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Original Research

A Retrospective Analysis of AngioVac Outcomes at a Tertiary Care Center

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ABSTRACT

Background: The AngioVac system is a vacuum aspiration device approved for removal of right-sided cardiac thrombi. It has also been used for management of right-sided endocarditis in selected cases. Retrospective case series have reported high success rate and acceptable 30-day mortality, but there is limited data regarding outcomes beyond the immediate postoperative period. The purpose of this study is to describe our institution's experience with the AngioVac system for thrombus, vegetation, and tumor removal with a significant improvement over previously reported 1-year survival rates.

Methods: A retrospective review of AngioVac cases performed at our tertiary care center from 2016-2022 was done. From 2016-2022, 23 patients were identified, and their outcomes are described.

Results: Our review demonstrates 81.8% procedural success, 100% procedure survival, 90.9% survival to discharge, and 81.8% 30-day survival rates. One-year survival rate was 72.7%. Complications including an 18.2% rate of new vasopressor use, 54.5% rate of transfusion requirement, and 4.5% rate of acute renal failure requiring hemodialysis were identified. Intraprocedural embolization occurred in 1 case requiring venoarterial extracorporeal membrane oxygenation support and thrombectomy. One case was converted to open surgical intervention.

Conclusions: Our review further supports the safety and efficacy of minimally invasive vacuum-assisted aspiration systems beyond the immediate post-operative period in intracardiac thrombus, tumor, and right-sided infective endocarditis. Our institution's experience emphasizes a team-based approach including interventional cardiology and cardiothoracic surgery with a standardized imaging approach with transesophageal echocardiogram. Future guidelines are needed to include an algorithmic approach to intracardiac masses.

Introduction

Intracardiac masses often present a difficult management challenge to the clinician. Depending on size and mobility, these masses are often associated with high mortality and rate of embolization if left untreated.[1,2] Right-sided lesions including thrombi, vegetations, and tumors are treated with medical management, thrombolysis, or embolectomy. Currently, there is a lack of consensus and guidelines regarding the best management approach in patients with right-sided intracardiac masses. In 2009, the United States Food and Drug Administration approved the AngioVac aspiration system (AngioVac Cannula and Circuit, AngioDynamics) for removal of intravascular material such as thrombi, tumors, foreign bodies, and vegetations.[3] There have been several retrospective studies and 1 prospective observation study that demonstrate the effectiveness of this minimally invasive aspiration-based technique.[4] In this retrospective analysis, we review 6 years of patient outcomes data to demonstrate longer-term safety of catheter-based suction embolectomy using the AngioVac system in a tertiary care level health system.

Material and methods

Study population

We reviewed all cases of intracardiac masses in which management included the decision to use AngioVac-assisted suction embolectomy. This included 23 patients from 2016-2022 at a tertiary care center at Wellstar Medical College of Georgia Health. The treatment and management decisions resulted from multidisciplinary collaboration between general and interventional cardiology, cardiothoracic surgery, and intensive care physicians. Retrospective data including

Abbreviations: CT, computed tomography; ECMO, extracorporeal membrane oxygenation; IVC, inferior vena cava; RV, right ventricle; SVC, superior vena cava; TEE, transesophageal echocardiogram; TV, tricuspid valve.

Keywords: AngioVac; endocarditis; intracardiac mass; thrombus; vegetation.

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demographics, past medical history, preoperative imaging and laboratory data, intraprocedural variables, and postoperative outcomes were recorded. Of the 23 patients identified, 1 patient was excluded due to suspected embolization or resolution prior to attempted aspiration based on the absence of the previously identified intracardiac mass on preprocedural transesophageal echocardiogram (TEE).

AngioVac system

The minimally invasive aspiration system consists of a disposable venovenous extracorporeal circulatory support designed to remove intravascular material including thrombi, emboli, vegetations, and some masses. The system requires 2 venous access sites. The system then uses a centrifugal pump to aspirate blood containing intravascular material through a 22F inflow cannula with a self-expanding tip. The blood products containing intravascular material pass through a filter to remove that material and the filtered blood is circulated through the centrifugal pump, returning to the body via a venous reinfusion cannula aiming to minimize blood loss.[5]

TEE

Preoperative TEE was performed in the operating room immediately before the procedure started to confirm the presence and location of the mass. Intraoperative transesophageal echocardiography was utilized to guide aspiration and evaluate results in 100% of cases. Mass removal was qualitatively assessed by the intraoperative echocardiographer which included cardiac anesthesiology in collaboration with interventional cardiology. Procedural success was categorized into 5 categories: not successful, meaning <24.9% of mass removed; minimally successful, meaning 25% to 49.9% of mass removed; somewhat successful, meaning 50% to 74.9% of mass removed; mostly successful, meaning 75% to 99% of mass removed; and completely successful, meaning >99% of mass removed.

Fluoroscopy

Fluoroscopy guidance in a hybrid operating room was used in 100% of cases for both wire and catheter manipulation.

Data collection

We reviewed retrospective data from each of the 23 patients from 2016 to 2022 including demographics, medical history, treatment, procedural indication, TEE imaging data, preoperative laboratory data, intraoperative procedural variables, and postoperative and long-term outcomes. Survival was determined at discharge, 30 days, and 1 year postprocedure. To assess the surgical risk in our population, a EuroScore II risk score was calculated retrospectively based on preoperative data.[6,7]

Statistical analysis

Quantitative variables were summarized by frequency counts, percentages, means, and standard deviations. Categorical variables have been summarized with the aid of using frequencies and percentages. Unless explicitly stated, percentages utilized a denominator representing the number of patients contributing to the end point.

Results

Preoperative characteristics

Demographic and preoperative clinical variables are listed in Tables 1 and 2, respectively. Of the 23 patients identified, 22 patients underwent AngioVac-assisted aspiration thrombectomy (11 male and 11 female). The average age was 47.4 years. Indications included intracardiac thrombus, endocarditis, or tumor. The locations of the intracardiac masses included inferior vena cava, superior vena cava, right atrium, and tricuspid valve (TV). Suspected infective endocarditis was the most common indication in 13 of the cases (59.1%), and 7 of those cases had evidence of septic emboli on preoperative chest imaging. Shock requiring vasopressor support was clinically present in 11 of the cases (50%). One patient received thrombolysis prior to intervention. The mean preoperative hemoglobin was 9.36 g/dL, and the mean creatinine was 1.12 g/dL, excluding patients with end-stage renal disease requiring hemodialysis at baseline. The mean left ventricular ejection fraction was 56.89%. The mean surgical risk was retrospectively calculated as 4.10% using the EuroScore II calculator.[6,7]

Table 1. Demographics and medical history.

	N = 22
Age, y	47.4 ± 16.1
Body mass index, kg/m^2	31.0 ± 9.3
Female sex	11 (50)
Medical history[a]	
End-stage renal disease	8 (36.4)
Coronary artery disease	3 (13.6)
Valvular disease	3 (13.6)
Venous thromboembolism	4 (18.2)
Heart failure	2 (9.1)
Diabetes	3 (13.6)
Chronic obstructive pulmonary disease	3 (13.6)
Malignancy	3 (13.6)
Iatrogenic immunosuppression	2 (9.1)
Prior cardiac devices	3 (13.6)
EuroScore II	4.10 ± 3.25

Values are mean ± SD or n (%).
[a] Documented on admission history and physical examination.

Intraoperative variables

The intraoperative variables are listed in Table 3. One hundred percent of the procedures were performed by a team consisting of cardiothoracic surgeons and interventional cardiologists. The AngioVac catheter used for aspiration was most frequently placed in the right

Table 2. Preoperative clinical variables.

	N = 22
Hemoglobin, g/dL	9.36 ± 1.92
Creatinine, mg/dL[a]	1.12 ± 0.71
Left ventricular ejection fraction, %	56.89 ± 9.79
Presence of septic emboli	7 (31.8)
Mechanical ventilation	7 (31.8)
Vasopressor requirement	11 (50)
Thrombolysis	1 (4.5)
Procedure indication	
Suspected tumor	2 (9.1)
Suspected thrombus	7 (31.8)
Suspected endocarditis	13 (59.1)
Mass characteristics	
Mobile	15 (68.2)
Location	
Inferior vena cava	1 (4.5)
Superior vena cava	3 (13.6)
Right atrium	11 (50)
Tricuspid valve	7 (31.8)
Device associated	
Pacemaker lead	2 (9.1)
Indwelling venous catheter	3 (13.1)

Values are mean ± SD or n (%).
[a] Excluding patients with baseline end-stage renal disease requiring hemodialysis.

Table 3. Intraoperative variables.

	N = 22
Procedural extracorporeal bypass time, min	38.87 ± 32.92
Estimated blood loss, mL	173.81 ± 160.95
AngioVac catheter insertion site	
Right internal jugular vein	13 (59.1)
Left internal jugular vein	0 (0)
Right femoral vein	9 (40.9)
Left femoral vein	0 (0)
Reinfusion cannula insertion site	
Right internal jugular vein	1 (4.5)
Left internal jugular vein	1 (4.5)
Right femoral vein	7 (31.8)
Left femoral vein	13 (59.1)

Values are mean ± SD or n (%).

internal jugular vein access in 59.1% of cases, with the right common femoral vein access site used in the remaining 40.9% of cases. The reinfusion site most frequently selected was the left common femoral vein (59.1% of cases), with the right femoral vein used as the second most common site (31.8% of cases). The mean time on extracorporeal bypass during the procedure was 38.87 minutes, with a mean estimated blood loss of 173.81 mL.

Postoperative variables

Table 4 illustrates the postoperative variables. Procedure success was documented as mostly successful or completely successful in 18 (81.8%) cases, and minimally successful or not successful in 4 (18.2%) cases. Procedure survival was 100%. Survival to discharge was observed in 20 cases (90.9%). Thirty-day survival, as evidenced by clinical documentation, was observed in 18 cases (81.8%). One-year survival, as evidenced by clinical documentation, was observed in 16 cases (72.7%). Two patients were confirmed deceased prior to discharge. Two patients were lost to follow-up prior to 30 days and survival is unknown. One patient was noted to have embolization of the intracardiac mass during the attempted procedure, leading to destabilization, obstructive shock, and cardiac arrest requiring mechanical circulatory support with venoarterial extracorporeal membrane oxygenation (ECMO) and mechanical thrombectomy. There was 1 case that was converted to open surgical valve replacement due to inadequate debulking with AngioVac and persistent TV regurgitation observed on preoperative TEE.

Table 4. Postoperative variables.

	N = 22
Procedure survival	22 (100)
Survival to discharge	20 (90.9)
30-d survival	18 (81.8)
1-yr survival	16 (72.7)
Conversion to open	1 (4.5)
Procedure success	
Not successful	2 (9.1)
Minimally successful	2 (9.1)
Somewhat successful	0 (0)
Mostly successful	12 (54.5)
Completely successful	6 (27.3)
Complications	
Access site hematoma	2 (9.1)
Transfusion	12 (54.5)
Embolization	1 (4.5)
New vasopressor requirement	4 (18.2)
Acute renal failure requiring hemodialysis	1 (4.5)
ECMO requirement	1 (4.5)
Cardiac arrest	1 (4.5)
Pathologic diagnosis	
Thrombus	12 (54.5)
Infective thrombus	3 (13.6)
Vegetation	6 (27.3)
Tumor	1 (4.5)
Time from diagnosis to retrieval, d	12.59 ± 39.81
Length of stay, d	15.86 ± 15.54
Hemoglobin, g/dL	9.05 ± 1.63
Creatinine, mg/dL[a]	1.02 ± 0.68

Values are mean ± SD or n (%).

[a] Excluding end-stage renal disease patients requiring hemodialysis.

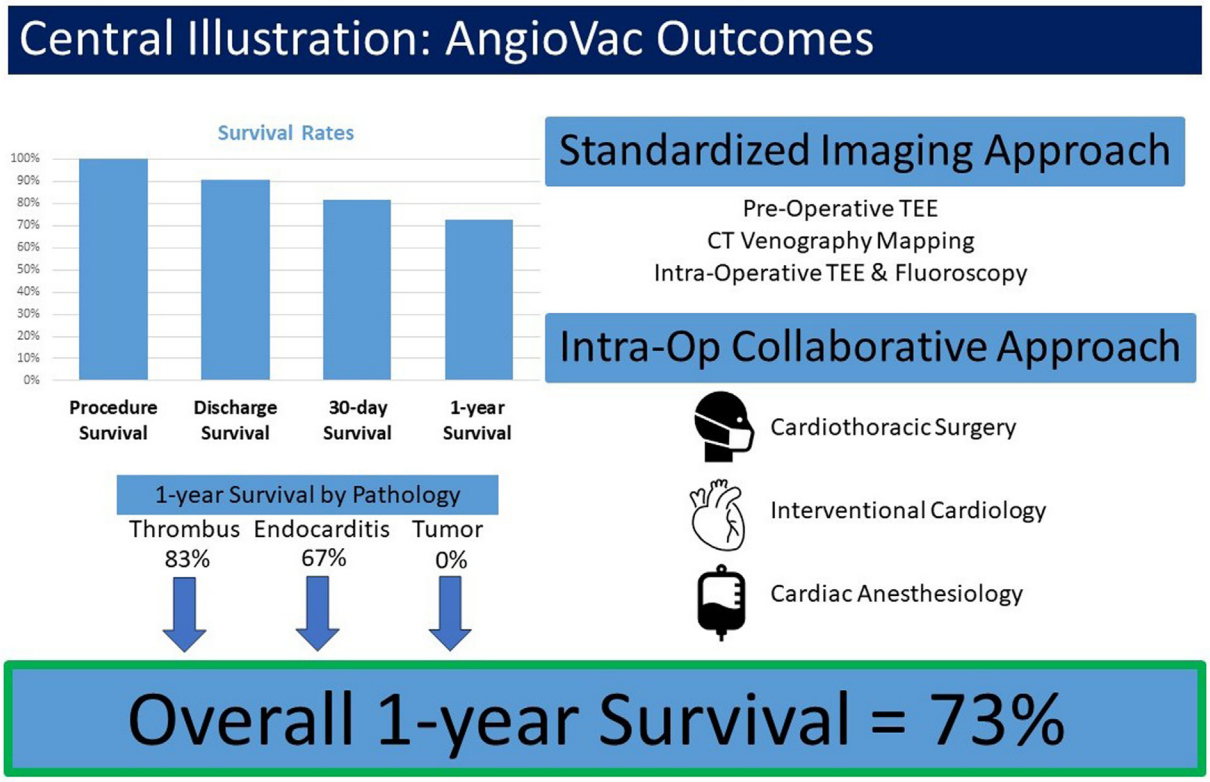
Discussion

Vacuum-assisted intracardiac mass removal systems, such as the AngioVac system, have proven to be safe and effective in removing intracardiac tumors, vegetations, and thrombi. However, while short-term success rate and survival to discharge have been reported, only a few studies have reported acceptable survival rates beyond the immediate postoperative period.[4,5,8–10] Supplemental Table S1 compares our data to previous AngioVac studies and their outcomes.[4,5,8–12] The most recent single-center retrospective study, by Katapadi et al[4] included 17 patients who underwent an AngioVac procedure with a 100% procedural survival rate. However, survival up to 1 year was significantly lower at 23.5% of the total cohort. In addition, the largest multicenter prospective study, the RAPID registry, performed by Moriarty et al,[5] included a large cohort of 234 patients and reported 98.7% procedural survival, but did not include overall survival at 1 year. Another recent study by Fallon et al[8] did report a 1-year survival rate of 8 patients out of only 9 who had confirmed 1-year follow-up in a total cohort of 58 patients who underwent the AngioVac procedure.

As shown in the Central Illustration, our data demonstrates an overall 1-year survival rate of 72.7%, which to date, is the largest reported volume of medium-term survival. This supports that AngioVac is a safe and effective option for mass removal even up to 1 year. This was also potentially underestimated due to 2 patients in our cohort who were lost to follow-up.

We contribute our procedural success, discharge survival, and 1-year survival rates to preoperative multidisciplinary planning, an intraoperative collaborative approach incorporating cardiothoracic surgery and interventional cardiology, and planned prolonged follow-up to evaluate the need for further surgical intervention. The utilization of the Heart Team model allows for preoperative planning to maximize procedural success using transthoracic echocardiography, TEE, and computed tomography venography mapping for strategizing a procedural approach to removing the mass. The model of both interventional cardiology and cardiothoracic surgery presence in the operating room provides expertise in minimally invasive techniques, combined with knowledge of mechanical circulatory support, and surgical skill. The presence of a cardiothoracic surgeon provides surgical rescue options if the need arises to convert to open thrombectomy or surgical resection and provides operator skill if ECMO support is required, as was demonstrated in 1 case in this study. The interventional cardiologist adds expertise of catheter manipulation, intravascular wire knowledge, and fluoroscopy skills which were of particular importance with the first generation of AngioVac catheters that lacked steering capabilities. Moreover, in our institution's model, the interventional cardiologist adds the expertise of percutaneous interventions for pulmonary embolism which allows for a broader approach and rapid response in the event of embolization or shock.

An additional component that contributed to our success was a standardized approach to imaging with preoperative and intraoperative TEE. In contrast to the largest study to date, the RAPID registry, which utilized a heterogeneous imaging approach to quantify success, 100% of the cases in our review used both preoperative and intraoperative TEE. Absence of a previously noted mass on preoperative TEE may indicate embolization, improvement, or resolution with medical therapy as was seen in 1 case that was excluded from this study. Along with fluoroscopy, intraoperative TEE provides a real-time 2-dimensional and



Central Illustration.
The 1-year survival rate, and the breakdown of 1-year survival by pathology achieved through standardized preoperative imaging and intraoperative collaboration. CT, computed tomography; TEE, transesophageal echocardiogram.

3-dimensional imaging modality useful for navigating the aspiration catheter in a 3-dimensional chamber. One case in this study, illustrated in Figure 1, highlights the effectiveness of intraoperative TEE in manipulating catheters and for recognizing complications such as embolization. These images show the presence of a right atrial thrombus that was highly mobile. During the aspiration attempt, the thrombus dislodged and embolized on TEE leading to further decompensation, shock, and cardiac arrest requiring ECMO support and mechanical thrombectomy. Intraoperative TEE allowed for quick recognition, leading to abrupt termination of the procedure and management of subsequent obstructive shock. Although the patient survived the procedure, she died prior to discharge accounting for 5 of the observed complications including embolization, acute renal failure requiring hemodialysis, new vasopressor use, ECMO requirement, and

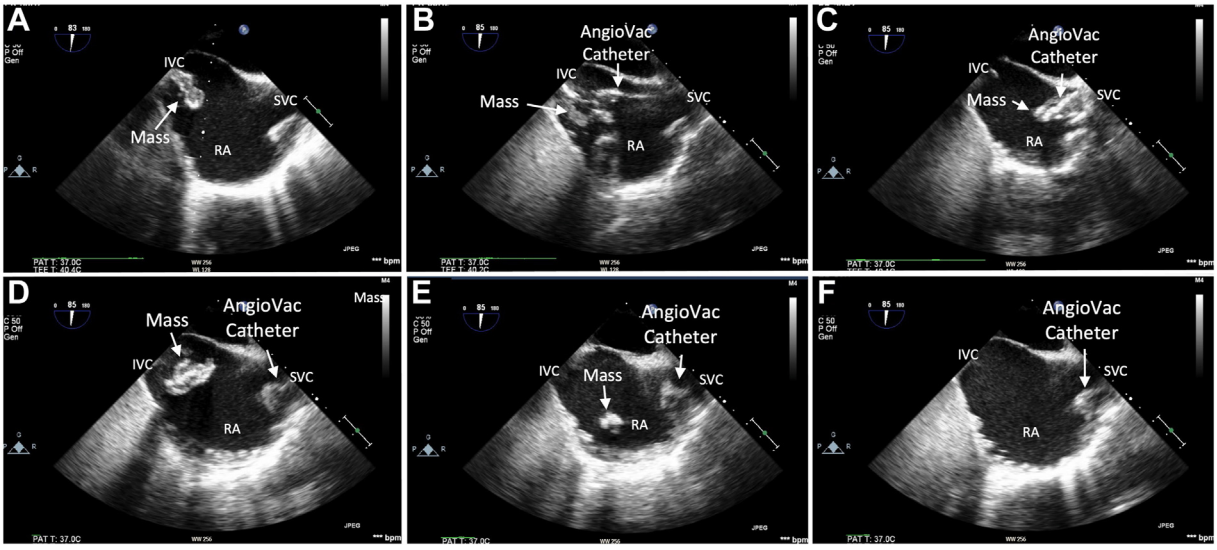


Figure 1.
Illustrative intraoperative transesophageal echocardiogram. (**A**) Panel A shows the right atrial mass attached to the junction of the inferior vena cava (IVC) and right atrium (RA). (**B**) Panel B demonstrates the AngioVac catheter engaging the mass in the RA. (**C**) Panel C shows the mass attached to the tip of the AngioVac catheter while withdrawing into the superior vena cava (SVC) during attempted extraction. (**D**) Panel D shows the mass dislodging from the AngioVac catheter. (**E**) Panel E demonstrates the mass mobilizing around the RA. (**F**) Panel F shows the mass no longer present in the RA suggesting embolization.

transfusion requirement. There was 1 case that was converted to open surgical valve replacement due to inadequate debulking with AngioVac and persistent TV regurgitation observed on preoperative TEE. The patient survived to 1 year and accounts for 3 of the complications including transfusion requirement, new vasopressor use, and worsening of preprocedural acute renal failure requiring hemodialysis. Another case documented concern for intraoperative pericardial hematoma recognized on TEE. The pericardial effusion was subsequently treated with a subxiphoid pericardiotomy for a pericardial window. The pericardial fluid was noted to be serous and therefore not considered to be a complication of the procedure. The patient survived to 1 year and accounts for 3 of the reported complications including transfusion requirement, access site hematoma, and new vasopressor use. It is important to note that vasoplegia is a well-documented phenomenon that occurs in 8% to 40% of patients undergoing extracorporeal bypass procedures confounding the clinical etiology of vasodilatory shock requiring postoperative vasopressor drugs.[13] Our experience suggests that a preoperative and intraoperative TEE performed by a trained echocardiographer allows for confirmation of intracardiac mass presence, recognition of intraoperative complications, and standardization of procedural success using a single imaging modality. Factors that contribute to complications or an unsuccessful procedure include chronic, fixed, large, or fibrocalcific appearing masses on echocardiogram. Emphasis on these features is imperative in patient selection for vacuum-assisted thrombectomy.

Treatment of right heart thrombi traditionally includes medical therapy with anticoagulants, thrombolytics, or surgical therapy with surgical thrombectomy. Although it is still unclear whether vacuum-assisted intracardiac mass removal has a mortality improvement over medical therapy for all indications, some studies suggest that there is a benefit in mass removal. The true incidence of right heart thrombus without pulmonary embolism is difficult to assess because most patients present after symptoms of embolization have occurred. Studies have suggested that the presence of right heart thrombi, specifically in the context of pulmonary embolism, is associated with higher mortality.[14,15] A recent study by Koć et al[16] suggested that this increase in mortality is more related to hemodynamic compromise than characteristics of the right heart thrombus itself. Our survival data continues to show that AngioVac is a safe and effective option, but currently, no randomized trials have compared vacuum-assisted intracardiac thrombectomy to surgical thrombectomy or to medical therapy alone.

Although AngioVac was originally approved for thrombus removal, there have been increasing reports of successful use in right-sided infective endocarditis. A recent meta-analysis by Mhanna et al[17] demonstrated acceptable procedural success and survival to hospital discharge; however, there was minimal reporting of medium-range survival. The recent work of Siddiqui et al[18] evaluated surgical vs medical management of drug use-associated right-sided endocarditis complicated by septic pulmonary embolism. This study demonstrated an increase in major adverse cardiac events, cardiogenic shock, and need for permanent pacemakers in the surgical group, but the overall mortality in the surgical group was lower. The increased number of major adverse cardiac events was attributed to increased cardiogenic shock and cardiac arrest, and the increase in pacemaker requirement was felt to be secondary to the increased risk of heart block with TV replacement. One retrospective analysis analyzing 29 patients with right-sided endocarditis demonstrated that percutaneous debulking was noninferior and superior to surgical intervention for the composite of in-hospital death or heart block. This study showed that 90% of patients with right-sided endocarditis post-AngioVac debulking did not require inpatient surgical intervention.[19,20] Table 5 shows a breakdown of our 1-year survival rates based on histopathologic confirmation of diagnosis. In a review of the 9 patients with the histopathologic confirmation of endocarditis or infected thrombus, the 1-year survival rate was 66.7%, which was also likely underestimated as 2 of these patients were lost to follow-up. In the 13 patients with a preoperative clinical suspicion of infective endocarditis, 7 patients had pending cultures with no growth to date on the day of the procedure, which later resulted as negative. In 4 of those 7 patients, the histopathology showed negative results for infective endocarditis indicating likely preoperative source control or bacteremia with concomitant sterile thrombus.

Table 5. One-year survival based on histopathologic diagnosis.

	N = 22
Right-sided infective endocarditis	6 (66.7)
Right-sided thrombus	10 (83.3)
Right-sided intracardiac tumor	0 (0)
Total	16 (72.7)

Values are n (%).

For our cohort, the mean EuroScore II preoperative risk was 4.10%. In this context, where surgical risk may be prohibitive to proceeding immediately to urgent or emergent surgical intervention, minimally invasive vacuum-assisted techniques can be utilized for stabilization as either a bridge with the goal of optimization prior to surgical planning, and/or for debulking. Our procedure success and 1-year survival rate add to the growing literature that AngioVac is not only effective for the treatment of right heart thrombi, but also right-sided endocarditis. These results also demonstrate that it is safe beyond the immediate postoperative period allowing for a staged surgical approach to reevaluate the need for surgical intervention if the surgical indication, such as source control or large mobile vegetation, is appropriately treated with minimally invasive techniques. This staged approach with AngioVac could be especially useful in patients where intravenous drug use raises the risk of reinfection in the setting of urgent valve replacement. To our knowledge, there has not been a direct comparison between AngioVac and immediate surgical intervention in high-risk patients with infective endocarditis. This remains an area of potential investigation. Furthermore, as minimally invasive techniques are becoming more advanced to include routine use of vacuum-assisted aspiration systems, guideline updates are needed to provide a treatment algorithm for management of intracardiac masses including tumors, thrombi, and infective endocarditis.

The limitations of our study include a small number of patients in our cohort. There is also limited follow-up documentation regarding the cause of death in patients who were documented as deceased. This information deficit is partly attributed to the broad geographic referral to our tertiary care system and lack of access to electronic medical records from referring health systems. This knowledge could help determine if the intracardiac mass significantly contributed to patient mortality. In our study, there is a lack of standardized measurement of each mass which introduces subjectivity. We recognize that a standardized measurement protocol including specific views and measurements is often difficult between masses with different locations, attachments, morphology, and mobility. In this retrospective analysis, we report the qualitative assessment of success as determined by the echocardiographer at the time of intervention which included both a cardiac anesthesiologist and interventional cardiologist in 100% of cases.

Conclusion

The safety and efficacy of vacuum-assisted mass removal using the AngioVac system have been well documented through a few retrospective case series and 1 prospective case series. Long-term survival data is currently lacking in the literature. Our review further supports the safety and efficacy of minimally invasive vacuum-assisted aspiration systems beyond the immediate postoperative period in intracardiac thrombi, tumors, and right-sided infective endocarditis. Furthermore,

we suggest a multidisciplinary model involving minimally invasive specialists such as interventional cardiologists and cardiothoracic surgery specialists for both preoperative planning and intraoperative collaboration. TEE should be utilized to reevaluate intracardiac masses preoperatively and intraoperatively to guide the aspiration procedure and standardize operative success. Currently, there are limited recommendations from guidelines regarding the approach to intracardiac masses including thrombi, vegetations, and tumors. Further prospective studies comparing surgical intervention to a staged approach using AngioVac are a potential subject of investigation. Furthermore, guidelines are also needed to help develop an algorithmic approach to intracardiac masses.

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Declaration of competing interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Ethics statement and patient consent

The local institutional review board approved this study and waived the requirement for informed consent.

Supplementary material

To access the supplementary material accompanying this article, visit the online version of the *Journal of the Society for Cardiovascular Angiography & Interventions* at 10.1016/j.jscai.2024.101979.

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