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Minimally Invasive Repair of Ascending Aortic Pseudoaneurysms: An Alternative to Open Surgical Repair in High-Risk Patients

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ABSTRACT

Development of a pseudoaneurysm of the ascending aorta is an uncommon complication of aortic surgery. Several nonsurgical techniques are available for treatment of ascending aortic pseudoaneurysms (AAPs). This report outlines a single-center retrospective experience with 14 nonsurgical procedures for treatment of AAPs in 10 patients. Modified stent grafts, septal defect occlusion devices, coil embolics, and liquid embolics were deployed by transthoracic and endovascular approaches. Complete stasis of the AAP was achieved in 7 of 10 patients (70%). Mean postprocedural recoveries occurred within 3.5 days. Nonsurgical techniques for repair of AAPs offer a comparatively safe and effective alternative to open surgical repair.

ABBREVIATIONS

AAP = ascending aortic pseudoaneurysm, TEE = transesophageal echocardiography, VSD = ventricular septal defect

Pseudoaneurysms of the ascending thoracic aorta are an uncommon but feared complication following surgeries involving the aortic valve and aortic root (1,2). Open surgical repair of ascending aortic pseudoaneurysms (AAP) remains the standard of care; however, repeat surgical intervention is associated with high morbidity and mortality due to risk of AAP rupture with repeated sternotomy (3,4). Furthermore, these procedures are associated with lengthy inpatient recovery times (5). Conservative management is generally not advisable, as spontaneous pseudoaneurysm rupture is almost uniformly fatal (6). Considering potential decrease in hemorrhage, overall complication rate, and improved inpatient recovery times, nonsurgical treatment options are therefore highly attractive. This paper describes the outcomes of AAPs treated with minimally invasive techniques at a single institution.

MATERIALS AND METHODS

Institutional review board approval was obtained for this retrospective study. Analyses of patient demographics, procedural details, and outcomes were performed. All cases of ascending thoracic aortic pseudoaneurysm repair performed between December 2015 and October 2018 were reviewed. All patients underwent contrast-enhanced computed tomography (CT) studies before the procedure was performed.

Each patient was reviewed for surgical, endovascular, or percutaneous management with a collaborative multidisciplinary team. Treatment approach (percutaneous, endovascular, or combined percutaneous and endovascular) was determined on a case-by-case basis based on AAP size and position, AAP neck diameter, and operator preference. Access sites included common femoral artery (n = 12; 86%),

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Figure E1 can be found by accessing the online version of this article on *www.jvir.org* and clicking on the Supplemental Material tab.

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Table 1. Patient Demographics

Patient	Age	Sex	Symptoms	Prior Sternotomies	Size of AAP (cm)	Size of Enhancing Portion of AAP (cm)	Anticoagulation at Time of Procedure	Time from Diagnosis to Treatment (days)
1	57	M	Chest pain	4	4.7 × 2.8	2.5 × 1.0	+	84
2	58	M	-	1	4.2 × 2.3	3.3 × 2.1	+	88
3	37	F	Hemoptysis	1	3.5 × 2.2	2.4 × 1.4	-	2
4	55	F	-	2	5.0 × 3.5	3.1 × 2.2	+	1562
5	68	M	-	2	2.1 × 2.1	1.6 × 1.4	-	326
6	70	M	-	2	5.4 × 2.1	4.2 × 2.1	-	48
7	76	M	Epigastric pain	2	6.3 × 4.4	4.3 × 3.4	+	7
8	68	M	Endophthalmitis	1	9.1 × 6.1	8.4 × 5.4	-	4
9	80	F	Dyspnea	1	8.9 × 5.6	6.8 × 5.3	+	2
10	55	M	-	2	4.7 × 3.1	2.1 × 1.0	+	7

direct percutaneous access through the chest wall (n = 8; 57%), axillary artery (n = 1; 7%), and or artery (n = 1; 7%), with a median arterial sheath size of 8-Fr (range 5–22 Fr). All but 1 case, performed percutaneously, involved use of common femoral arterial access for placement of a flush catheter to perform postprocedural aortography. Embolization agents included endovascular coils (n = 7; 50%), ethylene vinyl alcohol copolymer (n = 4; 29%; Onyx, Medtronic, Dublin, Ireland), ventricular septal defect (VSD) closure devices (n = 2, 14%), modified aortic stent grafts (n = 2; 14%; Medtronic), Valiant aortic extender endoprosthesis (n = 1; 7%; Gore Excluder line; Gore, Newark, Delaware), and atrial septal defect closure devices (n = 1, 7%).

A total of 14 consecutive procedures performed in 10 patients between 2015 and 2018 were included for analysis, consisting of 7 men and 3 women whose median age was 63 ± 43 years old. Patients had a mean of 1.8 ± 0.9 previous sternotomies. Patient demographics are summarized in Table 1.

Mean fluoroscopy time was 19.8 minutes ± 14.2 with a mean air kerma of 2,614.2 ± 2,244.7 mGy. Mean pseudoaneurysm size was 5.6 ± 2.1 cm × 3.5 ± 1.4 cm, with a mean enhancing portion of 3.9 ± 2.1 cm × 2.6 ± 1.6 cm. Mean time from procedure to first follow-up imaging study (CT or angiography) was 59 ± 90 days. Patients were followed with a mean of 2 ± 2 imaging studies. Clinical outcomes are outlined in Table 2.

Cases performed with CT guidance (Fig 1) involved transthoracic advancement of a Chiba needle (Cook, Bloomington, Indiana). After needle position was confirmed by CT, a 0.014-inch Transend wire (Stryker, Kalamazoo, Michigan) was passed into the pseudoaneurysm sac, followed by a straight Renegade STC-18 microcatheter (Boston Scientific, Marlborough, Massachusetts). The Chiba needle was stabilized, and the patient was transferred to the angiography suite where needle position was confirmed with an arteriogram of the pseudoaneurysm sac. Embolic material (coil embolic, liquid embolic, or combination) was deployed through the microcatheter system, after which the microcatheter was withdrawn and the needle track embolized using an absorbable collagen hemostat (Avitene; Bard, Franklin Lakes, New Jersey) slurry to the level of the sternum. Procedures in cases in which an endovascular approach (Fig 2) was used were performed under fluoroscopic guidance and, when necessary, using adjunctive intravascular ultrasound imaging. Transesophageal echocardiography (TEE) was used in selected endovascular and percutaneous cases to assist in guidance of the transthoracic needle placement, stent graft landing zone, and postprocedural assessment of flow within the AAP (Fig E1 [available online on the article's Supplemental Material page at *www.jvir.org*]). Those cases in which a stent graft was deployed involved a guidewire traversing the lesion, whereas those that used septal occluder devices required accessing the AAP with a guidewire and subsequent exchange for a catheter to accommodate the device. Stent grafts were trimmed to size on the back table by using electrocautery after landing zone measurement with preprocedural CT and intraprocedural TEE.

RESULTS

Five patients (1, 2, 4, 9, and 10) demonstrated residual enhancement of the pseudoaneurysm sac on follow-up CT imaging (mean interval of 89.8 ± 142.4 days); 4 patients proceeded to reintervention. Patient 2 demonstrated minimal residual enhancement of the pseudoaneurysm sac on completion angiography during the procedure, but it was believed that this would likely resolve due to altered sac hemodynamics. Patient 9 underwent 2 attempts at AAP repair and was subsequently lost to follow-up. Of the 4 patients who underwent a second intervention, only 1 showed some persistent filling on follow-up examination. Mean postprocedural hospital stay was 3.5 ± 3.2 days.

Overall complication rate was 3 of 14 (21%). One patient (patient 7) experienced postprocedural acute kidney injury, possibly related to intra-arterial contrast load. That patient was treated with hemodialysis, and renal function returned to baseline. One patient (patient 9) transitioned her care to another institution after a second treatment. Follow-up imaging obtained after her transfer showed the VSD closure device had dislodged into the pseudoaneurysm sac. One

Table 2. Clinical Outcomes

Patient	Procedures	Treatment Approach	Embolic Used	Stent graft Size (mm)	Residual Perfusion at Time of Procedure	Residual Perfusion First Follow-up Imaging	Time to Discharge (days)	Time to First Follow-up Imaging (days)	Time to Latest Follow-up Imaging (days)	Number of Follow-Up Imaging Studies (CT or angiography)	Alive at Follow-up	Cause of Death
1	1	Percutaneous	Coils		No	Yes	1	55	141	7	Yes	
1	2	Percutaneous	Coils		No	No	4	3	734	4	Yes	
2	3	Percutaneous	Coils		No	Yes	2	118	261	4	No	Respiratory failure
3	4	Endovascular	Stent graft	40 × 60	No	No	6	2	7	1	Yes	
4	5	Percutaneous	Coils, Onyx		Yes	Yes	1	1	304	3	Yes	
4	6	Percutaneous	Coils, Onyx		No	No	1	1	58	1	Yes	
5	7	Endovascular	Stent graft	36 × 45	No	No	2	188	288	1	Yes	
6	8	Percutaneous	Coils, Onyx		No	No	0	58	226	3	Yes	
7	9	Endovascular	VSD Closure Device		No	No	11	1	11	1	Yes	
8	10	Endovascular	Stent graft	42 × 100	No	NA	NA	NA	NA	0	No	Acute aortic insufficiency
9	11	Endovascular	ASD Closure Device		Yes	Yes	7	3	12	2	Yes	
9	12	Endovascular	VSD Closure Device		Yes	Yes	3	3	3	1	NA	
10	13	Percutaneous	Onyx		Yes	Yes	6	300	454	5	Yes	
10	14	Percutaneous	Coils		No	No	2	97	97	1	Yes	

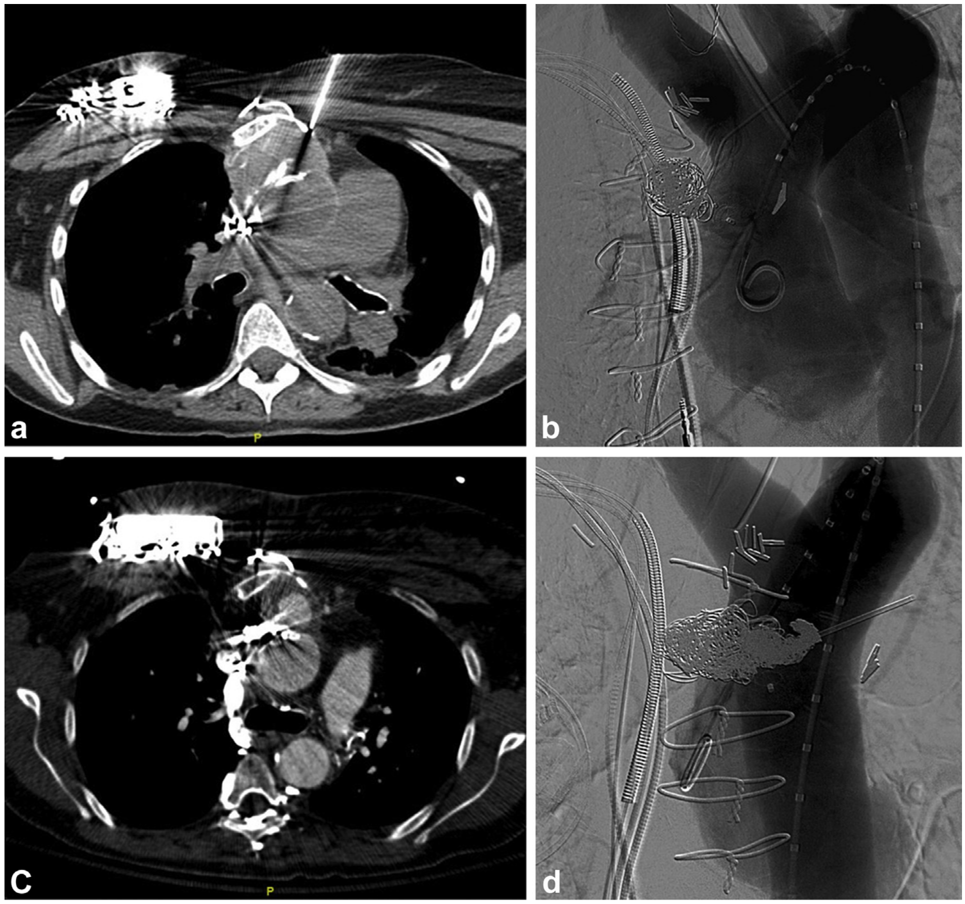

Figure 1. Percutaneous transthoracic approach in patient 1. **(a)** Axial nonenhanced CT. Percutaneous transthoracic 19-gauge Chiba needle (arrowhead) is shown approaching the ascending aortic pseudoaneurysm (arrow) in a patient with a history of bicuspid aortic valve and surgical repair of an ascending aortic aneurysm. A Renegade STC-18 microcatheter and V-18 microwire (Boston Scientific, Marlborough, Massachusetts) were used to secure access before transferring the patient from the CT scanner to the interventional radiology suite (not shown). A septal occluder device (curved arrow) is partially visualized, related to prior attempted closure of the AAP at an outside facility. **(b)** The AAP was embolized through the transthoracic Chiba needle by using Interlock coils (Boston Scientific), seen on digital subtraction angiography (*DSA*) (broad arrow). Absorbable collagen-based hemostatic material slurry was then used to seal the pseudoaneurysm sac and to embolize the percutaneous needle track to the level of the sternum. **(c)** Contrast-enhanced CT at the follow-up examination 2 months later shows a small area of persistent filling within the pseudoaneurysm (arrow). Coils (broad arrow) and the existing septal occluder device (curved arrow) are partially seen. **(d)** Postembolization angiography after repeated percutaneous embolization shows enlargement of the coil pack (broad arrow) and no further filling. Contrast-enhanced CT performed 3 days after the second procedure demonstrated no contrast enhancement of the AAP (not shown).

intraprocedural death occurred (patient 8). That patient's death represents the only major complication encountered in this series, and it occurred in a patient who underwent endovascular repair of a wide-necked, mycotic ascending aortic pseudoaneurysm. This was the only patient in the cohort treated for a pseudoaneurysm of infectious origin, further contributing to the risk of the procedure. To gain adequate seal, the target proximal landing zone included the sinotubular junction. Following deployment of the modified Valiant thoracic stent graft (Medtronic) with successful exclusion of the pseudoaneurysm sac, pulseless electrical activity ensued. Despite an attempt at cardiopulmonary resuscitation, the patient died on the angiography table. Autopsy findings suggested acute aortic insufficiency, likely due to stretching of the aortic annulus, as the immediate cause of death. One procedure (in patient 7) was aborted due to unsuccessful passage of a septal occluder device across the neck of the pseudoaneurysm, although no adverse complication occurred. The AAP was successfully treated 4 days later with a VSD closure device. Eight of 10 patients were alive at last follow-up; the second death, which was attributable to pneumonia, was likely unrelated to the procedure.

For comparison, results from open surgical repair of AAPs in a lower-risk cohort at the authors' institution between 2014 and 2017 were analyzed. Eleven patients were treated with open repair during that time. The average time to discharge was 11.2 $\pm$ 4.1 days, compared to discharge time in the nonsurgical cohort, unpaired single-tail 2-sample t-test demonstrated a statistically significant increase in inpatient recovery times ($P = .0005$). Complications occurred in 5 of 11 cases (45%).

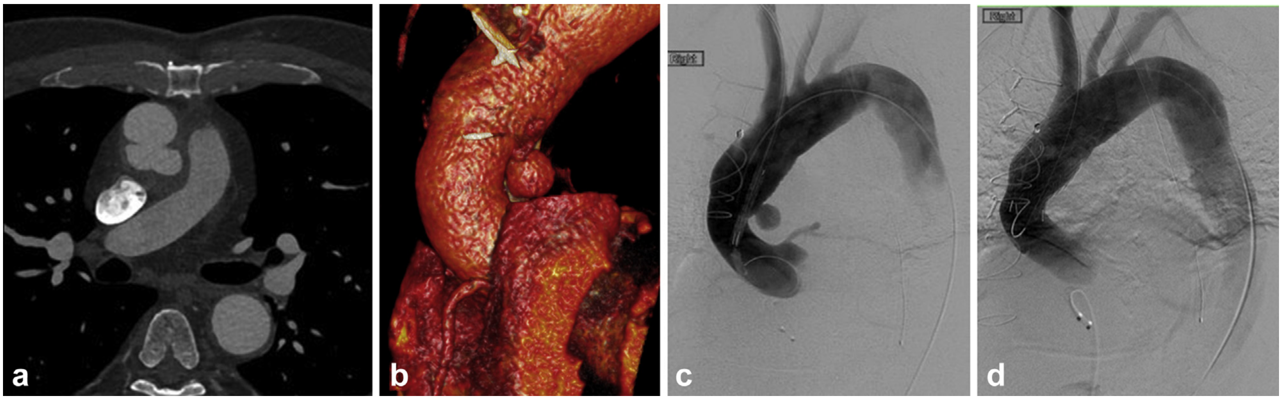

Figure 2. Endovascular treatment approach using a modified stent graft in patient 5. **(a)** Pretreatment contrast-enhanced CT shows an AAP arising from the posterior aspect of the aortic root (arrow). **(b)** Volume-rendered reconstruction confirms the posterior position of the AAP. **(c)** Access to the right axillary artery was achieved by cutdown with the assistance of cardiothoracic surgery due to the exaggerated angle of the aortic arch. digital subtraction angiography (*DSA*) shows the stent graft delivery device passing into the ascending aorta through the right brachiocephalic artery. The under-used modified stent graft (broad arrow) is positioned across the AAP (arrow). **(d)** DSA after deployment of the modified stent graft (broad arrow) demonstrates complete exclusion of the AAP. Follow-up contrast-enhanced CT 10 months after treatment shows complete thrombosis of the excluded AAP (not shown).

Postoperative mortality occurred in 1 open surgical case (9%). Compared to surgical treatment, there was no significant increase in the odds of complications in the nonsurgical cohort (odds ratio: 0.33; 95% confidence interval: 0.06–1.87).

DISCUSSION

Development of an AAP is a rare and feared complication of surgery involving the aortic root. Given the almost universal fatality of rupture, intervention is essential. Open surgical repair is the gold standard but is associated with high morbidity and mortality in certain populations (4). Various case reports and case series have demonstrated that minimally invasive techniques can offer a good alternative to standard open repair, especially in candidates in whom the risk of redoing sternotomy is considered prohibitive (7). This series demonstrates success with several methods of closure, including septal closure devices, coil embolics, liquid embolics, modified aortic stent grafts, and combinations thereof.

Open surgical repair does not preclude AAP recurrence, and repeated surgical repair poses a greater challenge given the need of sternotomy and frequent necessity of perioperative circulatory bypass techniques (5). In contradistinction, cases of incomplete embolization may be followed noninvasively, and repeated interventions may be performed as needed. The long-term relevance of incomplete occlusion of AAPs is unknown. As such, regular follow-up with contrast-enhanced CT is an important component of care for patients who receive nonsurgical treatment.

In this series, patients had a postprocedural hospital stay of 3.5 ± 3.2 days. In 1 single-center retrospective analysis of 43 patients who underwent surgical repair of aortic pseudoaneurysms, postsurgical hospital stay was 15 ± 14 days (8). Shorter recovery times are likely attributable to the fact that open surgical repair usually requires sternotomy and circulatory arrest, whereas the chief concerns in percutaneous and endovascular repairs are hemostasis at arteriotomy sites (3). Causes for hospital stays greater than 1 day were supervised resumption of therapeutic anticoagulation (n = 3), monitoring of fever to resolution (n = 1), treatment of pre-existing pressure wounds and management of systemic lupus erythematosus symptoms (n = 1), treatment of hospital-associated pneumonia (n = 1), treatment of acute kidney injury (n = 1), and treatment of lower extremity deep venous thrombosis (n = 1).

Complication rates in this series were relatively low. There were no cases of severe bleeding. No patients required postprocedural blood transfusion. One major complication was encountered in a critically ill patient with a large mycotic AAP described above. By contrast, open repair was associated with considerable perioperative morbidity and mortality. For example, in 1 series of 43 patients who underwent open repair of AAPs, 39% of cases experienced complications, including early reoperation for excessive bleeding, pneumonia, mediastinitis, and atrioventricular block (8). In another series of 11 patients treated with open repair, 2 died intraoperatively (5). These figures appear commensurate with data from the authors' institution.

Small sample size in this series limits evaluation of associations, such as in the relationship of aneurysm size to rate of initial treatment failure. Given the novelty of these procedures, there is no standardization of methods chosen to treat a given lesion; rather, treatment is based on anatomic considerations and operator preference. As this series was retrospective, direct comparison between surgical and nonsurgical cases is lacking; surgical cases referred to herein are compared because they were treated during nearly the same interval as the nonsurgical patients but were not matched control cases. Finally, frequent referral of patients from outside hospitals, follow-up outside of the authors' institution, and variability in insurance contribute to a wide variation in some important metrics including time from diagnosis to treatment and time from treatment to first imaging follow-up. New data will continue to be collected, and conclusions may be strengthened by means of collaborative efforts among institutions.

A percutaneous and endovascular approach to repair AAPs is a reasonable alternative to open surgical repair. It is conceivable that percutaneous and endovascular repair methods may also represent a valid temporizing measure until patients can undergo surgery or more definitive nonsurgical repair. Currently, the studied patient population represents those for whom surgical risk was considered prohibitive. However, given the success rate of AAP closure, decreased procedural complexity compared with open repair, and low complication rate, increased study of the potential role of these techniques in a larger, multi-institutional scale is warranted.

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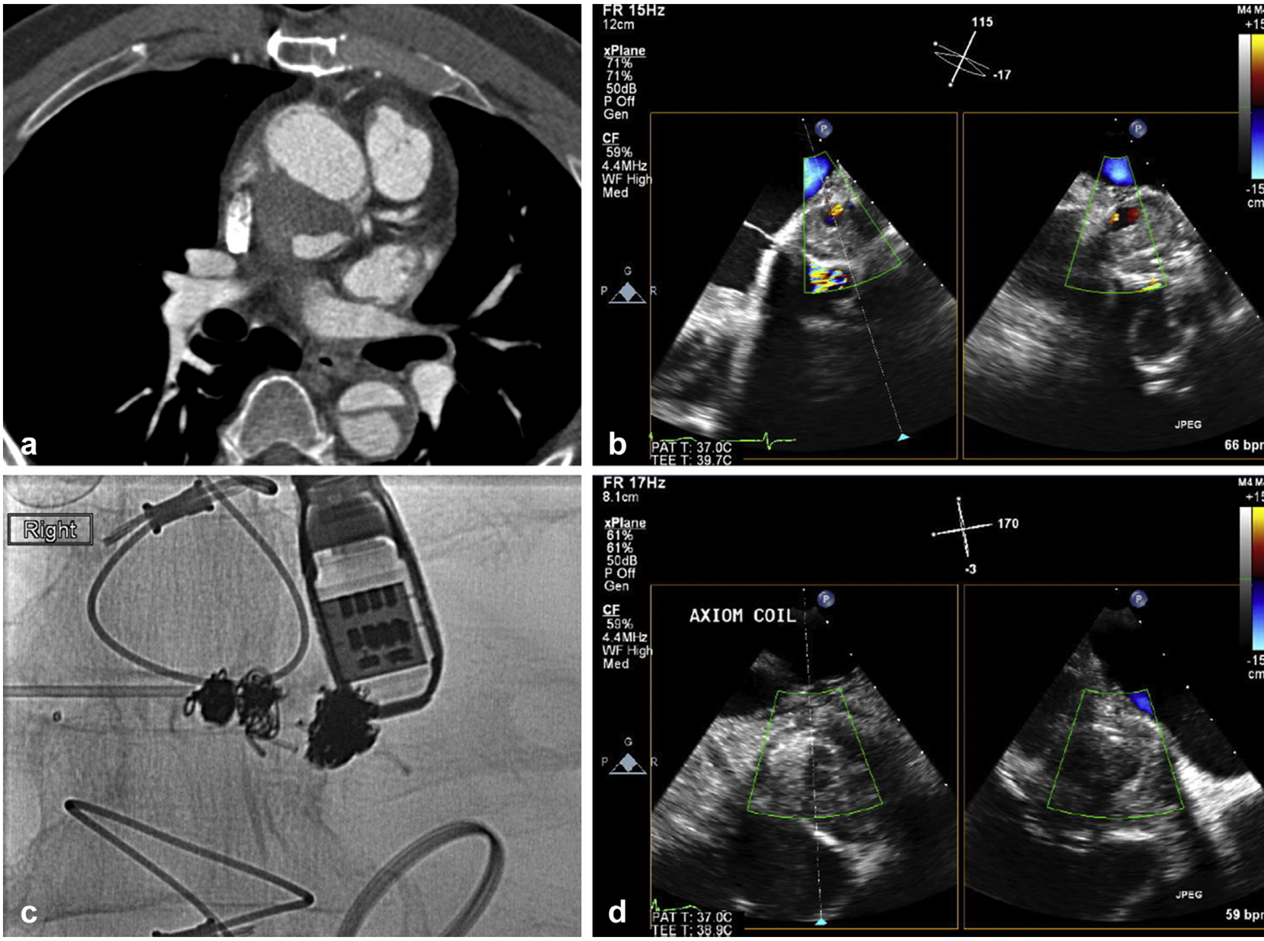

Figure E1. Percutaneous transthoracic approach with TEE assistance in patient 10. **(a)** Contrast-enhanced CT shows thrombus (arrow) filling most of an AAP arising from the posterior aspect of the true lumen of the aorta (arrowhead). A small amount of contrast filling is seen within the AAP (broad arrow). **(b)** Preprocedural TEE shows mostly thrombosed AAP (arrow) with a small area of flow seen with Doppler (broad arrow) corresponding to the area of opacification on CT. **(c)** Spot fluoroscopy image obtained during the intervention shows embolic coils being deployed into the AAP (arrow) through a percutaneous Chiba needle (arrowhead). **(d)** Postprocedural TEE with Doppler shows no persistent flow within the AAP (arrow).