

Transcatheter vacuum-assisted aspiration of large intracardiac and intravascular masses

Laura Besola, MD; Alessandro Fiocco, MD; Nicola Nencioni, CCP; Martina Dini, MD; Giacomo Ravenni, MD; Danilo Ruggiero, MD; Michele Celiento, MD; Andrea Colli*, MD, PhD, FECTS

*Corresponding author: Cardiac Surgery Unit, Heart Center, Department of Surgical, Medical and Molecular Pathology and Critical Care, University of Pisa, Via Paradisa, 2, 56124, Pisa, Italy. E-mail: andrea.colli@unipi.it

This paper also includes supplementary data published online at: <https://eurointervention.pcronline.com/doi/10.4244/EIJ-D-24-00245>

ABSTRACT

Intravascular and intracardiac masses are usually represented by thrombi, tumours, and vegetations. They can affect both the right and left chambers of the heart and the venous and arterial circulation. Traditionally, their treatment is surgical or, in some circumstances, based on systemic anticoagulation/fibrinolysis. However, the complexity and frailty of patients who sometimes present with these conditions have pushed surgeons to find alternative minimally invasive effective treatments. While small masses can be removed with multiple devices, large masses are a more challenging problem. Vacuum-assisted aspiration systems such as the AngioVac System were developed to treat intravenous and right-sided heart thrombi. The application of the AngioVac System was widened to right-sided endocarditis and, later, to left-sided thrombi and vegetations. This review summarises the clinical results of different uses of the vacuum-assisted aspiration system to treat intravenous and intracardiac masses.

Intracardiac masses, either located in the left or right heart chambers, have various origins but are mainly represented by thrombi, primary or secondary tumours, and endocarditis vegetations^{1,2}. Patients presenting with these conditions might be frail and have an unstable haemodynamic status. In such conditions, surgery may be affected by high perioperative mortality and morbidity^{1,2}.

Percutaneous vacuum-assisted aspiration of large intravascular/intracardiac masses has become a less invasive option for this subgroup of patients who cannot take advantage of conventional surgery³. While different solutions have been developed to deal with small masses, the only available system able to manage large masses is the AngioVac System (AngioDynamics). It was developed and approved to address right-sided heart disease⁴⁻⁸; however, off-label utilisations have been reported to remove left-sided masses through transseptal/transapical access in high-risk patients⁹⁻¹². It enables a vacuum-assisted aspiration of large heart and vascular masses, providing a circulatory support system which supports the patient's haemodynamics and returns large blood volumes to the patient.

The use of vacuum-assisted systems for intracardiac and intravascular masses is not yet included in current international guidelines, as the safety and efficacy data have been derived only from small retrospective studies, and large retrospective and clinical randomised trials are lacking.

We here summarise the clinical experience, indications, and controversies of the percutaneous aspiration system to treat right- and left-sided large masses.

The AngioVac System and procedure

The AngioVac System comprises a large-bore cannula, an extracorporeal circulation circuit including a filter connected to a centrifugal pump, and a reinfusion cannula to return blood to the patient. The original standard setup is a venovenous extracorporeal circuit with the aspiration cannula inserted in the internal jugular or femoral vein and the reinfusion cannula placed in the femoral vein (**Figure 1**). The 22 Fr aspiration cannula has a 20 or 180 degree angulated tip (**Figure 2**). A closed circuit is built, and a standard centrifugal pump generates vacuum aspiration. The suctioned material is trapped in the circuit filter placed ahead of the pump's inlet.

KEYWORDS: innovation; miscellaneous; multidisciplinary Heart Team

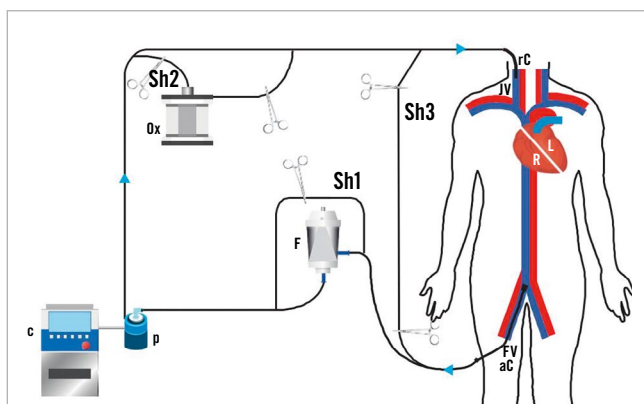


Figure 1. Standard cannulation setup. The aspiration cannula (aC) is inserted into the venous system through the femoral vein (FV). Thrombi and/or vegetations are aspirated with the venous blood and trapped in the filter (F). Filtered blood is then circulated by a console-controlled (C) centrifugal pump (P) and returned to the patient through the reinfusion venous cannula (rC) in the jugular vein (JV). The represented setup includes three shunting lines: the first one (Sh1) to bypass the filter, the second one (Sh2) to include an oxygenator (Ox) and the third one (Sh3) to exclude the whole circuit from the patient. R: right side; L: left side

The procedure is performed in a standard operating room under general anaesthesia. Real-time transoesophageal echocardiographic (TOE) guidance is mandatory and can be integrated with fluoroscopy. The aspiration cannula's insertion site depends on the mass location and can be surgical or percutaneous. As per hospital protocol, systemic heparinisation is necessary with a target activated clotting time (ACT). The reinfusion cannula insertion site depends on the aspiration site.

The **Central illustration** summarises the possible circuit setup for aspiration of masses located in the right and left sections.

Current clinical application

We systematically searched PubMed's MEDLINE, Google Scholar and Ovid for single- and multicentre studies and registries assessing the use of the AngioVac System to treat intravascular (venous and arterial) and intracardiac (right- and left-sided) masses. We found 149 relevant articles that mentioned the use of the AngioVac System. Preoperative, procedural, and postoperative results were examined, and relevant data were summarised in the present review. The most important articles are reported in **Table 1**.

Intracardiac right heart and intravenous masses THROMBI AND TUMOURS

The presence of right heart thrombi or tumours (RHT) is often associated with extensive ilio caval thrombosis and/or

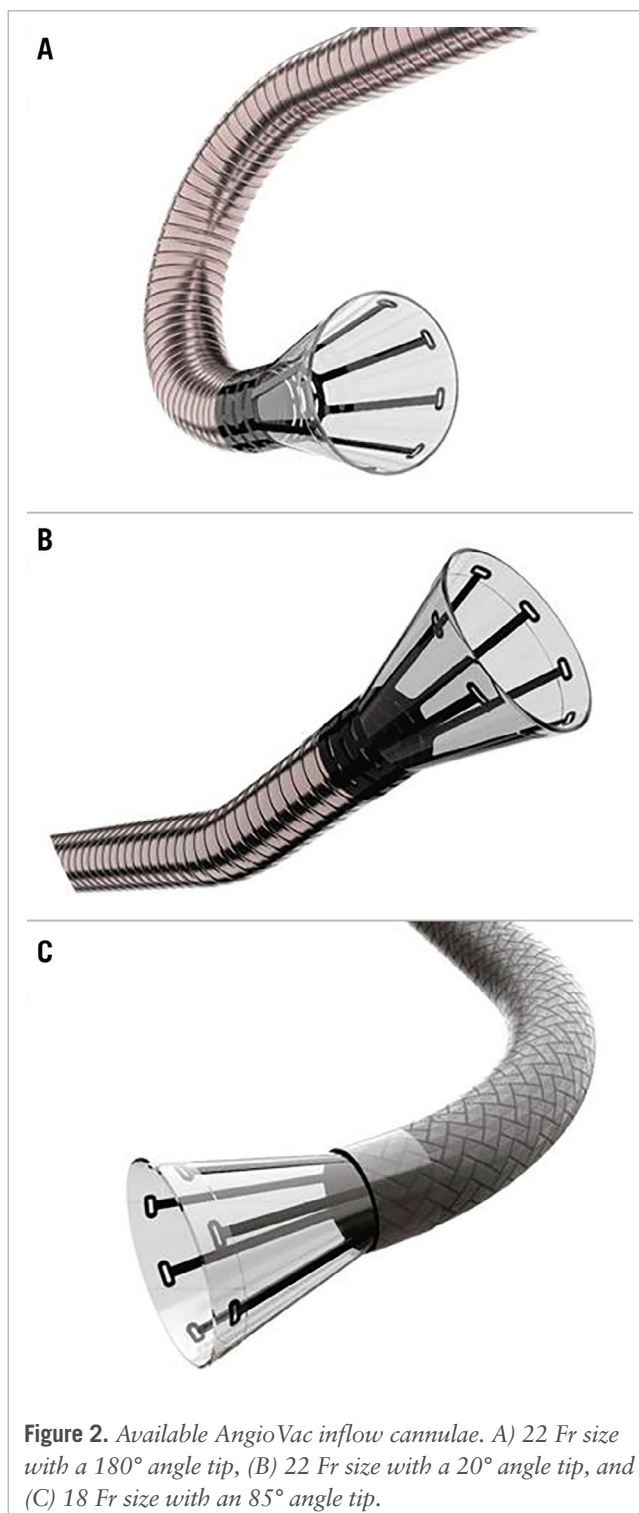


Figure 2. Available AngioVac inflow cannulae. A) 22 Fr size with a 180° angle tip, (B) 22 Fr size with a 20° angle tip, and (C) 18 Fr size with an 85° angle tip.

pulmonary embolism (PE)^{1,13} and carries poor outcomes¹³. Patients with RHT usually benefit from surgery more than from anticoagulation or thrombolytic therapy alone¹⁴. The

Abbreviations

PE pulmonary embolism
RHT right heart thrombosis

RV right ventricular
TV tricuspid valve

Table 1. Main articles relative to the use of AngioVac with reported mortality and success rates.

Authors	No. of cases	Mass type	Success	Death	Study type
Donaldson CW et al ³	14	IVC thrombus/RHT (11) PE (5)	73%	13% (30 d)	Retrospective single-centre
Hameed I et al ⁴	182	VC/RHT (101) RH endocarditis (81)	71.6% (VC/RHT 80.5%, PE 30.4%) 74.5%	23.3% (VC/RHT 14.8%, PE 32.3%) 14.6%	Meta-analysis
Jabaar AA et al ⁵	13	VC	83%	NA	Systematic review
Resnick SA et al ⁷	7	IVC/RHT (6) PE (1)	86%	0	Retrospective single-centre
Moriarty JM et al ⁸	16	IVC (10) RHT (6)	100% 67%	87.5%	Retrospective single-centre
Qintar M et al ¹¹	10	LH endocarditis	80%	0	Retrospective single-centre
Al Badri A et al ¹⁷	7	IVC/RHT (5) Leads vegetation (2)	86%	0	Retrospective single-centre
Al-Hakim R et al ²²	5	PE	40%	80% (30 d)	Retrospective single-centre
D'Ayala M et al ²³	12	IVC (4) RHT (5) PE (3)	100% 60% 33% (partial)	NA	Retrospective single-centre
Mhanna M et al ²⁸	301	RH endocarditis	79.1%	89.7%	Meta-analysis
George B et al ²⁹	33	TV endocarditis	90.0%	61%	Retrospective single-centre
Patel N et al ³⁰	3	Leads vegetation	100%	0	Retrospective single-centre
Schaerf RHM et al ³¹	20	Leads vegetation	100%	0	Retrospective single-centre
Starck C et al ³²	78	RH endocarditis	91.7%	0	Retrospective single-centre
Tarzia V et al ³³	13	Leads vegetation	92.3%	0	Retrospective single-centre

d: days; IVC: inferior vena cava; LH: left heart; PE: pulmonary embolism; RH: right heart; RHT: right heart thrombosis; TV: tricuspid valve; VC: vena cava

AngioVac System was initially proposed for high-risk patients^{2-5,15}. This procedure was safe in the described cases¹⁶⁻¹⁸ (**Figure 3, Moving image 1**). The success rate may vary depending on the centres' experience and an acute versus chronic origin of the thrombi, as confirmed by a recent meta-analysis showing complete removal of RHT in between 68% and 85% of cases depending on the thrombosis acuteness¹⁶. Similarly, Resnick⁷ and Al Badri¹⁷ reported partial or completely unsuccessful thrombi aspiration only in the case of chronic conditions.

In ilio caval thrombosis, success rates were reported up to 85%, with a 14.8% rate of procedure-related mortality^{4,16,17}. Donaldson et al³ reported a 73% success rate and hospital survival of 87% in a small population presenting extensive thrombosis. In contrast to other experiences^{4,16,17}, they reported a high incidence of postoperative transfusion (55%) and access site complications (4%), probably related to patient frailty.

The AngioVac System has also been used to locally debulk intravenous neoplastic infiltration of the inferior vena cava in patients with kidney tumours, restoring venous drainage from the inferior part of the body^{19,20}, followed by nephrectomy (**Figure 4, Moving image 2**).

PULMONARY EMBOLISM

PE has an incidence of 0.95 per 1,000 subjects per year and a mortality rate of 1% for submassive PEs to more than 65% for massive PEs²¹. Treatment mainly relies on systemic

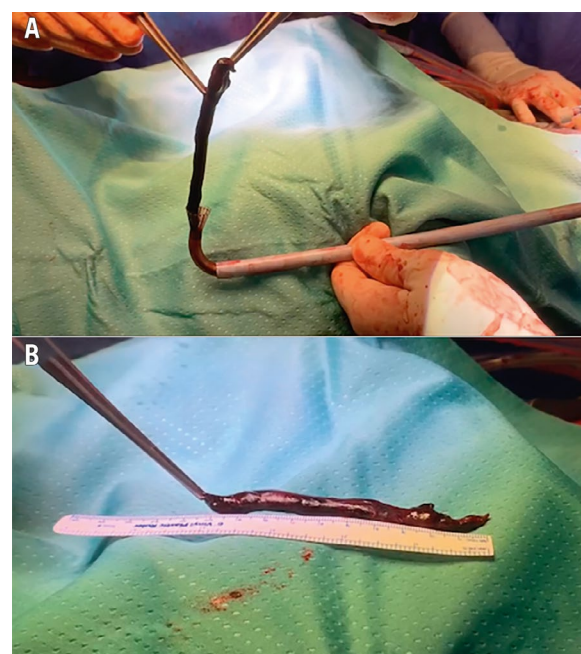


Figure 3. Superior vena cava-right atrium thrombus. Patient with port-a-cath thrombosis. A) The aspirated thrombus is extracted from the funnel-shaped tip of the AngioVac cannula. B) The entire thrombus is shown, measuring over 10 cm.



Figure 4. Inferior vena cava thrombus/tumour infiltration. The patient was affected by kidney carcinoma and inferior vena cava neoplastic infiltration and thrombosis. A) Filter containing the aspirated material; (B) fragments of the intravenous mass.

thrombolysis and may require extracorporeal membrane oxygenator (ECMO) support in case of severe haemodynamic instability, as indicated by international guidelines²¹. Surgical embolectomy is indicated in case of massive PEs involving proximal pulmonary artery branches; however, in frail patients, the risk might be prohibitive²¹.

The AngioVac System has been previously used to treat PE as an alternative to standard medical or surgical management¹¹. PE treatment with percutaneous aspiration is limited to high-risk and haemodynamically unstable patients, and outcomes are poor when compared to RHT and ilio caval aspiration. Indeed, Al-Hakim et al had a 40% success rate in their 5 patients with 80% perioperative mortality²². Another single-centre case series, including 12 patients with massive PE, had a 33% success rate with high in-hospital mortality and intraoperative complications, including right ventricular (RV) perforation and tricuspid valve (TV) apparatus tearing²³. Renew et al recently described a successful case of a massive saddle-shaped PE treated using the AngioVac with an ECMO circuit to provide circulatory support and oxygenation²⁴. In all described cases, the procedure was performed under TOE and fluoroscopy guidance.

ENDOCARDITIS

Most commonly, vegetation in the right heart involves the TV (native or prosthetic) and intravenous rhythm device leads²⁵. Despite advancements in diagnosis and treatment, hospital mortality is still significant²⁶. Surgery is indicated in the presence of severe TV regurgitation and vegetations larger than 2 cm, persistent sepsis despite *ad hoc* therapy, and recurrent PE²⁷.

Percutaneous aspiration has emerged as an alternative to surgery in prohibitive surgical risk patients^{4,6} (Figure 5). Experience is still limited to small single-centre case series. However, a meta-analysis²⁸ showed up to 75% clinical success (combination of residual vegetation size <50%, in-hospital survival, absence of persistent bacteraemia, and satisfactory valve function not requiring further interventions) and 15%

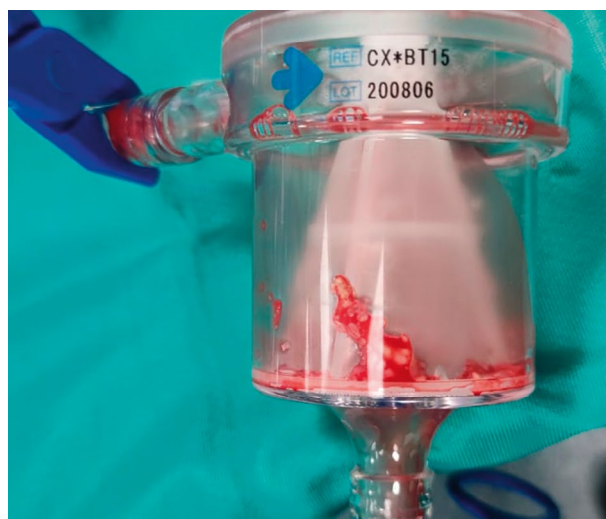


Figure 5. Tricuspid endocarditis. The filter containing the suctioned vegetation.

perioperative mortality. In a single-centre experience, George et al had a 61% reduction of the vegetation size in 33 patients with 90% in-hospital survival²⁹.

The AngioVac System has also been used to remove vegetation of intravenous rhythm device leads. Patel et al and Schaerf et al had a technical success rate of >80%, no infection recurrence, and >90% in-hospital survival^{30,31}. Starck's group³² treated 35 patients (83 leads) with systemic infections, obtaining complete vegetation debulking with no intraoperative death in 88.6% of the patients, while Tarzia et al³³ reported 92.3% procedural success with a 7.7% intraoperative complication rate. In all series, vegetation debulking was followed by lead extraction.

Intracardiac left heart and intra-aortic masses ENDOCARDITIS

The prevalence of mitral and aortic native and prosthesis endocarditis has increased over the last decade. Surgery is indicated in the presence of acute heart failure, local tissue destruction, large vegetations, and persistent bacteraemia despite optimal prolonged antibiotic therapy²⁷. About 20% of patients with infective endocarditis are not referred for surgery because of their high surgical risk³⁴. The percutaneous aspiration of left-sided vegetation has been proposed⁹⁻¹² (Figure 6). Its clinical application is still limited, and no multicentre data are available. Gerosa et al were the first to describe a case of transapical (TA) aspiration of mitral prosthesis vegetation with patient survival⁹. Other cases have been described, mainly with a transseptal left atrium (LA) approach¹⁰⁻¹². Differently from Gerosa's group, who used left heart extracorporeal assistance (left ventricle [LV] to common femoral artery) with the interposition of an oxygenator, other groups preferred a venovenous cannulation with aspiration in the LA through the interatrial septum and reinfusion in the contralateral femoral vein without an oxygenator. In most cases, a percutaneous cerebral protection device was used to prevent potential vegetation embolisation to the supraoptic vessels. Xu et al recently described a case of mitral prosthesis endocarditis that was successfully treated

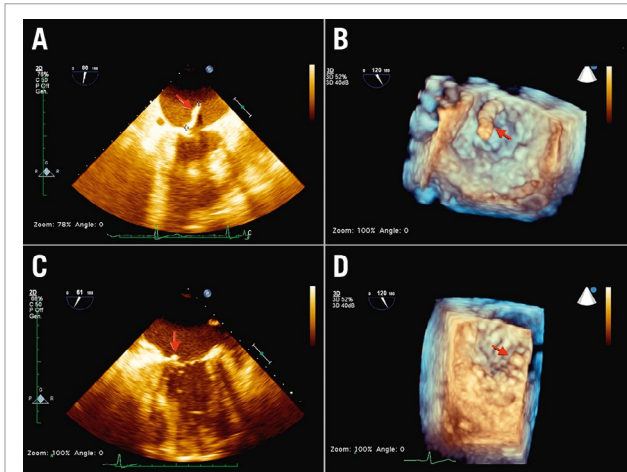


Figure 6. Native mitral valve endocarditis. Transapical aspiration access and femoral artery reinfusion. A,B) Preoperative 2D/3D TOE: vegetation attached to the posterior mitral leaflet and floating in the left atrium during systole (red arrow). C,D) Postoperative 2D/3D TOE: the vegetation is almost completely removed (red arrow). 2D: two-dimensional; 3D: three-dimensional; TOE: transoesophageal echocardiography

with staged transseptal vegetation aspiration and mitral valve-in-valve implantation using a transcatheter valve in a patient who had been deemed unsuitable for conventional redo surgery because of high surgical risk³⁵.

AORTIC MASSES

Thoracic aortic mural thrombus is relatively uncommon. Its management is not standardised and depends on its location and extent, patient comorbidities, and the physician's preferences. The literature describes the application of percutaneous aspiration combined with a cerebral embolic protection device to remove bulky thrombi in the ascending and descending aorta in high-risk patients. Tsilimparis et al³⁶ aspirated a large ascending aorta thrombus from the left subclavian artery extending close to the supra-aortic vessels without complications. Frisoli³⁷ and Kang³⁸ described ascending and descending thoracic aorta thrombus removal from the common femoral artery and reinfusion through the contralateral femoral vein. Rolon et al³⁹ described a case of extensive descending aorta thrombus with infrarenal occlusion, inferior limb, and small bowel ischaemia. The patient underwent infrarenal surgical thrombectomy, aortobisiliac bypass and AngioVac aspiration of the supraceliac part of the thrombus. In this case, the suction cannula was advanced in the aorta using one of the branches of the vascular graft, and blood was reinfused in the contralateral femoral vein. The patient survived without major complications. Transcaval aortic access was described by Qintar et al, who successfully managed a case of distal arch thrombosis in a 55-year-old woman with multiple cerebral and upper limb embolisations⁴⁰.

Discussion

The AngioVac System was first developed to treat large intravenous masses^{15,16}, but its use has expanded to the

aspiration of intracardiac masses^{17,18}, including valves^{9-12,28,29}, lead vegetations^{31,32}, and PE^{21,23}. While published results suggest that the AngioVac System is a safe and effective minimally invasive option to treat large intravenous thrombi and kidney-related tumours¹⁵⁻¹⁸, data supporting its use in right-sided intracardiac masses and PE are insufficient. Still, in the case of chronic ilio caval thrombosis, results might be suboptimal for acute and subacute thrombosis¹⁶. The use of the AngioVac System for PE has shown high perioperative mortality^{21,22}, and successful cases have been just anecdotal²³. Its application in this subset is mainly limited by the size and stiffness of the aspiration cannula and the risk of damaging the TV subvalvular apparatus or perforating the RV, as reported in the literature^{21,22}. Based on our experience, a possible solution to avoid TV crossing and RV navigation is introducing the AngioVac cannula into the pulmonary trunk through a left minithoracotomy in the second intercostal space or mini-upper sternotomy. Pulmonary artery (PA) cannulation can be performed either directly with a DrySeal sheath (W. L. Gore & Associates) or with the interposition of an 8-10 mm vascular graft to prevent arterial tearing during the manipulation of the AngioVac cannula. However, even with this setup, the complete removal of distal emboli is unlikely (**Figure 7**).

Therefore, the use of AngioVac for PE treatment should be reserved only for prohibitive-risk haemodynamically unstable patients to debulk massive embolisation in the main PA and its branches and then proceed either with a percutaneous smaller

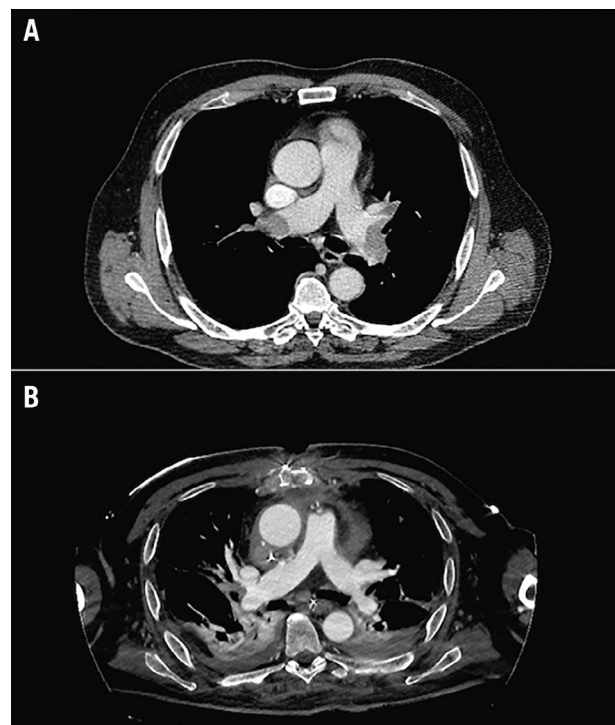
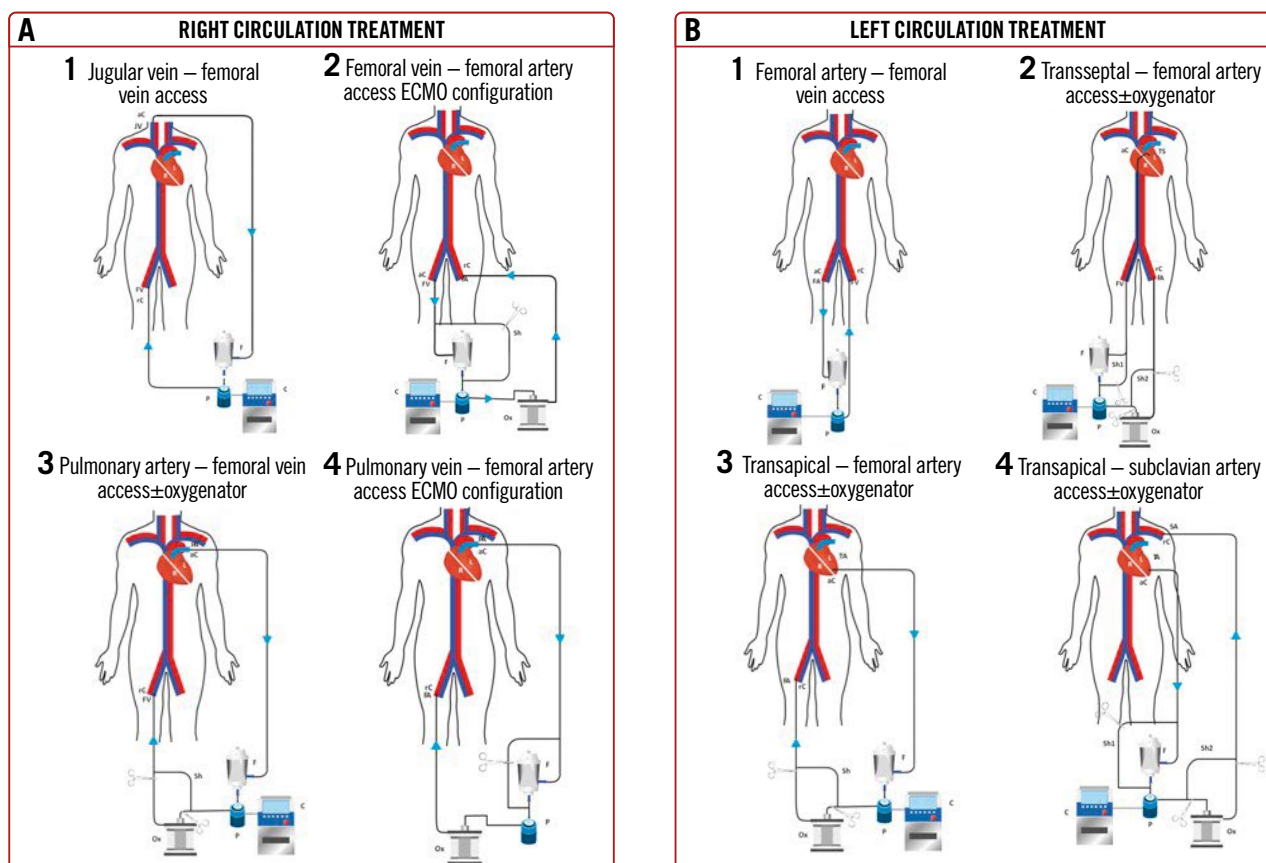


Figure 7. Massive pulmonary embolism. A) Preprocedural angio-CT: the principal pulmonary branches show almost complete occlusion. B) Postprocedural angio-CT: almost complete reperfusion is appreciable on both sides. CT: computed tomography

catheter or surgical embolectomy in a second stage when the patient is more stable or with intravenous anticoagulation with or without ECMO support depending on the patient's clinical conditions. Moreover, when this option is chosen,

we prefer an ECMO-like setup with the interposition of an oxygenator (**Central illustration**). This would indeed provide circulatory support and blood oxygenation during the procedure and might be switched to midterm paracorporeal

Circuit setups.



Laura Besola et al. • EuroIntervention 2024;20:e1267-e1275 • DOI: 10.4244/EIJ-D-24-00245

A) Right-sided masses. A1) Jugular vein – femoral vein access: superior caval, tricuspid, atrial and jugular vein mass suction. This is preferable to treat haemodynamically stable patients, since the reinfusion cannula is positioned in the femoral vein, and therefore, there is no chance to mechanically assist the patient. A2) Femoral vein – femoral artery access ECMO configuration: right-sided masses suction and circulatory assistance. A shunt line allows for filter bypassing, in case of need for assistance >6 h. A3) Pulmonary artery – femoral vein access ± oxygenator: for pulmonary embolism. By switching the reinfusion cannula into the femoral artery, the system can be shifted to a temporary ECMO. A4) Pulmonary artery – femoral artery access ECMO configuration: this configuration enables the operator to treat pulmonary embolism, ensuring mechanical support to the circulation. The oxygenator and the shunt line provide the chance to bypass the filter in case of need for >6 h of use, transforming the circuit into an ECMO. B) Left-sided masses. B1) Femoral artery – femoral vein access: this configuration has been described for abdominal aorta mass suction procedures. B2) Transseptal – femoral artery access ± oxygenator: this setup has been described to approach left atrial/mitral valve/LV masses. The optional use of an oxygenator increases the filtering and assists blood oxygenation in case the patient needs prolonged mechanical circulatory support; in this case, a shunt line allows for filter bypassing and prolonged left mechanical assistance. B3) Transapical – femoral artery access ± oxygenator: mitral and aortic valve masses. This setup includes two shunt lines: one to bypass the filter in case of need for prolonged left mechanical assistance and one to allow the potential use of an oxygenator. B4) Transapical – subclavian artery access ± oxygenator: the reinfusion cannula can be positioned in the subclavian artery when femoral arteries are not available. This configuration allows for prolonged left mechanical assistance by means of a shunt line bypassing the filter. ECMO: extracorporeal membrane oxygenation; LV: left ventricular

circulatory support (ECMO or right ventricular assist device) until complete recovery of RV function and improvement of pulmonary circulation are achieved.

As shown in the **Central illustration**, we usually prefer adding an oxygenator to the circuit to improve filter capacity and to provide stable oxygenation during aspiration. This is of paramount importance in case the aspiration cannula is on the right side or in the pulmonary system and the infusion cannula is inserted in the arterial system. Furthermore, when treating intravascular tumours that tend to fragment into numerous very small particles, the presence of an oxygenator provides extra filtering capacity, preventing the reinfusion of part of the debris. In case of an increased risk of bleeding and therefore necessity of lower ACT values, the oxygenator can be excluded thanks to a shunt line. This setup gives extreme versatility to the circuit, providing the opportunity to mechanically assist the patient even when the procedure has been completed.

In case of right-sided endocarditis, available data suggest that the use of the AngioVac System should be reserved for frail patients with high surgical risk and no TV regurgitation^{27,28}. In this case, the rationale is to reduce the size of the vegetation, possibly lowering the microbial burden with a positive impact on the effect of antibiotic therapy²⁸. Surgery remains mandatory in the presence of local infection extension or when the valve or prosthesis malfunctions, causing acute heart failure and haemodynamic instability. Moreover, suction on the TV carries an increased risk of chordal tearing that can lead to acute TV regurgitation. Initial treatment of lead endocarditis with AngioVac is possible to reduce the microbial burden and the risk of PE; however, in all cases, it must be followed by conventional lead extraction^{31,32}.

Treatment of left-sided endocarditis⁹⁻¹² and aortic thrombi³⁵⁻³⁹ with the AngioVac System is relatively new, and data are scant. Therefore, its use should be limited to inoperable patients when medical therapy is ineffective. As described in the literature, in all cases, a cerebral embolism protection device should be used in consideration of the high risk of distal embolism during wire/sheath insertion and mass manipulation^{40,41}.

Treatment of mitral endocarditis can be achieved either with a transapical or transseptal approach⁹⁻¹² with comparable outcomes. While avoiding an open-chest procedure and puncture of the left ventricular apex, the transseptal approach entails the creation of an iatrogenic septal atrial defect that, in some selected cases, might need to be closed with a closure device. Placement of material inside the heart in infected patients should be carefully considered and if possible avoided. Apical insertion of the aspiration cannula has the advantage of allowing for contemporary treatment of aortic and mitral valves in case of multivalvular endocarditis (**Figure 8**). However, the best access site should be chosen based on each patient's characteristics and the location of the vegetations (atrial or ventricular aspect of the valve; involvement of one or two valves). Direct access to the mitral valve might also be obtained with insertion of the aspiration cannula via the right upper pulmonary vein with a mini-thoracotomy approach. Combined transseptal AngioVac and valve-in-valve implantation for mitral prosthesis endocarditis has been described³⁴. Even if attractive, this option should be

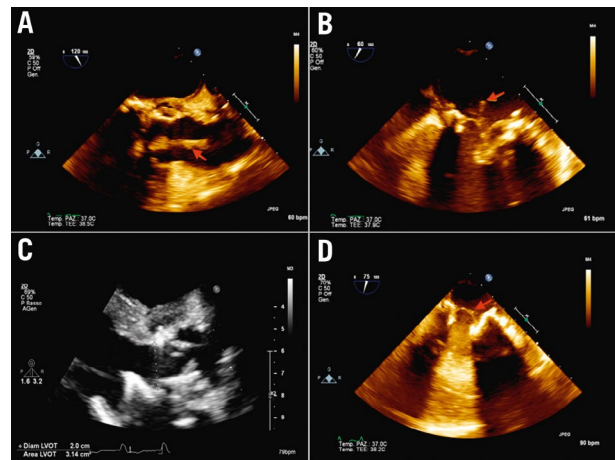


Figure 8. Mitral and aortic prosthesis endocarditis.

Transapical aspiration access and femoral artery reinfusion.

A) 2D preoperative transoesophageal echocardiography (TOE) showing the presence of a mass (red arrow) attached to the aortic prosthesis and floating in the aortic root, (B) 2D preoperative TOE showing a mass (red arrow) attached to the mitral prosthesis on the atrial side, (C) postoperative 2D TOE showing no residual mass on the aortic prosthesis, (D) postoperative 2D TOE showing a residual minimal stump (red arrow) on the mitral prosthesis. 2D: two-dimensional

considered very carefully, because the experience is currently limited to a single case, and complete removal of the infected material is not achievable.

Transcatheter vacuum-assisted aspiration has become a new part of the therapeutic strategy for intracardiac and intravascular masses in specific high-risk clinical scenarios; it can work either in isolation or as a step in a combination of different procedures. It offers reduced invasiveness and, so far, good clinical results with respect to the type of treated patients. However, in consideration of its novelty, preprocedural multidisciplinary Heart Team evaluation is mandatory. Depending on the disease, the planning should include access site definition, circuit setup, further therapeutic steps (either medical or interventional/surgical) and optimal imaging guidance.

Conclusions

Transcatheter vacuum-assisted aspiration has become an alternative to conventional surgery in different clinical scenarios to treat high-risk patients. However, based on the current experience, it should be indicated only in iliofemoral and right heart thrombosis. Application to right- and left-sided endocarditis, PE and aortic thrombi is still not supported by sufficiently reliable results. It should therefore be limited to carefully selected inoperable/high-risk patients after multidisciplinary Heart Team evaluation.

Authors' affiliation

Cardiac Surgery Unit, Department of Surgical, Medical and Molecular Pathology and Critical Care, University of Pisa, Pisa, Italy

Conflict of interest statement

The authors have no conflicts of interest to declare.

References

- Torbicki A, Galić N, Covezzoli A, Rossi E, De Rosa M, Goldhaber SZ; ICOPER Study Group. Right heart thrombi in pulmonary embolism: results from the International Cooperative Pulmonary Embolism Registry. *J Am Coll Cardiol*. 2003;41:2245-51.
- Mohanany D, Mohadjer A, Pettersson G, Navia J, Gordon S, Shrestha N, Grimm RA, Rodriguez LL, Griffin BP, Desai MY. Association of Vegetation Size With Embolic Risk in Patients With Infective Endocarditis: A Systematic Review and Meta-analysis. *JAMA Intern Med*. 2018;178:502-10.
- Donaldson CW, Baker JN, Narayan RL, Provias TS, Rassi AN, Giri JS, Sakhuja R, Weinberg I, Jaff MR, Rosenfield K. Thrombectomy using suction filtration and veno-venous bypass: single center experience with a novel device. *Catheter Cardiovasc Interv*. 2015;86:E81-7.
- Hameed I, Lau C, Khan FM, Wingo M, Rahouma M, Leonard JR, Di Franco A, Worku BM, Salemi A, Girardi LN, Gaudino M. AngioVac for extraction of venous thromboses and endocardial vegetations: A meta-analysis. *J Card Surg*. 2019;34:170-80.
- Jabaar AA, Jenkins JS. The role of vacuum assisted thrombectomy (AngioVac) in treating chronic venous thromboembolic disease. Systematic review and a single center's experience. *Cardiovasc Revasc Med*. 2018;19:799-804.
- Abubakar H, Rashed A, Subahi A, Yassin AS, Shokr M, Elder M. AngioVac System Used for Vegetation Debulking in a Patient with Tricuspid Valve Endocarditis: A Case Report and Review of the Literature. *Case Rep Cardiol*. 2017;2017:1923505.
- Resnick SA, O'Brien D, Strain D, Malaisrie C, Schimmel D, Salem R, Vogelzang R. Single-Center Experience Using AngioVac with Extracorporeal Bypass for Mechanical Thrombectomy of Atrial and Central Vein Thrombi. *J Vasc Interv Radiol*. 2016;27:723-9.e1.
- Moriarty JM, Al-Hakim R, Bansal A, Park JK. Removal of Caval and Right Atrial Thrombi and Masses Using the AngioVac Device: Initial Operative Experience. *J Vasc Interv Radiol*. 2016;27:1584-91.
- Gerosa G, Longinotti L, Bagozzi L, D'Onofrio A, Zanella F, Pittarello D, Tarzia V. Transapical Aspiration of a Mitral Mass With the AngioVac System on a Beating Heart. *Ann Thorac Surg*. 2020;110:e445-7.
- Memon S, Goldman S, Hawthorne KM, Gnall EM. Percutaneous transeptal mitral valve endocarditis debulking with AngioVac aspiration system. *Catheter Cardiovasc Interv*. 2022;100:667-73.
- Qintar M, Wang DD, Lee J, Villablanca P, Eng MH, Frisoli T, O'Neill BP, O'Neill WW. Transcatheter vacuum-assisted left-sided mass extraction with the AngioVac system. *Catheter Cardiovasc Interv*. 2022;100:628-35.
- Ramanan T, Maheshwari V, Iyer V, Zlotnick DM. Trans-septal AngioVac Debulking Of Mitral Valve Endocarditis. SCAI 2020. Virtual conference. <https://scai-prod-public.s3.amazonaws.com/down/20an/45097.pdf> (Last accessed 15 August 2024).
- Chatterjee S, Chakraborty A, Weinberg I, Kadakia M, Wilensky RL, Sardar P, Kumbhani DJ, Mukherjee D, Jaff MR, Giri J. Thrombolysis for pulmonary embolism and risk of all-cause mortality, major bleeding, and intracranial hemorrhage: a meta-analysis. *JAMA*. 2014;311:2414-21.
- Jiménez D, de Miguel-Díez J, Guijarro R, Trujillo-Santos J, Otero R, Barba R, Muriel A, Meyer G, Yusen RD, Monreal M; RIETE Investigators. Trends in the Management and Outcomes of Acute Pulmonary Embolism: Analysis From the RIETE Registry. *J Am Coll Cardiol*. 2016;67:162-70.
- Basman C, Rashid U, Parmar YJ, Kliger C, Kronzon I. The role of percutaneous vacuum-assisted thrombectomy for intracardiac and intravascular pathology. *J Card Surg*. 2018;33:666-72.
- Callese TE, Yang EH, Levi D, Srinivasa RN, Moriarty JM. Concomitant AngioVac thrombectomy and patent foramen ovale closure in a patient with a large right atrial thrombus and recent paradoxical embolic stroke. *Diagn Interv Radiol*. 2021;27:272-4.
- Al Badri A, Kliger C, Weiss D, Pirelli L, Wilson S, DeLaney ER, Jelnin V, Kronzon I, Perk G, Hemli JM, Patel NC, Raoof S, Ruiz CE. Right Atrial Vacuum-Assisted Thrombectomy: Single-Center Experience. *J Invasive Cardiol*. 2016;28:196-201.
- Seiler A, Gnadinger P, Glotzbach J, Silverton NA. Transesophageal Echocardiography-Guided Tumor/Thrombus Debulking Using the AngioVac Transcatheter Aspiration Device. *J Cardiothorac Vasc Anesth*. 2020;34:1005-9.
- Gerosa G, Bagozzi L, Tessari C, Pittarello D, Zanella F, Mancini M, Prayer-Galetti T, Cillo U, Zattoni F, Tarzia V. Proof of Concept: Microinvasive AngioVac Approach in Renal Cell Carcinoma With Atrial Thrombosis. *Ann Thorac Surg*. 2021;112:e193-6.
- Ranka S, Mohanany D, Agarwal N, Verma BR, Villablanca P, Mewhort HE, Ramakrishna H. Chronic Thromboembolic Pulmonary Hypertension-Management Strategies and Outcomes. *J Cardiothorac Vasc Anesth*. 2020;34:2513-23.
- Konstantinides SV, Meyer G, Becattini C, Bueno H, Geersing GJ, Harjola VP, Huisman MV, Humbert M, Jennings CS, Jiménez D, Kucher N, Lang IM, Lankeit M, Lorusso R, Mazzolai L, Meneveau N, Ni Ainle F, Prandoni P, Pruszczyk P, Righini M, Torbicki A, Van Belle E, Zamorano JL; ESC Scientific Document Group. 2019 ESC Guidelines for the diagnosis and management of acute pulmonary embolism developed in collaboration with the European Respiratory Society (ERS). *Eur Heart J*. 2020;41:543-603.
- Al-Hakim R, Park J, Bansal A, Genshaft S, Moriarty JM. Early Experience with AngioVac Aspiration in the Pulmonary Arteries. *J Vasc Interv Radiol*. 2016;27:730-4.
- D'Ayala M, Worku B, Gulkarov I, Sista A, Horowitz J, Salemi A. Factors Associated with Successful Thrombus Extraction with the AngioVac Device: An Institutional Experience. *Ann Vasc Surg*. 2017;38:242-7.
- Renew JR, Wittwer ED, Robb TM, Fritock MD. AngioVac Removal of a Saddle Pulmonary Embolus Using TEE Guidance and Venoarterial ECMO Support. *J Cardiothorac Vasc Anesth*. 2016;30:749-52.
- Baddour LM, Wilson WR, Bayer AS, Fowler VG Jr, Tleyjeh IM, Rybak MJ, Barsic B, Lockhart PB, Gewitz MH, Levison ME, Bolger AF, Steckelberg JM, Baltimore RS, Fink AM, O'Gara P, Taubert KA; American Heart Association Committee on Rheumatic Fever, Endocarditis, and Kawasaki Disease of the Council on Cardiovascular Disease in the Young, Council on Clinical Cardiology, Council on Cardiovascular Surgery and Anesthesia, and Stroke Council. Infective Endocarditis in Adults: Diagnosis, Antimicrobial Therapy, and Management of Complications: A Scientific Statement for Healthcare Professionals From the American Heart Association. *Circulation*. 2015;132:1435-86.
- Moreillon P, Que YA. Infective endocarditis. *Lancet*. 2004;363:139-49.
- Delgado V, Ajmone Marsan N, de Waha S, Bonaros N, Brida M, Burri H, Caselli S, Doenst T, Ederhy S, Erba PA, Foldager D, Fosbøl EL, Kovac J, Mestres CA, Miller OI, Miro JM, Pazdernik M, Pizzi MN, Quintana E, Rasmussen TB, Ristić AD, Rodés-Cabau J, Sionis A, Zühlke LJ, Borger MA; ESC Scientific Document Group. 2023 ESC Guidelines for the management of endocarditis. *Eur Heart J*. 2023;44:3948-4042.
- Mhanna M, Beran A, Al-Abdoh A, Jabri A, Sajdeya O, Al-Aaraj A, Alharbi A, Khuder SA, Eltahawy EA. AngioVac for Vegetation Debulking in Right-sided Infective Endocarditis: A Systematic Review and Meta-Analysis. *Curr Probl Cardiol*. 2022;47:101353.
- George B, Voelkel A, Kotter J, Leventhal A, Gurley J. A novel approach to percutaneous removal of large tricuspid valve vegetations using suction filtration and veno-venous bypass: A single center experience. *Catheter Cardiovasc Interv*. 2017;90:1009-15.
- Patel N, Azemi T, Zaeem F, Underhill D, Gallagher R, Hagberg R, Sadiq I. Vacuum assisted vegetation extraction for the management of large lead vegetations. *J Card Surg*. 2013;28:321-4.
- Schaerf RHM, Najibi S, Conrad J. Percutaneous Vacuum-Assisted Thrombectomy Device Used for Removal of Large Vegetations on Infected Pacemaker and Defibrillator Leads as an Adjunct to Lead Extraction. *J Atr Fibrillation*. 2016;9:1455.
- Starck CT, Dreizler T, Falk V. The AngioVac system as a bail-out option in infective valve endocarditis. *Ann Cardiothorac Surg*. 2019;8:675-7.
- Tarzia V, Ponzone M, Evangelista G, Tessari C, Bertaglia E, De Lazzari M, Zanella F, Pittarello D, Migliore F, Gerosa G. Vacuum-Implemented

Removal of Lead Vegetations in Cardiac Device-Related Infective Endocarditis. *J Clin Med*. 2022;11:4600.

34. Chu VH, Park LP, Athan E, Delahaye F, Freiburger T, Lamas C, Miro JM, Mudrick DW, Strahilevitz J, Tribouilloy C, Durante-Mangoni E, Pericas JM, Fernández-Hidalgo N, Nacinovich F, Rizk H, Krajinovic V, Giannitsioti E, Hurley JP, Hannan MM, Wang A; International Collaboration on Endocarditis (ICE) Investigators. Association between surgical indications, operative risk, and clinical outcome in infective endocarditis: a prospective study from the International Collaboration on Endocarditis. *Circulation*. 2015;131:131-40.
35. Xu J, Turaga S, Bhama J, Vallurupalli S, Dhar G. Percutaneous Aspiration (AngioVac) of a Mitral Valve Vegetation followed by a Transcatheter Mitral Valve-in-Valve Intervention. *Methodist Debaque Cardiovasc J*. 2022;18:37-44.
36. Tsilimparis N, Spanos K, Debus ES, Rohlfes F, Kölbel T. Technical Aspects of Using the AngioVac System for Thrombus Aspiration From the Ascending Aorta. *J Endovasc Ther*. 2018;25:550-3.
37. Frisoli TM, So CY, Guruswamy JG, Chebl AB, Lee JC, Eng MH. Vacuuming in Crowded Dangerous Spaces: Aspiration of Large Ascending Aortic Thrombus. *JACC Case Rep*. 2020;2:1979-83.
38. Kang J, Fleischman F, Saremi F, Shavelle DM. En Bloc AngioVac Removal of Thoracic Aortic Mass. *Tex Heart Inst J*. 2020;47:315-8.
39. Rolon S, Wood JC, Mansukhani NA, Hieb RA, Malinowski MJ, Lewis BD, Brown KR, Rossi PJ. Hybrid repair for acute aortic occlusion using

aortobifemoral bypass and AngioVac thrombectomy. *J Vasc Surg Cases Innov Tech*. 2021;7:429-32.

40. Qintar M, Wang DD, O'Neill WW, O'Neill B. Vacuum to the Rescue: Aspiration of a Large Mobile Aortic Arch Thrombus With the AngioVac System Utilizing Transcaval Access. *J Invasive Cardiol*. 2021;33:E756-7.
41. Fiocco A, Colli A, Besola L. Case report: Treatment of left-sided valve endocarditis using the Transapical AngioVac System and cerebral embolism protection device: A case series. *Front Cardiovasc Med*. 2023;10:1121488.

Supplementary data

Moving image 1. 10 cm long thrombus removed from the right atrium/superior vena cava. The patient presented with distal pulmonary embolism and a mass floating in the right atrium impinging the tricuspid valve.

Moving image 2. Inferior vena cava thrombus/tumour infiltration specimens inside the AngioVac filter.

The supplementary data are published online at:
<https://eurointervention.pcronline.com/doi/10.4244/EIJ-D-24-00245>

