SURGERY **ORIGINAL PAPERS**

COMPUTED TOMOGRAPHY IMAGING IN POST-SURGICAL SURVEILLANCE OF THORACIC AORTA REPAIR

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COMPUTED TOMOGRAPHY IMAGING IN POST-SURGICAL SURVEILLANCE OF THORACIC AORTA REPAIR (Abstract): Thoracic aorta surgery is essential for managing life-threatening conditions such as acute aortic syndromes and thoracic aortic aneurysms. Postoperative complications are increasingly detected due to advancements in imaging and surgical techniques, necessitating precise imaging protocols to differentiate true complications from mimics. **Materials and methods:** We conducted a retrospective study at the Institute for Cardiovascular Diseases Iași, analyzing 24 patients who underwent thoracic aorta surgery and subsequent CT imaging between November 2023 and December 2024. CT protocols included unenhanced, arterial, and late-phase acquisitions with ECG-gated imaging. Data on demographics, comorbidities, surgical indications, and procedures were statistically analyzed. **Results:** The cohort (79.16% male, mean age 54.83 years) presented aneurysms (38.46%) and dissections (34.6%) as primary surgical indications. Hypertension was the most prevalent comorbidity (66.66%). Common procedures included the Bentall procedure (29.62%) and thoracic endovascular aortic repair (37%). Complications were identified in 54.16% of cases, including pseudoaneurysms, intramural hematomas, and endoleaks. Symptomatic patients had a higher detection rate, but 50% of asymptomatic individuals also demonstrated complications. Reintervention was required in 16.66% of cases. **Conclusions:** CT imaging plays a pivotal role in postoperative surveillance, providing critical insights into complications and mimics. Optimized imaging protocols, including ECG-gated acquisitions and delayed-phase imaging, enhance diagnostic accuracy. Routine follow-up imaging is essential, even for asymptomatic patients, to guide timely interventions and improve outcomes in thoracic aortic surgery. **Keywords:** THORACIC AORTA SURGERY, COMPUTED TOMOGRAPHY IMAGING, THORACIC ENDOVASCULAR AORTIC REPAIR, POSTOPERATIVE COMPLICATIONS.

INTRODUCTION

Thoracic aorta surgery is a cornerstone in managing life-threatening conditions, its main indications being represented by acute aortic syndromes (AAS) and thoracic aortic aneurysms (TAAs) (1, 2). AAS defines a spectrum of life-threatening conditions characterized by damage to the aortic wall induced by similar pathophysiological mechanisms, often sharing overlapping clinical presentations and diagnostic and therapeutic strategies. This spectrum encompasses acute aortic dissection (AAD), intramural hematoma (IMH), penetrating aortic ulcer (PAU), aortic pseudoaneurysm, and traumatic aortic injuries (TAI) (3, 4).

While classic open surgical techniques remain standard for ascending aorta repair, aortic arch management has evolved with advanced open and endovascular approaches, often combined to enable more complex and extended anatomical repairs. Surgical ascending aorta repairs associating replacement of the aortic valve (with either a mechanical or biologic valve) can be done with a supracoronary ascending aorta graft (Wheat procedure, not requiring coronary reimplantation) or by employing a composite artificial graft with coronary reimplantation (Bentall and Cabrol procedures). Valve-sparing techniques include the supracoronary replacement of the ascending aorta usually with a synthetic (Dacron) graft, the Yacoub procedure and the David-valve sparing technique and its derivatives. Aortic arch repairs are often performed alongside ascending or descending aorta repairs, utilizing techniques such as hemiarch repair, “island patch” technique, and hybrid aortic arch approaches (5,6). For pathologies of the descending thoracic aorta, thoracic endovascular aortic repair (TEVAR) represents the primary interventional treatment modality, with open surgical repair reserved for patients presenting with anatomies unsuitable for endovascular approaches (7).

Surgical techniques for thoracic aorta repair often result in characteristic computed tomography (CT) imaging appearances that may resemble complications. Accurate interpretation requires awareness of these techniques, understanding the clinical contexts in which they are employed, and familiarity with the typical locations and imaging features of such mimics. For example, structures like coronary buttons, felt buttresses (pledgets and rings), occluded coronary bypass grafts, or debranching grafts may mimic pseudoaneurysms. Similarly, perigraft hematomas, seromas, or hemostatic agents can resemble perigraft abscesses, while graft kinks, elephant trunk or reverse elephant trunk procedures, and the Cabrol procedure may mimic aortic dissection. Recognizing these mimics is crucial to avoid unnecessary surgical consultations, follow-up imaging, or revisions. Optimized imaging protocols play a vital role in distinguishing true complications from their mimics. True complications of thoracic aorta repairs encompass a broad spectrum, including infections (e.g, perigraft abscess, infectious pseudoaneurysm, endocarditis, sternal dehiscence, or osteomyelitis), non-infectious prosthetic material failure (e.g., pseudoaneurysms at anastomosis or cannulation sites), hemorrhage, endograft-related issues (e.g., endoleaks, stent migration, collapse, or false lumen deployment), and pathology involving the adjacent aorta (e.g., aneurysms, aortic dissection, or intramural hematomas) (5, 8, 9, 10).

As the number of patients undergoing thoracic aorta repair increases (due to ageing population and surgical technique improvement) and imaging techniques continue to advance, the detection of complications has become more frequent. These complications, often associated with significant morbidity, may remain clinically silent, underscoring the essential role of CT imaging in patient follow-up protocols. The aim of this study is to evaluate the role of CT imaging in the post-surgical surveillance of thoracic aorta repair, with a focus on identifying complications, distinguishing between true complications and mimics, and highlighting the clinical implications of these findings in guiding patient management.

MATERIALS AND METHODS

We conducted a retrospective, single-center study on the patients who underwent CT examinations at the Institute for Cardiovascular Diseases Iași between November 2023 and December 2024. The inclusion criterion was the history of thoracic aorta surgery, as mentioned by the CT reports and confirmed by the identification of surgical thoracic aorta prosthetic material on the acquired images. In the aforementioned time frame, from the total of 2,819 CT reports reviewed, we identified 24 patients eligible for this study, who were scanned either as a part of their regular post-operative follow-up or due to the appearance of signs and symptoms suggestive of a potential complication.

The images were acquired using a 256-slice dual-source CT-scanner, using slice thickness reconstructions of 1 mm within a coverage from the thoracic inlet to the femoral arteries. For the optimal assessment of the aortic valve, root and proximal ascending aorta retrospective electrocardiographic (ECG) gating was employed. The standard protocol included unenhanced and arterial phase (employing the "Bolus-tracking" technique) acquisitions, late phase acquisitions being used only in selected cases. The iodinated contrast material was administered intravenously (preferably through a right antecubital vein) at an injection rate of 5 mL/sec, followed by a saline chaser, the total dose being adjusted according to the patient`s body weight.

Data regarding patients' demographics, comorbidities, surgical indication and procedures were collected by consulting the electronic database of the hospital, then introduced into a *Microsoft Excel* database and statistically analyzed.

RESULTS

The study cohort predominantly consisted of male patients, accounting for 79.16% of the total population. Patient ages ranged from 18 to 76 years, with a mean age of 54.83 years. The average age for male patients was 52.79 years, while female patients had a higher mean age of 63 years.

Cardiovascular comorbidities were common in the study group, with essential arterial hypertension observed in 66.66% of patients. Other notable cardiovascular conditions included bicuspid aortic valve (12.5%) and Takayasu arteritis (4.16%). Chronic heart failure was present in 25% of cases, evenly distributed between those with preserved ejection fraction and those with mildly reduced ejection fraction. Additionally, chronic coronary syndrome (12.5%) and atrial fibrillation (20.83%) were frequently identified. The young patients from our study associated systemic disorders such as Marfan syndrome and Turner syndrome, known for their induced predisposition for aortic dilatation and/or dissection. Respiratory comorbidities included obstructive sleep apnea (12.5%) and chronic obstructive pulmonary disease (4.16%). Metabolic disorders were also prevalent, with dyslipidemia identified in 62.5% of patients, chronic kidney disease in 12.5%, and type 2 diabetes mellitus in 8.33%. Three patients presented with oncologic or hematologic conditions: one case each of bronchopulmonary carcinoma, chronic lymphocytic leukaemia, and myelodysplastic syndrome (tab. I).

TABLE I.
Associated comorbidities and their prevalence in the study group

Associated comorbidity	Prevalence
Essential arterial hypertension	66.66%
Chronic heart failure	25%
Atrial fibrillation	20.83%
Chronic coronary syndrome	12.5%
Bicuspid aortic valve	12.5%
Marfan syndrome	12.5%
Turner syndrome	4.16%
Takayasu disease	4.16%
Obstructive sleep apnea syndrome	12.5%
Chronic obstructive pulmonary disease	4.16%
Dyslipidemia	62.5%
Chronic kidney disease	12.5%
Type 2 diabetes mellitus	8.33%

The primary indications for thoracic aortic interventions in the study cohort included thoracic aortic dissection in 34.6% of cases, with Stanford A dissections accounting for 23.07% and Stanford B for 11.53%. Pseudoaneurysms were observed in 19.23% of cases, distributed as 7.69% in the ascending aorta, 3.84% in the aortic arch, and 7.69% in the descending aorta. Aneurysms represented the most common indication, affecting 38.46% of patients, with 26.92% involving the ascending aorta and 11.54% the descending aorta. Less frequent indications included infectious endocarditis (3.84%) and aortic coarctation (3.84%). Notably, 71.42% of patients undergoing ascending aortic aneurysm repair presented with severe aortic valve dysfunction necessitating valvular replacement. The surgical techniques employed varied widely, with the Bentall procedure performed in 29.62% of cases and TEVAR in 37%, half of which included debranching procedures. Other approaches included the Wheat procedure (3.7%), Tirone-David procedure (11.11%), and ascending aorta replacement with Dacron grafts (14.8%). Open surgical repair of the thoracic aorta was performed in one patient with anatomy unsuitable for TEVAR (3.7%) (fig. 1). Aorto-coronary bypass for myocardial revascularization was concurrently conducted in two cases.

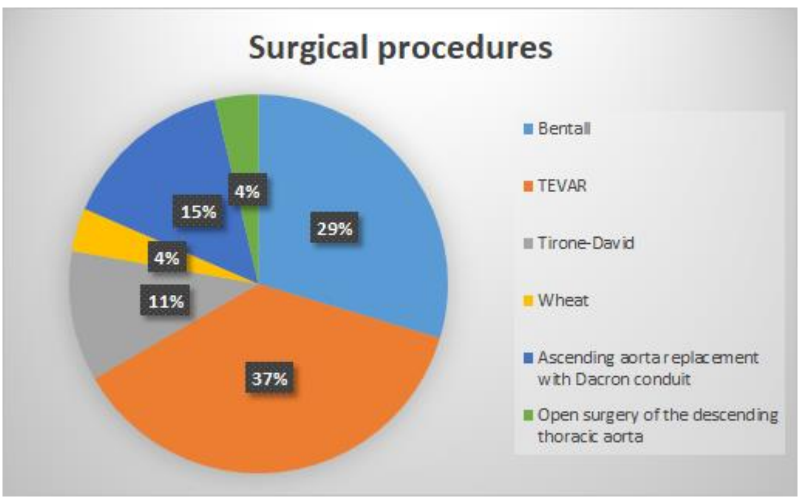

Fig. 1. Graphical representation of the surgical procedures used in the study cohort.

In terms of follow-up imaging, 66.66% of patients were asymptomatic and underwent CT scans as part of routine postoperative monitoring. A further 16.66% were scanned during the immediate postoperative period (within two weeks of surgery) as part of standard post-surgical checks. The remaining 16.66% were scanned due to symptoms suggestive of complications, including fever, chest pain, sudden-onset dyspnea, or syncope. Excluding immediate postoperative checks, the mean interval between surgery and follow-up imaging was 42.6 months.

Complications related to thoracic aortic interventions were identified in 54.16% of cases. These included perianastomotic pseudoaneurysms (12.5%), de novo dissection flaps (8.33%), intramural or periprosthetic hematomas (12.5%), surgical wound dehiscence (8.33%), and issues involving debranching conduits such as thrombosis or anastomotic stenosis (8.33%). Other complications included endoleaks (4.16%), hemopericardium (4.16%), and prosthetic material displacement (4.16%). Half of the asymptomatic patients undergoing routine follow-up imaging, as well as half of the patients scanned as an immediate postoperative check demonstrated surgery-related complications. Among symptomatic patients, CT imaging confirmed the presence of surgical complications in nearly all cases, with the sole exception being a patient in whom acute pulmonary embolism was excluded (fig. 2). 16.66% of the cases included in the study exhibited imaging findings necessitating surgical reintervention (the minor revision of the surgical wound dehiscence and the drainage of the hemopericardium not included). All the required reinterventions were successfully performed, except in one patient with infectious endocarditis complicated by a perivalvular abscess, rupture of the mitro-aortic continuity, and prosthetic material breakdown. This patient succumbed shortly after imaging confirmed the diagnosis.

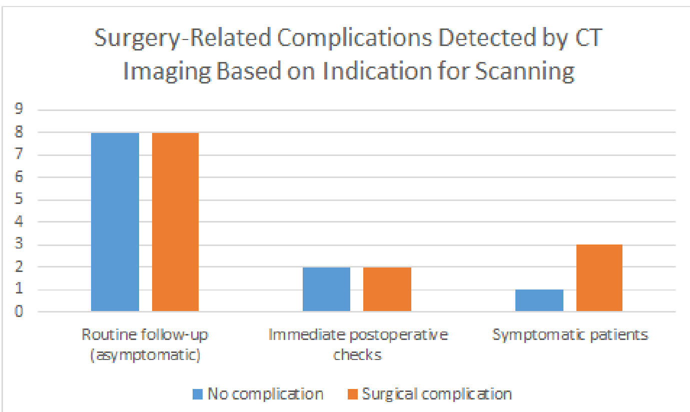

Fig. 2. Postsurgical complications detected by CT imaging based on the indication for scanning.

DISCUSSION

In our cohort, aneurysms and dissections emerged as the predominant indications for thoracic aortic interventions, accounting for over 70% of cases, both of them encountered with a higher prevalence in males. The ascending aorta was the predilect zone for the development of the aneurysmal dilatation, and Stanford A dissections were more frequently encountered than Stanford B, reflecting a distribution consistent with existing literature (11, 12, 13).

Systemic arterial hypertension was the most prevalent comorbidity in our study cohort, consistent with its established role in the literature as the primary risk factor for thoracic aortic aneurysms and the most common contributor to aortic dissection (14). Heritable thoracic aortic conditions (HTAD), bicuspid aortic valve (BAV), Takayasu disease and previous aortic surgeries are more commonly observed in patients under the age of 40 (15, 16). This trend was also observed in our study, where the four patients under 40 years of age undergoing surgery were diagnosed with Marfan syndrome (two cases, one with concomitant BAV), Turner syndrome (with associated BAV), and Takayasu disease. Metabolic comorbidities, especially diabetes mellitus is associated with a higher risk of surgical wound dehiscence, by delaying tissue repair, increasing the risk of infections, and reducing collagen synthesis due to hyperglycemia-induced vascular and immune dysfunction (17). Respiratory comorbidities significantly impact thoracic aortic pathology. Obstructive sleep apnea syndrome (OSAS) is an independent risk factor for aortic dissection and root dilation, while chronic obstructive pulmonary disease (COPD) increases the risk of descending thoracic aortic aneurysm rupture (2). Notably, the study's only COPD patient presented with a complicated descending thoracic aneurysm, manifesting as a pseudoaneurysm from a contained rupture.

In our cohort, the Bentall procedure emerged as a frequent intervention, reflecting its utility in addressing complex pathologies involving the ascending aorta, aortic root and aortic valve, particularly in patients with connective tissue disorders or severe aortic valve dysfunction. Similarly, TEVAR was the predominant approach for descending thoracic aorta pathologies, with half of these cases necessitating debranching to extend anatomical coverage-a testament to the growing reliance on hybrid techniques for managing extensive or anatomically challenging disease. In cases with favorable anatomy and after considering the risk of late dilatation of sinuses when spared, valve-sparing techniques were also employed. In cases of isolated dilation of the ascending tubular (supracoronary) aorta, the diseased ascending aorta was replaced with a tubular Dacron graft, with the distal anastomosis positioned immediately proximal to the aortic arch. Management strategies in AAS aligned with current guidelines, with open surgical repair being the standard for Stanford A lesions due to their proximal location and life-threatening nature, while endovascular approaches such as TEVAR were more commonly employed for Stanford B lesions, highlighting the shift towards less invasive techniques for distal aortic pathologies (18, 19, 20, 21, 22).

Various imaging modalities, including transthoracic echocardiography (TTE), transesophageal echocardiography (TOE), cardiac computed tomography (CCT), and cardiac magnetic resonance (CMR), are used for follow-up after thoracic aortic interventions, with CCT being the most commonly utilized and accessible. However, no standardized imaging protocol exists, as recommendations are primarily based on expert opinion or single-center studies. Follow-up schedules vary by surgical indication and procedure type: imaging after TAA repair occurs less frequently (usually at discharge, one year, and every five years if stable), while AAS repair involves closer monitoring (every six months in the first year, annually until year three, and every two-three years thereafter). TEVAR requires stricter surveillance, including imaging at one month and annually for at least five years, due to a higher risk of late reinterventions and complications such as retrograde type A dissection (RTAD) (2, 23, 24). Notably, although RTAD usually occurs at the time of the index procedure, up to 31% of the cases may be diagnosed later than 3 months after the endovascular or hybrid repair, as observed in one study patient who developed RTAD one-year post-TEVAR with debranching for a pseudoaneurysm (25, 26).

The imaging protocol at our institution is designed to ensure precise postoperative evaluation by incorporating retrospective ECG-gated acquisition, non-contrast imaging, and delayed-phase imaging (60-90 seconds delay) in selected cases, alongside the standard arterial phase. ECG gating plays a crucial role in reducing motion artifacts and improving visualization of the aortic root and ascending aorta. Retrospective ECG gating, in particular, enables optimal cinematic reconstructions throughout the cardiac cycle, leading to the detection of complications such as small leaks or pseudoaneurysms, which may only be apparent during specific phases of the cardiac cycle. Initial non-contrast images are essential for distinguishing hyperdense surgical materials from pseudoaneurysms or leaks and for identifying hyperdense blood products and postoperative hematomas that may be obscured in contrast-enhanced images (fig. 3). Delayed-phase imaging is crucial for detecting endoleaks, late opacification of the false lumen in residual dissections, and complications such as inflammatory fat stranding or rim enhancement associated with infection (8, 27, 28, 29).

One of the most significant challenges for radiologists is accurately distinguishing normal postoperative findings from potentially life-threatening complications, which necessitates a thorough understanding of surgical procedures and their potential imaging mimics. Synthetic aortic grafts can be identified on noncontrast CT scans by their hyper-attenuating appearance relative to the native aorta, a feature that may be less apparent on postcontrast images due to the adjacent blood pool. Additionally, aortic grafts often display a nonanatomic configuration, being less pliable than the native aorta. Instead of a smooth, curved morphology, they tend to have a straighter shape with associated angulations, appearing more redundant than expected. These grafts may also produce folds or kinks, which can occasionally resemble a short dissection flap on axial imaging but are readily identifiable as such on coronal and sagittal reformats (5, 8). The contrasting aspects of normal aortic graft folds and the presence of a true intimal flap in a patient who developed RTAD after TEVAR associating debranching are depicted in figure 4. Pseudoaneurysms commonly arise at anastomotic suture lines and appear as saccular outpouchings of contrast extending beyond the aorta's expected contours. They may also develop at cardiopulmonary bypass cannulation sites or locations of infection or abscesses. On CT imaging, pseudoaneurysms are characterized by a communication with the aortic lumen, typically contained by the aorta or surrounding tissues. Infectious pseudoaneurysms exhibit irregular borders, may have a saccular shape with a narrow neck, are associated with inflammatory stranding, and tend to grow rapidly. In contrast, noninfected pseudoaneurysms generally lack inflammatory stranding, grow more slowly, and are located at sites of potential structural failure, such as anastomoses or cannulation sites (5). Dense felt pledgets used to reinforce anastomotic suture lines can mimic pseudoaneurysms on CT. Differentiation relies on correlation with noncontrast images and recognition of typical locations (27, 28). The differences between felt pledgets, infectious and non-infected pseudoaneurysms are depicted in figure 3.

Thrombosis of a bypass graft used as a debranching conduit can also mimic a pseudoaneurysm if a short patent lumen persists at the ostium (8). This distinction proved crucial in a patient imaged 16 months post-TEVAR with debranching, where identifying conduit occlusion with retrograde flow through a secondary bypass graft avoided an unnecessary surgical intervention (had it been misinterpreted as a pseudo-aneurysm). Graft infections may occur at any postoperative stage, initially presenting as abnormal fluid or gas bubbles, which can be challenging to differentiate from perioperative inflammation, particularly in the early postoperative period. Delayed contrast-enhanced images are often useful for identifying rim enhancement indicative of infected peri-graft fluid or abscess formation. Advanced infections may result in pseudoaneurysms or fistulas. In the immediate postoperative setting, complex fluid and gas collections at the surgical site, including mediastinal blood products and hemostatic materials (Gelfoam© or Surgicel©), are common and often benign. Mild rim enhancement may also be normal and not indicative of infection (5, 28, 29). The timing of imaging relative to surgery is crucial for accurate interpretation of these findings.

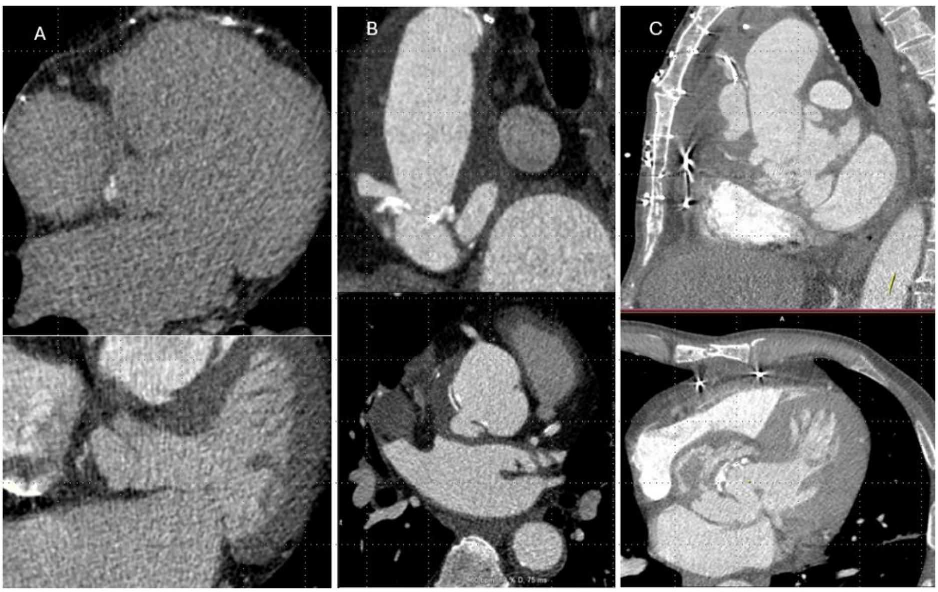

Fig. 3. A. Felt pledget in wall of the aortic root (non-coronary sinus) potentially mimicking a small pseudoaneurysm in the arterial phase (below), the confusion being avoided by the hyperdense aspect present in the non-contrast scan (above). **B.** Noninfected pseudoaneurysm in a typical location, at the proximal anastomosis, without significant stranding in the nearby tissues. Peri-graft fluid collection (seroma) with no mass effect on the ascending aorta graft. **C.** Multiple infectious, communicating pseudoaneurysms surrounding the proximal ascending aorta (with important systolic compression on the ascending aorta graft) in a patient with infective endocarditis on the prosthetic aortic valve, following Bentall procedure.

A breach is demonstrated in the mitro-aortic continuity. An epicardial cardiac stimulation wire courses through one of the pseudoaneurysm.

Fig. 4. A. Normal postoperative aspect after Bentall procedure and TEVAR associating debranching in a 42-year-old female with Takayasu disease - the normal graft folds in the axial plane are not to be confused with an intimal dissection flap (coronal and sagittal reformations are helpful in avoiding a misdiagnosis). **B.** Retrograde type A aortic dissection in a male patient one year after TEVAR associating debranching. Fortunately, the debranching conduit supplying the branches of the aortic arch originates from the true lumen.

In alignment with existing literature, the most common complications observed in the study cohort were pseudoaneurysms and TEVAR-specific complications (RTAD, type II endoleak, debranching conduit occlusion and anastomotic stenosis), particularly in cases performed under emergency conditions (2). The rate of complications necessitating re-intervention was 16.6%, closely approximating previously reported rates of approximately 10% (24). Notably, while the detection rate of complications was higher among symptomatic patients, CT imaging also identified complications in 50% of asymptomatic individuals. The critical role of CT imaging in the postoperative setting is further emphasized by its superior diagnostic capability; transthoracic echocardiography (TTE) raised suspicion of potential complications in only 15% of cases subsequently confirmed by CT.

CONCLUSIONS

This study highlights the critical role of CT imaging in the postoperative surveillance of thoracic aorta repairs, emphasizing its utility in identifying both true complications and their mimics. Complications were observed in over half of the cases, with a significant proportion detected even in asymptomatic patients, underscoring the importance of routine follow-up imaging. Advanced imaging protocols, including ECG-gated acquisitions and delayed-phase imaging, proved essential in distinguishing benign postoperative findings from potentially life-threatening conditions. Furthermore, the findings reiterate the importance of a tailored imaging approach, given the varied surgical techniques and associated imaging appearances. This study reaffirms CT imaging as an indispensable tool in guiding timely interventions, ultimately improving patient outcomes in the complex management of thoracic aortic pathology.

CONFLICT OF INTEREST AND FUNDING

The authors declare that there is no conflict of interest, and they received no specific funding regarding this scientific research.

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