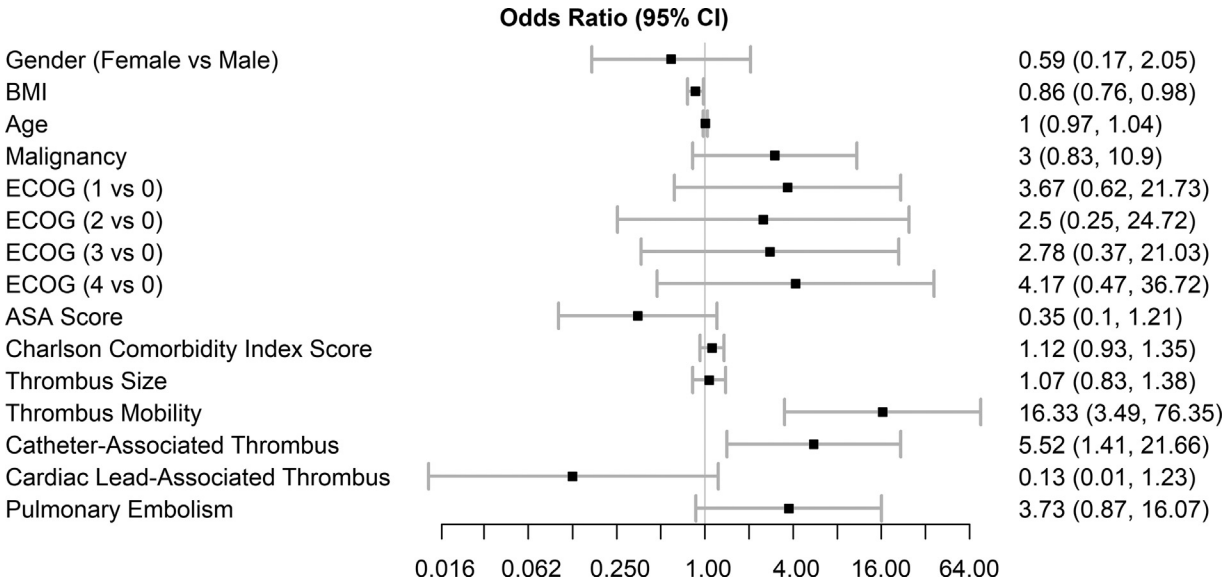

Fig. 4. Forest plots showing odds ratios of technically successful right atrial thrombus removal based on various factors. CI, confidence interval; BMI, body mass index.

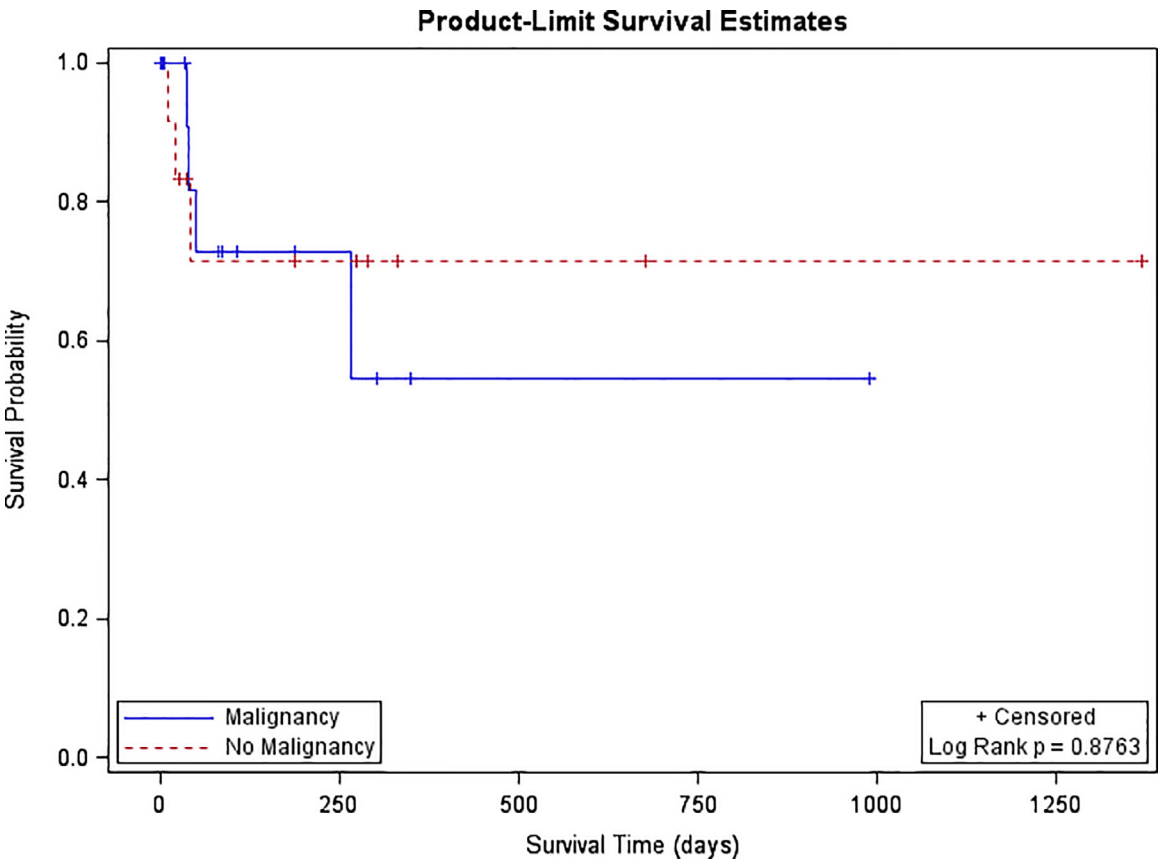

Fig. 5. Kaplan-Meier survival estimates in patients with and without active malignancy at time of intervention.

Comparative analysis of baseline characteristics showed a difference in CCI scores, primarily driven by the scoring system which heavily weights the presence of malignancy (Table I). Within the non-oncology group, there was a significantly higher rate of moderate-to-severe kidney disease.

Fifteen (34%) patients presented with concurrent pulmonary embolism. This is critical because the natural history of RAT is propagation into the pulmonary vasculature resulting in PE and patients with cancer are at significantly increased risk of fatal PE. Submassive and massive pulmonary embolism require urgent recognition and treatment. The classical mainstays of treatment are systemic and catheter-directed thrombolysis or open pulmonary embolectomy. There is a paucity of literature regarding AngioVac thrombectomy for pulmonary embolism, however, early reports describe technical challenges navigating the semi-rigid aspiration cannula through the tortuous right ventricular access tract into the pulmonary vasculature and limited clinical benefit.[14] Management of RAT prior to further embolization may be critical to successful patient outcomes.

Intraoperative fluoroscopy time, contrast use, and blood loss were not statistically different between the groups. Only 1 patient required a transfusion of packed red blood cells for postoperative anemia, which was due to a groin access site hematoma. The advantage of the ability to use minimal contrast or none at all is that patients with acute kidney injury or chronic kidney disease are candidates for this procedure. A large series of open pulmonary embolectomy cases for PE reported 6% rate for postoperative acute kidney injury.[13] No patients developed acute kidney injury in this study.

Percutaneous access was achieved in all cases and technical success, defined as >70% mass resection, was achieved in 61% of patients.[6] There was no statistically significant difference in technical success between the oncology and non-oncology groups. Size was not a statistically significant predictor of success. However, mass mobility was a significant predictor with technical success associated with mobile masses, consistent with previous reports.[3,15]

There was no difference in survival between groups which serves to demonstrate that this procedure is as safe in cancer patients.

There was a total of 9 complications, including 6 mild (SIR Class I), 1 moderate (SIR Class II), 1 severe (SIR Class III), and 1 death (SIR Class V). There were 4 access site hematomas which were managed conservatively. Access site hematomas are a common complication following endovascular procedures utilizing large-bore cannulae.[16]

A Class 3 complication involved perforation of the right atrium during successful AngioVac thrombectomy which was successfully treated with a short-term pericardial drain. The AngioVac aspiration cannula is designed to prevent collapse through use of coil-reinforcements. These coils successfully prevent collapse of the cannula however they impart increased rigidity to the system.[14] The incidence of cardiac perforation is not well-described in the literature, however the risk of perforation is worrisome and is likely increased in the case of adherent or chronic clot.[4]

A feared complication of any venous thrombectomy procedure is thrombus propagation which can result in pulmonary embolism. There were 2 cases of intraoperative distal thrombus embolization. One was immediately recognized on intraop TEE and successfully managed with catheter maceration and no postoperative sequelae (SIR Class I). A second case resulted in intraoperative death (SIR Class V) following the distal embolization of the remaining thrombus into the pulmonary arteries causing immediate hemodynamic collapse and cardiac arrest. Prior to distal embolization, approximately 25% of the initial thrombus had been removed and the procedure was terminated as the thrombus was deemed refractory to aspiration. It was after the removal of all cannulae and initiation of emergence from anesthesia that the patient developed cardiopulmonary arrest. TEE demonstrated thrombus within the proximal pulmonary artery. At this point, resuscitation efforts were initiated and further attempts for salvage pulmonary thrombectomy began, including catheter-directed thrombolysis and thrombectomy, angioplasty, and utilization of additional mechanical thrombectomy devices without success.

Study Limitations

This study has limitations inherent to retrospective single-center case-control studies. Additionally, this study included a relatively small cohort limiting comparative statistics. There was an element of subjective interpretation of technical success based on pre and postoperative echocardiography image interpretation. The cases included in this series were performed by a single operator with high-volume experience and extrapolation to other centers with varying expertise and resources may not yield similar results. Additionally, there is an unknown incidence of “incidental” right atrial thrombus identification in oncology patients undergoing

imaging for other reasons and a lack of data on risk stratification in this scenario. It is possible this group comprises an intrinsically low risk PE group, although this is unlikely. While this study does demonstrate no difference in survival, this result does not reflect long-term survival as patients with malignancy have a decreased comparative life expectancy.

CONCLUSIONS

We report on the safety and efficacy of endovascular aspiration thrombectomy of right atrial thrombus using the AngioVac device in 44 patients with and without cancer. High rates of technical success were achieved in both groups with no difference in safety. These data indicate that in cancer patients who develop the challenging and rare diagnosis of right atrial thrombus, an endovascular approach utilizing the AngioVac aspiration thrombectomy system is a safe and effective option. As utilization rates of aspiration thrombectomy using the AngioVac device increase, further studies should be aimed at aiding in risk stratification and patient selection.

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