Open Thrombectomy for Primary Aortic Thrombus in Thoracic Aorta

**Methods:**
- 10 patients with primary aortic thrombus located on various levels of thoracic aorta
- 9 of those underwent open thrombectomy

**Results:**
- No operative mortality observed
- 2 patients developed recurrence due to difficulty managing anticoagulation, one underwent redo thrombectomy, one managed medically

**Implications:**
Open thrombectomy remains an excellent treatment modality for primary aortic thrombus
Surgical Management of Primary Aortic Thrombus in Thoracic Aorta

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Glossary of Abbreviations:
BMI (body mass index), CPB (cardiopulmonary bypass), CTA (CT angiography), HIV (human immunodeficiency virus), PE (pulmonary embolism), PAT (primary aortic thrombus), SCA (subclavian artery), SMA (superior mesenteric artery), TEE (transesophageal echocardiography)

Data Availability Statement
All the co-authors have full access to the patient data. Also, all the datasets analyzed in the present study are available from the corresponding author on reasonable request.

Central Message (163 characters)
The paper demonstrates that open aortic thrombectomy via median sternotomy or thoracotomy can be done with low morbidity and mortality for primary aortic thrombus.

Perspective Statement (225 characters)
Primary aortic thrombus is a rare phenomenon with little existing published data. We hope to add our findings to the current literature so that surgeons and clinicians may have more resources to help managing their patients.

Central Picture Legend (90 characters)
Nine patients with PAT on various locations of thoracic aorta underwent open thrombectomy.
Abstract (239 words)

**Objective:** Primary aortic thrombus (PAT) in the absence of underlying aortic pathology such as atherosclerosis or aneurysm is quite rare and presents with various symptoms related to distal embolization. Treatment options include anticoagulation alone, open surgical thrombectomy, endovascular repair or a combination of these. The optimal management remains controversial.

**Methods:** Between 2016 and 2020, a total 10 patients (6 female, mean age 49.1 years) presented to our institution with PAT in the thoracic aorta. All patients were active tobacco users, 6 patients were found to have an underlying hypercoagulable state. Locations of the PAT included the ascending aorta in 4, the descending thoracic aorta in 3, and the aortic root, aortic arch, and thoracoabdominal aorta in 1 each. At presentation, 2 patients had developed myocardial infarction, and 2 others had cerebral infarction. All the patients, except 1 who was managed medically for PAT, underwent open surgical thrombectomy via either sternotomy or left thoracotomy. Concomitant procedures included coronary artery bypass grafting in 2 and pulmonary thromboembolectomy in 1. There were no operative mortalities. During a median follow-up of 18 months, 2 patients developed recurrent PAT primarily due to lack of compliance with anticoagulation. One required redo open thrombectomy. Two patients were found to have mesenteric ischemia requiring small bowel resection.

**Conclusions:** Open surgical thrombectomy of the thoracic aorta can be performed with low mortality and morbidities, however PAT can recur, especially in patients who have difficulty managing anticoagulation.

**Keywords:** primary aortic thrombus, distal embolization, open repair, hypercoagulable state
INTRODUCTION

Primary aortic thrombus (PAT) in the absence of underlying aortic pathology such as atherosclerosis or aneurysm is quite rare and usually presents with various symptoms related to distal embolization. The symptoms can vary depending on the location of the PAT and organs affected. Although the definitive cause of thrombus formation is usually unknown, many patients have an underlying hypercoagulable state. Some physicians prefer conservative management because of their concerns about possible recurrence and questionable benefits from a complex operation, however, a delay or failure in conservative treatment can cause serious complications. Interventional treatment options include open surgical thrombectomy or thoracic endovascular aortic repair (TEVAR). The optimal management remains controversial and there is no clear consensus.

SUBJECTS AND METHODS

Between October 2016 and December 2020, a total of 10 patients were admitted to our institution with evidence of PAT. We reviewed the medical charts, cardiovascular images and the operative records to identify the patient characteristics, end-organ dysfunctions, operative techniques used, and surgical results. Mid-term outcomes were determined from clinic records when available or from written correspondence with patients’ physicians. This study was approved by the Temple University Institutional Review Board (Protocol number: 28911, approved on November 2, 2021). Patient consent requirements were waived.

Indications
At the time of clinical presentation, all the patients underwent CT angiography (CTA) as well as transthoracic and/or transesophageal echocardiography (TEE) for definitive diagnosis. The presence of an intracardiac thrombus was first ruled out. The exact locations and characteristics of the PAT were evaluated with these imaging studies. Surgical decisions were made depending on the location, size and characteristics of the thrombus, end-organ dysfunction, and/or poor response/resistance to medical management including IV anticoagulation. As a routine screening, all the patients underwent hematology consultation to screen for a hypercoagulable state.

**Patient Follow-up**

Patients were followed up for 2 to 4 weeks by the attending surgeon at an outpatient clinic, and every 3 to 6 months by the referring physician thereafter. Additional image studies were performed when the patients developed any further symptoms.

**RESULTS**

**Patient Characteristics**

The baseline patient characteristics are shown in Table 1. Of these 10 patients, 6 were female, and the mean age was 49.1 ± 9.4 years (median, 48 years). Obesity was very common (mean body mass index (BMI), 32.1 ± 5.2, median 33.6), in fact 7 patients had a BMI of more than 30. All the patients were active smokers at the time of initial presentation, and 6 patients had a hypercoagulable state, including Leiden V factor in 2, idiopathic thrombocytosis in 2, and hyper-homocysteinemia in 2. Two patients were found to have antinuclear antibodies, and one had decreased levels of both antithrombin III and Protein S. Two patients were active oral substance abusers. One patient was on highly active antiretroviral therapy for HIV infection. There were no
female patients who were on oral contraceptives in this series. The locations of the PAT included the ascending aorta in 4, the descending thoracic aorta in 3, and the aortic root in 1, the aortic arch in 1, and the thoracoabdominal aorta in 1. Two of these patients had multiple thrombi. A distal embolization was common, especially in those who had PAT in the descending thoracic aorta, as shown in Table 1.

Surgical Approach and Intraoperative Findings

All open surgeries were performed under standard cardiopulmonary bypass (CPB). In terms of surgical approach, a standard median sternotomy was used for open thrombectomy of a PAT located in the aortic root and the ascending aorta, while a left thoracotomy approach was used for a PAT in the descending thoracic aorta. One patient (Patient 3, Figure 2), who was found to have multiple large thrombi on both the descending thoracic aorta and the abdominal aorta, underwent thoracoabdominal spiral incision. Intraoperative direct aortic ultrasound study (epiaortic echo) was often utilized for accurate identification of locations. Care was taken not to manipulate the aorta too much to prevent dislodgement of the thrombus. Under an aortic cross-clamping on distal ascending aorta followed by cardiac arrest with cardioplegia in sternotomy cases, while an aortic cross-clamping on both the proximal and the distal side of the aorta in thoracotomy cases with partial CPB, the aorta was opened and the thrombus was gently removed. The intima of the aorta was carefully inspected to make sure there was no residual component of the thrombus, and the inside of the aorta was copiously irrigated with saline solution. In some cases (Patients 4 and 6), a small piece of the aortic wall was also resected along with the attachment of the thrombus, and this was repaired with either direct suture closure or interposition with a Dacron vascular graft. Also, if necessary, the aortotomy incision was closed using a Dacron patch to prevent any
significant narrowing of the aorta (Patients 1 and 3). No patient required deep hypothermic circulatory arrest in this series.

One patient (Patient 2, Figure 1), who presented with ST-elevation myocardial infarction (MI), had emergency surgery. Prior to surgery, this patient underwent a coronary angiogram, which showed total occlusion of the right coronary artery due to embolization from a large thrombus located in the sinus of Valsalva of the aortic root. Another patient (Patient 8, Figure 4) who presented with non-ST-elevation MI was found to have severe proximal left anterior descending coronary artery stenosis, which appeared to be due to a thrombus. This patient was also found to have a large highly mobile thrombus in the distal ascending aorta. These two patients underwent concomitant coronary artery bypass grafting in addition to urgent open thrombectomy.

One patient (Patient 4, Figure 3), who presented with acute onset of hemiplegia and was diagnosed with cerebral infarction due to a total occlusion of the right middle cerebral artery, underwent an emergency catheter-based mechanical thrombectomy by a neurosurgical team. He was found to have a highly mobile large thrombus in the ascending aorta by CTA. A few days later, his ischemic stroke developed a hemorrhagic transformation. The decision was made to proceed with an open surgical thrombectomy of the PAT in the ascending aorta, given that his imaging and neurologic status remained stable for one week after the development of the hemorrhagic transformation. Interestingly, this patient was found to have massive bilateral pulmonary emboli (PE) by intraoperative TEE, therefore bilateral pulmonary artery thromboembolectomy was performed at the time of open thrombectomy.

One patient with a sessile PAT at the distal aortic arch (Patient 9), who developed what appeared to be retrograde cerebral infarction, was initially managed pharmacologically. This
patient did not undergo open surgery for this PAT because repeat CTA showed that the thrombus had decreased in size, responding to anticoagulation, and was discharged home.

Postoperative Management and Early Outcomes

All the patients received intravenous (IV) heparin infusion with a target activated partial prothrombin time of 60 to 80 seconds once postoperative bleeding was settled. Usually, the patients started an oral anticoagulant such as warfarin or a novel oral anticoagulant in addition to aspirin and/or clopidogrel on postoperative day 1, then IV heparin infusion was discontinued thereafter. There were no operative mortalities. All the patients had a steady recovery without any significant complications.

Patient Follow-up

During a median follow-up of 18 months (mean, 18.7 ± 15.9 months), 1 patient who had been receiving treatment for HIV infection (Patient 2) died due to pneumonia related to COVID-19 infection. There were 2 patients who suffered recurrence of PAT. One patient (Patient 3) was readmitted for chest and abdominal pain 4 months after surgery, and was found to have recurrence of the thrombus at the same location of the distal descending thoracic aorta extending to the supra-celiac and infra-renal abdominal aorta. She was placed on therapeutic IV heparin and was reimaged several days later, with CTA showing decreased thrombus burden in the aorta. Her symptoms improved and she was discharged on warfarin with a higher target INR due to the recurrence. She was later readmitted to another facility for a new onset of minor cerebral infarction, and was discharged to an acute rehabilitation facility. Another patient who developed recurrence (Patient 10) was not on any oral anticoagulant after surgery because of a previous history of
intolerance to oral anticoagulants, and instead she was on enoxaparin via subcutaneous injection. Two months later, she was readmitted for leg pain and found to have recurrent PAT at the same location in the proximal descending thoracic aorta (Figure 5), as well as an acute right popliteal artery occlusion. She underwent a right femoral artery to posterior tibial artery bypass performed by a vascular surgery team. She again presented 6 months after the index operation with left upper and lower extremity weakness due to a suspected transient ischemic attack, and a significantly worsened descending thoracic aortic thrombus since the prior study. She subsequently underwent a redo left thoracotomy, and the recurrent thrombus was excised. The new thrombus had a larger surface attachment than the original thrombus, as shown in Figure 5. She had a relatively uncomplicated postoperative course, and was discharged on postoperative day 11. She was also switched to warfarin with the hope of improved compliance. Unfortunately, she continued to have poor compliance with anticoagulation, and was readmitted for acute mesenteric ischemia secondary to the superior mesenteric artery (SMA) thrombus related to the aortic thrombus recurrence. She required extensive small bowel resections during her last admission, and was ultimately discharged to hospice. Please see Figure 6 for a graphical abstract of the study.

It is important to note that the patient (Patient 9) who did not undergo open surgery for PAT due to evidence of a decrease in size of the original thrombus, was readmitted due to a new onset of abdominal pain. Repeat CTA revealed complete disappearance of the original thrombus at the distal aortic arch, however, it demonstrated multiple thrombi at the distal SMA branches and thickened small bowel. This patient underwent small bowel resection secondary to strictures from the small bowel ischemia.

DISCUSSION
PAT is defined as thrombosis in the absence of atherosclerotic or aneurysmal disease of the aorta. As part of the criteria, there must be no cardiac source of the thrombus. This entity is exceedingly rare in clinical practice, with only a few case studies and systemic reviews in the literature. The incidence of an aortic thrombus was found to be as low as 0.45% based on autopsy data on over 10,000 bodies in the 1900s. However, the actual incidence is still yet to be determined. Due to the paucity of cases, the management of this condition is widely varied and institution-dependent, with no overriding consensus.

Disease categorization is important, and unlike aortic dissection, there is no universal classification system for PAT. Verma et al. developed a system in which a thrombus was assigned a type I-VI classification based on its anatomical location. These were as follows: type I, a mural thrombus in the ascending aorta up to the level of the origin of the left subclavian artery (SCA); type II, a thrombus located in the descending thoracic aorta, between the left SCA and celiac artery; type III, a thrombus located at the level between the celiac artery to the lowest renal artery; type IV, a thrombus located at the level between the lowest renal artery and the aortic bifurcation. The most common anatomic location for PAT is reportedly the descending thoracic aorta (38%), while the least common is the ascending aorta (12%), as seen in the meta-analysis by Fayad et al. Interestingly, 5 of our 10 patients presented with a PAT in the aortic root/ascending aorta. The classification system of Verma et al. may be useful to determine the optimal management strategy.

The most dreaded complication of an aortic thrombus is embolization to vital end organs. Unfortunately, many patients already present this at the time of diagnosis. The consequences of cerebral infarction, MI, acute limb ischemia, or mesenteric ischemia can be devastating. The decision to use anticoagulant with close monitoring and short-interval surveillance imaging should be carefully tailored to the patient and the thrombus characteristics. Features that have been
associated with a high risk for embolization and recurrent embolization include pedunculated and highly mobile lesions. In the case of a PAT in the ascending aorta or the proximal aortic arch, we prefer urgent open surgery over anticoagulation and surveillance given the risk of cerebral infarction. In fact, Fayad et al. reported in a systemic review that thrombus location in the ascending aorta and the aortic arch were the two strongest predictors of embolization recurrence.

As for the descending thoracic aorta, the risk of cerebral infarction is low. Although we observed this in 1 patient (Patient 9), retrograde embolization to the brain causing cerebral infarction is extremely rare, and this mechanism for stroke has only been theorized recently in severely atherosclerotic aortas, not those with PAT. This fact can sometimes allow for a short observation interval with anticoagulation in those who are minimally symptomatic with a descending thoracic aortic thrombus, as has been shown by some small studies. As demonstrated in 1 of our patients (Patient 9), a devastating complication (ischemic bowel) can occur during conservative management even in the course of resolution of the primary PAT. Thus, the conservative decision to anticoagulate and observe should be used cautiously, as there is still risk for distal embolization.

In recent years, TEVAR has become an attractive interventional treatment option because of its less invasiveness, especially for those with descending thoracic aortic aneurysms. This technique can be applied to some patients with PAT in the descending aorta. A literature review by Meyermann et al. found that there is a trend in more recent years to report cases describing successful TEVAR for initial management. Twenty-nine patients (39.2%) out of 74 patients enrolled in their review with descending PAT initially underwent TEVAR. Twenty-seven (93.1%) had fully excluded thrombus at the time of the procedure, with no recurrence or evidence of repeated embolic phenomena at follow-up. Needless to say, direct manipulation of the PAT during TEVAR can cause significant complication of proximal and/or distal embolization, especially if
the thrombus is highly mobile, and the surgical decision should be made carefully among a multidisciplinary team. Also, this technique cannot be applied to a PAT located at the ascending aorta and the aortic arch. Therefore, the open surgical approach should still be considered as the primary treatment in the majority of these cases. One must weigh the risks and benefits of each treatment arm and decide which option is best for the patient.

Out of our 10 patients, 2 had recurrence of the thrombus. This was apparently attributable to non-adherence to anticoagulation. One of our patients (Patient 3) had a compliance issue stemming from severe menorrhagia secondary to warfarin. Her thrombus resolved during readmission with anticoagulation alone. Another patient (Patient 10) had a longstanding history of unprovoked PE on lifelong enoxaparin, for which she had been noncompliant for years prior to the operation. In the aforementioned literature review, out of 26 patients who initially underwent medical management, 9 patients (34.6%) had persistent thrombus. While of the patients who initially underwent open surgical repair, 6 patients (31.6%) had persistent thrombus; of these patients, 4 underwent TEVAR thereafter. Therefore, continuous careful observation with optimal medical therapy is crucial regardless of the initial treatment to monitor possible recurrence and prevent devastating complications.

Limitations

The present study had several limitations. First, this was a single-center, retrospective observational study with a small sample size, which confers an inherent selection bias. Second, we had no experience utilizing the TEVAR technique in this group of patients, thus, without a control group, comparison of the results was limited. Third, the follow-up duration was short, and the late results remain unknown.
CONCLUSIONS

This case series demonstrates that open surgical thrombectomy is an excellent treatment modality for primary aortic thrombus in the thoracic aorta. However, careful postoperative management, including optimal medical therapy, is mandatory to prevent recurrence.
REFERENCES


Figure Legends

**Figure 1** (Patient 2). (a) Chest CT demonstrating a large thrombus in the right coronary sinus of Valsalva. (b) Intraoperative image of aortotomy with a large thrombus. (c) Intraoperative image following thrombectomy.

**Figure 2** (Patient 3). (a) CTA sagittal view demonstrating a large thrombus in the distal descending thoracic aorta extending to the supra celiac abdominal aorta. (b) CTA sagittal view of abdomen showing multiple large mural thrombi in the abdominal aorta. (c) CTA axial view demonstrating that approximately half of the aortic lumen was obliterated by the mural thrombus with clear evidence of splenic infarct.

**Figure 3** (Patient 4). (a) Selective cerebral angiogram showing a total occlusion of the right middle cerebral artery. (b) Successful recanalization of the artery after mechanical thrombectomy. (c) Hemorrhagic transformation in the right lentiform nucleus adjacent to the recent embolic stroke. (d) CTA chest coronal view demonstrating a large ascending aortic thrombus. (e) Aortic resection with a firmly adhered thrombus. (f) Bilateral large pulmonary artery thrombi.

**Figure 4** (Patient 8). CTA images showing a pedunculated ascending aortic thrombus: (a) sagittal, (b) coronal, (c) axial view. (d) Intraoperative image of aortotomy with a new thrombus, (e) resected specimen.

**Figure 5** (Patient 10). (a) CTA sagittal view demonstrating a large thrombus in the mid-descending thoracic aorta. (b) Surgical specimen removed during the initial surgery. (c) CTA sagittal view 6 months after the initial operation showing a recurrent large thrombus with a much wider attachment on the aortic lumen, (d) surgical specimen removed during the redo surgery.

**Figure 6.** Graphical abstract
Table 1. Patient Characteristics and Clinical Data

<table>
<thead>
<tr>
<th>No.</th>
<th>Year</th>
<th>Age</th>
<th>Gender</th>
<th>Location and Characteristics</th>
<th>End Organ Involved</th>
<th>Comorbidities / Risk factors</th>
<th>BMI</th>
<th>Surgical Procedure</th>
<th>Postop Antiplatelet /Anticoagulation</th>
<th>Late Event</th>
<th>FU (Mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2016.10</td>
<td>56 F</td>
<td>Descending thoracic aorta x3 (13, 14, 9mm, mobile)</td>
<td>Spleen, Kidney, LE</td>
<td>Factor V Leiden (heterozygous), Anticardiolipin IgM, Thrombocytosis (&gt;1000K)</td>
<td>23.4</td>
<td>Left thoracotomy, thrombectomy with and without patch repair</td>
<td>ASA</td>
<td>Warfarin</td>
<td>Superficial wound dehiscence</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>2016.12</td>
<td>49 F</td>
<td>Aortic root (right coronary sinus, 23mm, sessile)</td>
<td>STEMI, (RCA) TIA</td>
<td>HIV on HAART</td>
<td>38.4</td>
<td>Sternotomy, Thrombectomy with direct aortic repair, CABGx1 (RITA-RCA)</td>
<td>Clopidogrel</td>
<td>Warfarin</td>
<td>Died due to pneumonia</td>
<td>52</td>
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<tr>
<td>3</td>
<td>2018.12</td>
<td>35 F</td>
<td>Distal descending thoracic aorta (28mm), Distal descending, infra-renal abdominal aorta x2 (29, 42mm, sessile)</td>
<td>Spleen, Kidney, LE</td>
<td>Hyper-homocysteinemia,</td>
<td>33.3</td>
<td>Thoracoabdominal spiral approach, thrombectomy with patch repair x2</td>
<td>ASA, Warfarin (not compliant)</td>
<td></td>
<td>Thrombus recurrence (medically managed, 2019.4), CI (minor, 2020.9) Alive 2021.3</td>
<td>27</td>
</tr>
<tr>
<td>4</td>
<td>2019.3</td>
<td>47 M</td>
<td>Ascending aorta (30mm, mobile)</td>
<td>CI (Major, Right MCA)</td>
<td>Factor V Leiden (heterozygous) PE (Bilateral PA)</td>
<td>38.6</td>
<td>Sternotomy, thrombectomy with graft replacement, PTE</td>
<td>ASA, Warfarin</td>
<td></td>
<td>CTA 2020.10 showing no recurrent thrombus, Alive 2022.1</td>
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<tr>
<td>5</td>
<td>2019.7</td>
<td>60 M</td>
<td>Ascending aorta (20mm, mobile)</td>
<td>Kidney LE</td>
<td>DVT, PAD with past LE bypass, Elevated homocysteine</td>
<td>33.9</td>
<td>Sternotomy, thrombectomy with aortic resection and direct repair</td>
<td>ASA, Rivaroxaban</td>
<td></td>
<td>CTA 2021.11 showing no recurrent thrombus, Alive 2023.6, lost to Cardiac follow-up</td>
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<td>#</td>
<td>Year</td>
<td>Age</td>
<td>Location</td>
<td>Symptoms</td>
<td>Procedures</td>
<td>Medications</td>
<td>Status</td>
<td>Notes</td>
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<td>6</td>
<td>2019.10</td>
<td>61 F</td>
<td>Ascending aorta (19mm, mobile)</td>
<td>Bilateral LE, DVT, Positive anti-nuclear antibodies</td>
<td>Sternotomy, thrombectomy with direct aortic repair, Right LE embolectomy and fasciotomies</td>
<td>Warfarin</td>
<td>Alive 2021.9, lost to follow-up thereafter</td>
<td></td>
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<tr>
<td>7</td>
<td>2020.3</td>
<td>57 M</td>
<td>Proximal descending thoracic aorta (28mm, mobile)</td>
<td>Spleen, Possible lung cancer</td>
<td>Left thoracotomy, primary repair</td>
<td>ASA, Warfarin</td>
<td>Lost to follow-up</td>
<td></td>
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<tr>
<td>8</td>
<td>2020.5</td>
<td>36 F</td>
<td>Ascending aorta (16mm, mobile)</td>
<td>NSTEMI, (LAD), Substance abuse Decreased protein S and AT III activity, Elevated lipoprotein A</td>
<td>Sternotomy, Thrombectomy with direct aortic pair, CABG x1 (LITA-LAD)</td>
<td>ASA, Warfarin</td>
<td>Alive 2021.5, lost to follow-up thereafter</td>
<td></td>
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<tr>
<td>9</td>
<td>2020.7</td>
<td>47 M</td>
<td>Distal aortic arch (9mm, sessile)</td>
<td>CI, Kidney, SMA, Anti-nuclear antibody</td>
<td>Not operated for primary aortic thrombus</td>
<td>Apixaban</td>
<td>AKI, Ischemic bowel requiring resection for strictures (2020.8) Alive 2023.4, no surveillance imaging</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>10</td>
<td>2020.8</td>
<td>43 F</td>
<td>Proximal descending thoracic aorta (51mm, mobile)</td>
<td>Kidney, Spleen, SMA, Substance abuse Thrombocytosis</td>
<td>Left thoracotomy, Thrombectomy with primarily aortic repair</td>
<td>ASA, Enoxaparin (not compliant)</td>
<td>Recurrence, LE distal bypass (2021.10), redo open thrombectomy (2021.2) Extensive small bowel resection (2021.7), Discharged to hospice (2021.7)</td>
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*All patients were active smokers at the time of diagnosis.*
AKI, acute kidney injury; ASA, aspirin; AT, antithrombin; BMI, body mass index; CABG, coronary artery bypass grafting; CI, cerebral infarction; DVT, deep venous thrombosis; FU, follow-up; HAART, highly active antiretroviral therapy; HIV, human immunodeficiency virus; LAD, left anterior descending artery; LE, lower extremity; LITA, left internal thoracic artery; MCA, middle cerebral artery; NSTEMI, non-ST-elevation myocardial infarction; PE, pulmonary embolism; PTE, pulmonary thromboembolectomy; RCA, right coronary artery; RITA, right internal thoracic artery; SMA, superior mesenteric artery; STEMI, ST-elevation myocardial infarction
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Figure 1 (Patient 2)
Figure 2 (Patient 3)
Figure 3 (Patient 4)
Figure 4 (Patient 8)
Figure 5 (Patient 10)
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