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CT Scan Natural History of Post-Operative Thoracic Aortic Surgery Patients

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CT SCAN NATURAL HISTORY OF POST-OPERATIVE THORACIC AORTIC SURGERY PATIENTS. Jessica L. Kirk, Anne McB Curtis. Department of Radiology, Yale University, School of Medicine, New Haven, CT.

This study evaluated post-operative CT scans to determine the normal postoperative appearance following thoracic aorta surgery. The 188 CT studies in 102 patients were analyzed for presence of perigraft fluid collections and pleural effusions. Fifty-seven of 102 patients (56%) had perigraft fluid at the time of their first postoperative CT scan. The majority of collections disappeared over time but some persisted with 22% scans showing fluid at greater than 24 months post-operatively. Pleural effusions were present on 86% of scans in the first post-operative month and only 9% of scans after 1 year. Pseudoaneurysms occurred in 3 of 48 ascending aortic procedures (6.2%) and 4 of 38 descending aortic procedures (10.5%). Complications were rare and identifying prognostic characteristics was difficult. Postoperative CT scans frequently have benign characteristics which may be interpreted as pathological. Knowledge of operative procedures is essential for correct interpretation of postoperative CT scans.

INTRODUCTION

Successful thoracic aortic surgery repair began in the 1950s. The descending aneurysm of the thoracic aorta was repaired first in 1953 as an extension of work on surgical repair of abdominal aneurysms.[1] With the development of cardiac bypass, techniques progressed to allow ascending aorta replacement in 1956 by Cooley and DeBakey and the aortic arch in 1957 by DeBakey et al.[7,8] These repairs used allografts. Experiments with artificial constructs, including the introduction of Dacron grafts by DeBakey, led to the advanced grafts used today.

Surgical procedures on the thoracic aorta are often described by anatomic location (Figure 1). Ascending aorta repair may extend from the aortic root to the origin of the innominate artery. If the aortic valve is compromised, it is typically replaced at the same time with a composite device of a pre-attached valve and graft. Depending on the segment of aorta sacrificed, reimplantation of the coronary arteries may be necessary.[4]

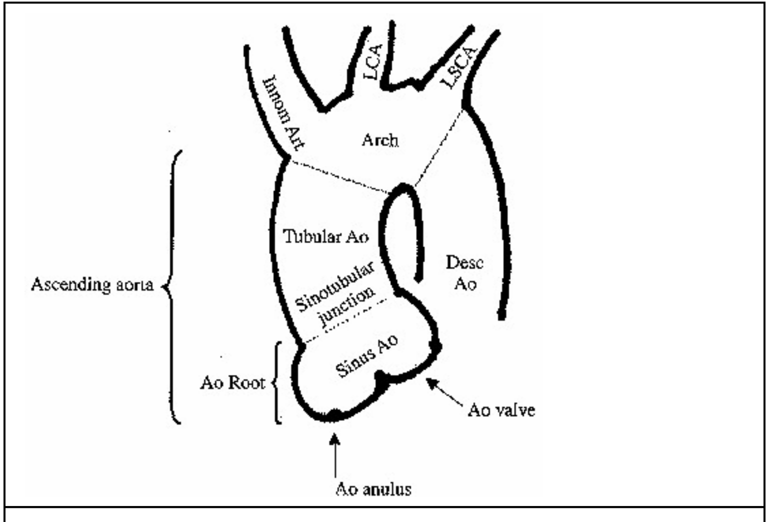

Figure 1. Illustration of Aorta Anatomy. *Ao* = aorta, *Innom Art* = innominate artery, *LCA* = left carotid artery, *LSCA* = left subclavian artery, *Desc Ao* = descending aorta.[4]

The transverse aortic arch includes the section of the aorta proximal to the origin of the innominate artery and distal to the origin of the left subclavian artery. Arch repair carries significant risk for neurological injury and patients are placed under deep hypothermic circulatory arrest (15-18° C) during the operation.[9]

Descending thoracic aorta repairs occur distal to the takeoff of the left subclavian artery and may extend to the level of the diaphragm. The artery of Adamkiewicz originates from the descending thoracic aorta and is the main blood supply to the spinal cord. When surgery extends below the diaphragm, repairs are described as thoracoabdominal aorta procedures and both vascular and cardiothoracic surgeons may be involved.[10]

Reasons for surgery

Aneurysmal dilatation is the most common indication for thoracic aorta surgery. Aneurysm is defined as a permanent localized dilatation of the aorta that results in a diameter that is at least 50% greater than normal (Figure 2).[11] Before the development of penicillin, syphilis was the major cause for thoracic aneurysm development. Today cystic medial necrosis, genetic conditions such as Marfan disease and Ehlers-Danlos syndrome, chronic dissection and bicuspid aortic valve are important contributing factors in the development of an ascending aortic aneurysm.[12] Different risk factors exist for aneurysms of the descending aorta: hypertension, coronary artery disease, obstructive pulmonary disease, and tobacco use are important in the descending aorta in addition to metabolic abnormalities and chronic dissections.[13]

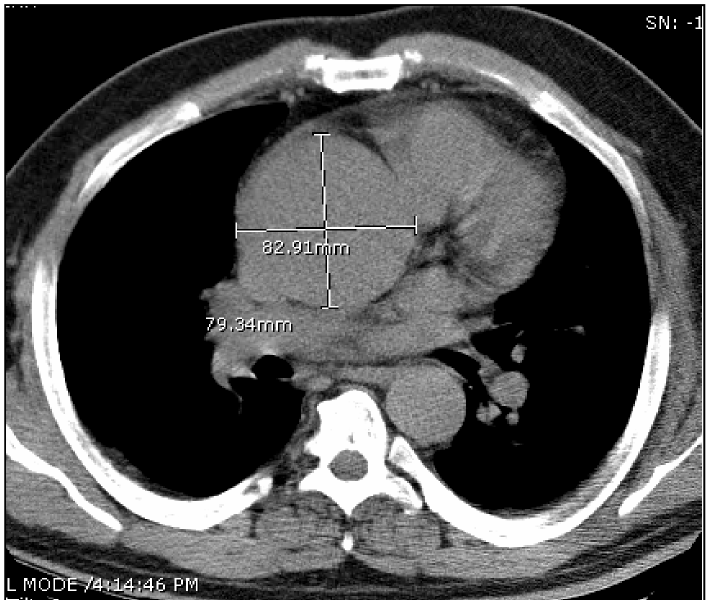

Figure 2: Example of pre-operative aneurysm in the ascending aorta. Lines indicate anterior-posterior dimensions of 7.9 cm and lateral dimensions of 8.2 cm. In general, the upper limit of normal is 5.0 cm in the ascending aorta. This patient underwent repair 2 weeks following this CT scan.

Epidemiologic studies conducted at Yale New Haven Hospital showed large or rapidly enlarging aneurysms were at highest risk for dissection and rupture.[14] This research led to development of surgical guidelines for aneurysm repair. Ascending aneurysms larger than 5.5 cm and descending aneurysms larger than 6.5 cm are typically scheduled for repair. Patients with Marfan syndrome usually have surgical correction at lesser degrees of dilatation due to increased risk of dissection and rupture from abnormal elastin fibers in the aortic wall.[15] Additionally, Marfan patients typically have valve replacements at the time of aneurysm repair because of frequent aortic root dilatation.[12]

Aortic dissection follows aneurysm as the second most frequent indication for thoracic aorta surgery. It occurs less frequently than aneurismal dilation, but has a much higher mortality.[16,17] Dissection occurs when blood separates the layers of the aortic media, usually through a tear in the intima. Hypertension is a serious risk factor for aortic dissection. Additionally, connective tissue disorders, pregnancy, and family history also contribute to risk for dissection. Historically, atherosclerosis was thought to be a major risk factor for dissection. Its contribution remains controversial although most researchers believe it is negligible.[18] Thoracic aortic dissections are typically categorized by one of two classification schemes. Debakey created the older classification scheme based on the anatomic distribution.[19] The Stanford classification combines Debakey Type I and II and correlates with prognosis (Figure 3): Type A dissections have significantly higher mortality[20,21] (Figure 4). Patients with acute Type A dissections typically have urgent repair while Type B dissections are usually managed with aggressive blood pressure reduction (Figure 5).

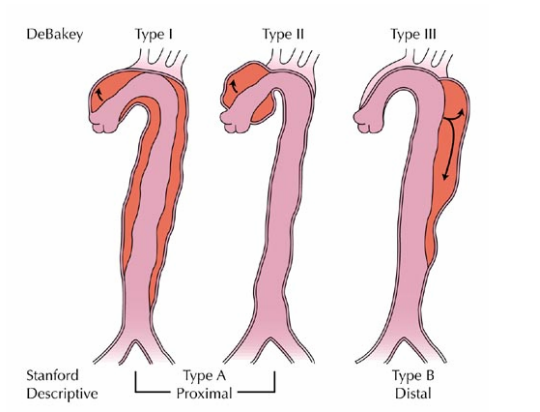

Figure 3. Comparison DeBakey and Stanford classifications for aortic dissections. ImagesMD.com

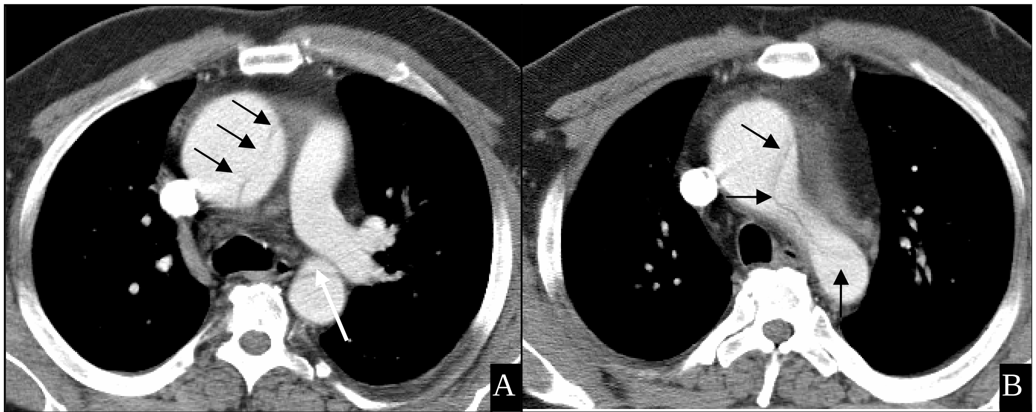

Figure 4. Example of a dissection in the ascending aorta, transverse arch, and descending aorta. A. Black arrows point to dissection flap in ascending aorta. White arrow points to dissection flap in the descending aorta. B. Dissection across the aortic arch.

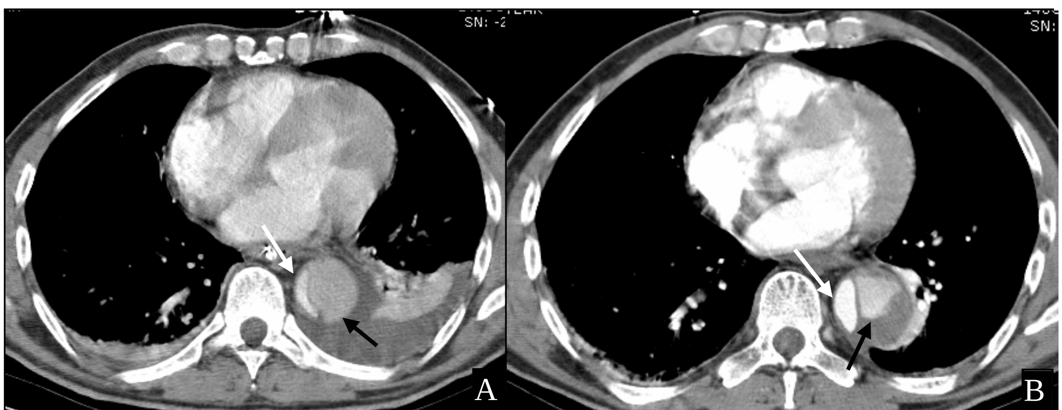

Figure 5. Example of Type B dissection in the descending aorta. CT scan in B taken two weeks prior to scan A. The true lumen of the aorta has high intensity contrast (white arrow) while the false lumen created by the dissection has lower intensity due to slower mixing of contrast and old blood (black arrow). Scan B was incorrectly interpreted as increased size of the false lumen. The patient became symptomatic and urgently went to the operating room four days later. These scans illustrate the difficulty in interpreting dissection images.

Two entities related to aortic dissection are the penetrating atherosclerotic ulcer and the intramural hematoma. On CT scan, penetrating atherosclerotic ulcers appear as a collection of contrast that extends beyond the contours of the aorta. Intramural hematomas look like a collection of contrast within the intramural wall without an intramural flap (Figure 6). These lesions are typically circumferential as opposed to the oblique angles of the aortic dissection.[18] Pathologically, ulcers originate from atheromatous plaques which disrupt the internal elastic lamina and burrow into the aortic media. Intramural hematomas are thought to occur from rupture of the vasa vasorum within the aortic wall. Patients with either ulcers or intramural hematoma are at much greater risk of rupture than patients with simple dissections. Rupture rate has been reported at 42% for penetrating atherosclerotic ulcers and 35% with intramural hematomas, compared with 4% for dissections.[18] Because of the difference in prognosis, correct diagnosis is important. A retrospective review of imaging at Yale-New Haven Hospital showed that these two variations were read as aortic dissections 16% of the time, despite their difference in prognostic outcomes.[18]

Figure 6. A. Penetrating aortic ulcer in the descending thoracic aorta. White arrow shows the ulcer as an out-pouching of contrast beyond the aortic walls. Arrowheads show resulting thickening of the aortic wall. B. Intramural hematoma in the descending aorta. Arrow points to high attenuation material within the aortic wall.[2]

Thoracic aorta surgery descriptions

Operative techniques vary with the part of the aorta involved and the type of lesion. This significantly affects post-op imaging appearance. An inclusion graft repair necessitates opening the aorta, inserting and suturing the graft, and then finally closing the aorta around the graft (Figure 7). If there is a dissection, the false lumen is obliterated and sutured closed.[22] With the inclusion graft procedure, a potential space is created that may contain thrombus or flowing blood.[23] This blood flow is not a serious concern post-operatively unless patients are hypotensive.[2] There is a greater risk of pseudoaneurysm using this technique compared with the interposition graft and is less frequently used today.[24]

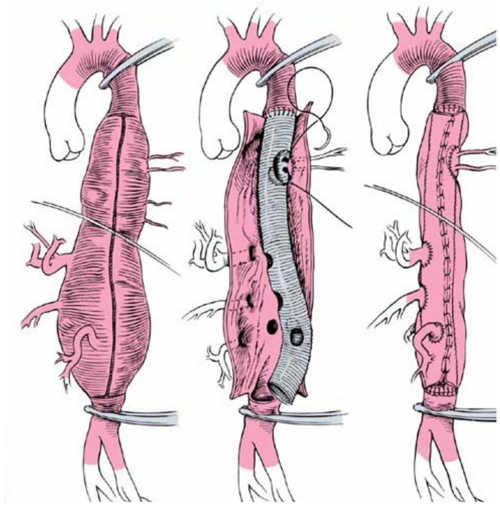

Figure 7. Example of inclusion graft technique for repair of thoraco-abdominal aortic aneurysm. Diseased aorta is opened, graft inserted, and native aorta closed around graft. *Images.MD*

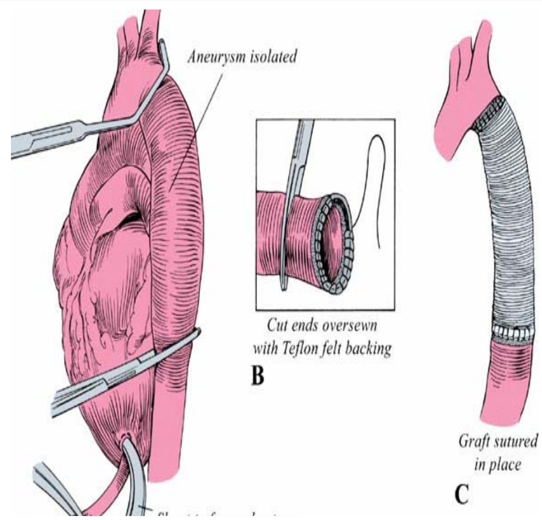

Figure 8. Example of the interposition graft technique. Diseased aorta is removed and remaining ends attached by graft. *Images.MD*

The interposition graft technique involves the resection of the aneurysmally dilated aortic section and the synthetic graft bridges the defect (Figure 8). Depending on the extent of disease in the arch, different anastomic techniques are used (Figure 9). For example, the aortic arch may be implanted into the graft as individual vessels or as a large island of native aorta with the innominate, left common carotid and left subclavian still attached. Points of weakness exist between the suture lines between the native aorta and the Dacron graft. Some surgeons reinforce the suture lines with Teflon strips. These strips appear as high attenuation rings and indicate the sites of anastomoses.[4,6] Additional high attenuation structures such as surgical clips may exist along the aorta. Occasionally felt pledgets, material used to control bleeding, are used to reinforce the site of the heart bypass cannula placement (Figure 10).[6]

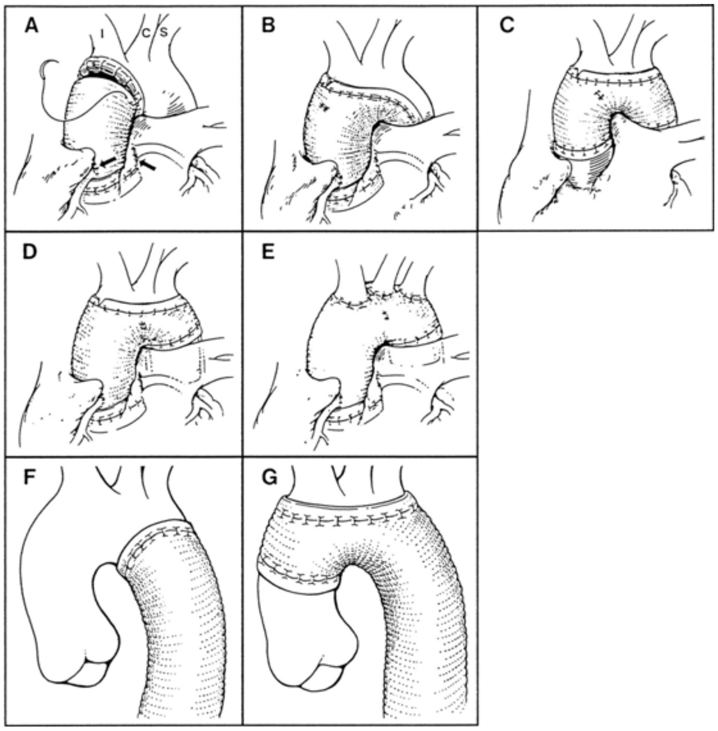

Figure 9. Diagram of some of the different surgical procedures performed. *A*, Root replacement with the distal anastomosis at the level of the brachiocephalic (innominate) artery (*I*). Arrows = coronary artery anastomoses, *C* = left common carotid artery, *S* = left subclavian artery. *B*, Root, ascending aorta, and partial arch replacement. *C*, Complete arch replacement with reimplantation of the arch vessels as a single island. *D*, Complete root and arch replacement with the elephant trunk technique used as a staged procedure for complete replacement of the aorta. *E*, Same as *D* except each arch vessel was implanted separately. *F*, Descending aortic graft. *G*, Descending aortic graft with complete arch replacement and reimplantation of the arch vessels as a single island. Coronary arteries are anastomosed to the root graft in parts *A*, *B*, *D*, and *E*. (Frontal view; heart removed in *F* and *G*).[6]

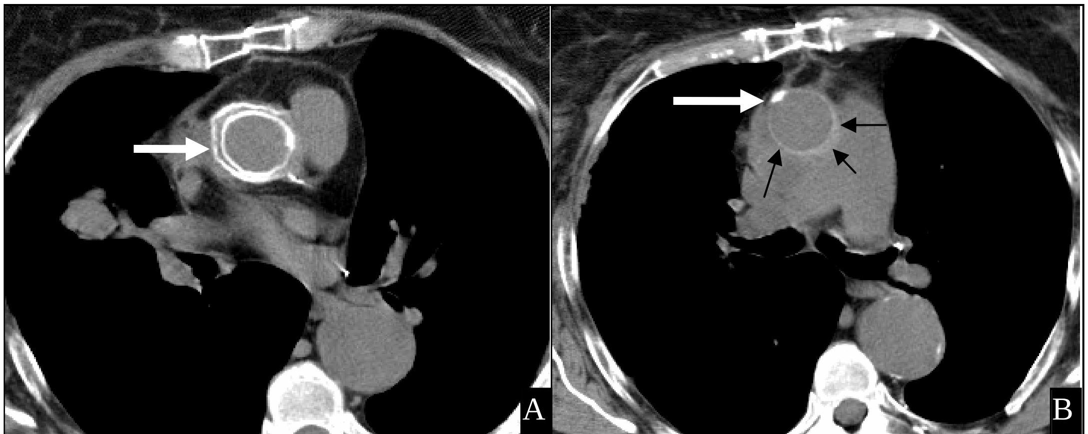

Figure 10: High attenuation structures near aortic graft. A. Teflon (white arrow) strip reinforcing the suture line between native ascending aorta and graft. The double cuff appearance may decrease over time to a single ringed structure. B. Pledget (white arrow) located in ascending aorta. These are used for hemostatic control. Lower attenuation graft material is visible outlining the aortic wall (black arrows).

For very extensive disease, an elephant trunk operation may be used. This is frequently a staged procedure that necessitates multiple operations. The technique was developed due to high mortality and morbidity rates associated with replacing the entire aorta during one procedure.[25] During the procedure, the graft is sewn proximally to intact aorta wall. Downstream, the distal end of the graft floats freely in the aortic lumen. Subsequently, this piece can be attached end-to-end to an additional graft segment for the replacement of the distal aorta (Figure 11). This is technically easier and less time consuming than suturing graft to a section of diseased aorta.[26] Patients frequently have imaging procedures between surgeries for additional operative planning.

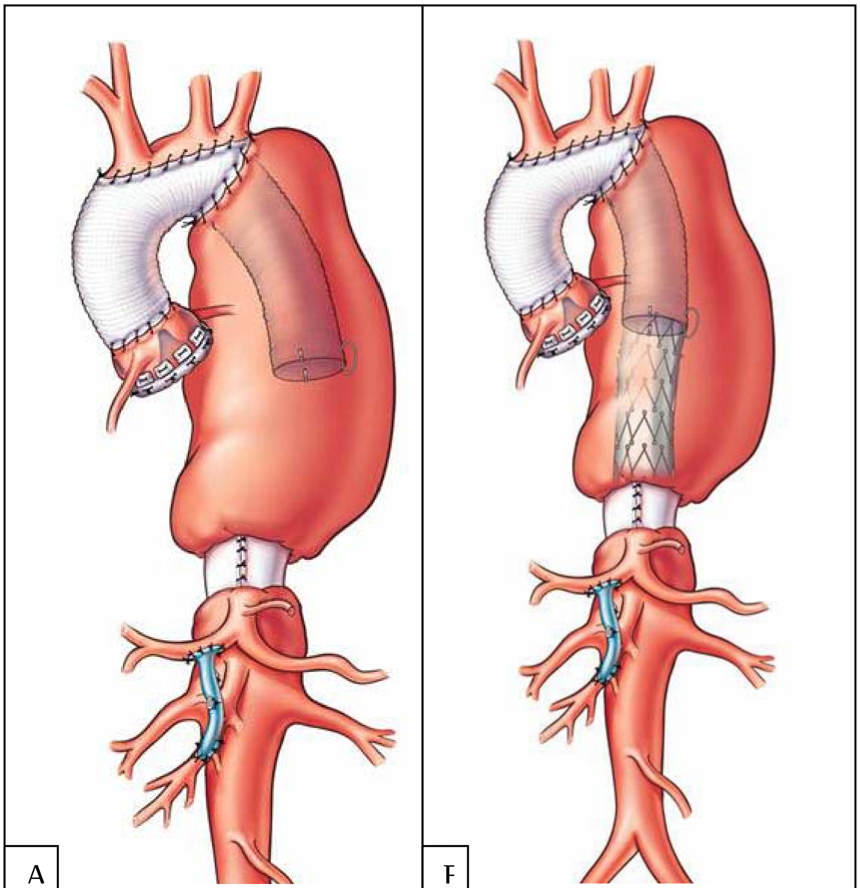

Figure 11. Example of elephant trunk procedure for aortic aneurysm. *A*, s/p first procedure. Replacement of ascending aorta and arch with proximal graft end hanging freely in descending aorta. Optional wrap of aorta where it crosses the diaphragm. *B*, after 2nd staged of elephant trunk procedure connecting distal graft to descending thoracic aorta. *Cleveland Clinic Heart Center*.

When the extent of aortic disease precludes an aortic graft attachment site, aortic exclusion is used. Surgeons insert a large-bore graft that connects the ascending aorta to the descending or abdominal aorta. The descending aorta becomes thrombosed as the majority of flow goes through the conduit to the abdominal area. Retrograde flow theoretically allows continued perfusion to major arterial branches feeding the spinal cord. Variations of the extra-anatomic can be used to solve other problems, such as coarctation (Figure 12).[27]

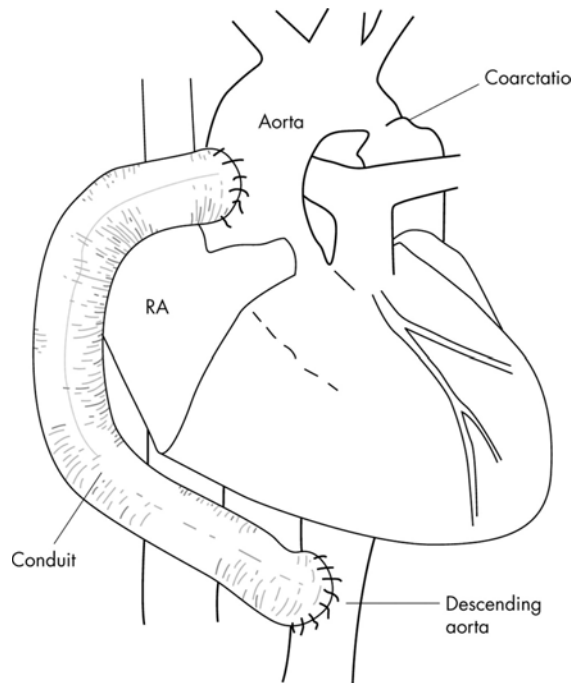

Figure 12. Example of extra-anatomic bypass procedure for aortic coarctation. *RA* = right atrium. Graft bypasses diseased aorta with the majority of blood flowing into the descending aorta.[3]

While the new aortic grafts are effective conduits for arterial blood flow, additional smaller grafts may be needed for specific organ perfusion. The coronary arteries enter the ascending aorta at the aortic root. When the aortic root is replaced with graft material, the coronary arteries are frequently reimplanted using the Bentall procedure or one of its modifications. The coronary arteries remain attached to an island of native aortic tissue. The island is implanted onto the graft and is known as a coronary button. These may be mistaken for a pseudoaneurysm or graft dehiscence on postoperative CTs (Figure 13).[4,6] In the descending aorta, surgeons maintain spinal perfusion by connecting cobrahead grafts between intercostal arteries and the aortic graft (Figure 14). Like coronary buttons, these can be misinterpreted as ulcers or pseudoaneurysm.

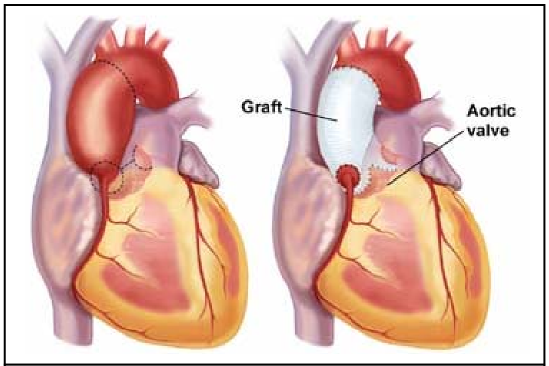

Figure 13. Coronary artery reattachment to graft as "button" of material from native aorta. *Massachusetts General Hospital Cardiac Surgery.*

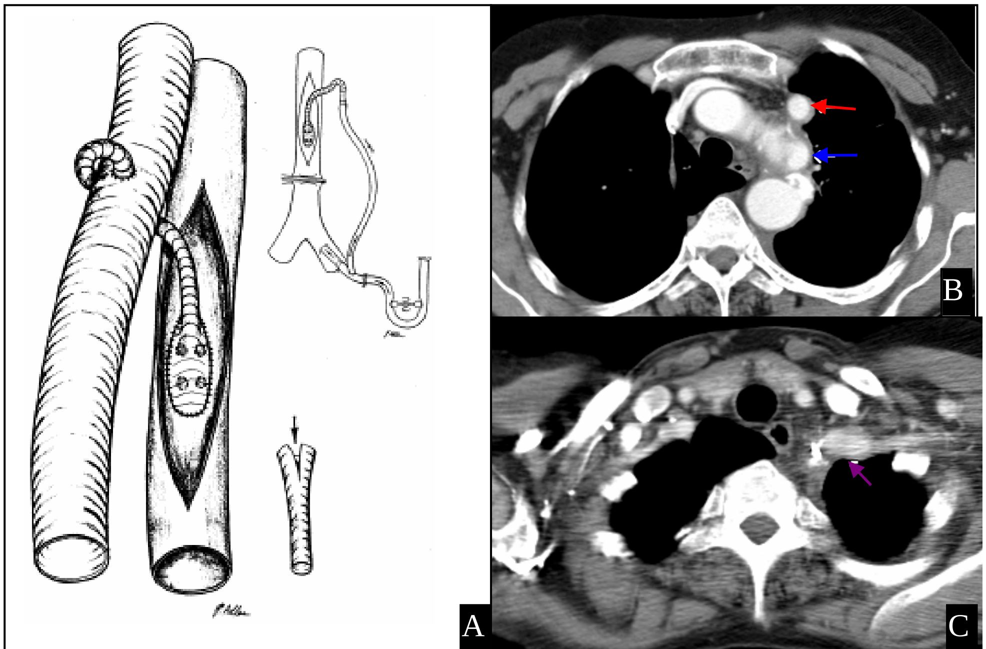

Figure 14. A. "Cobrahead" graft used for graft-accessory artery anastamosis. Insets show spatulation of the graft (lower right) and depiction of connection to arterial perfusion circuit that allows prompt restoration of spinal cord blood flow (upper right).[5] B. Patient with cobrahead graft from its origin at the aortic arch (blue arrow) to left subclavian artery (red arrow). C. Graft connects with subclavian artery (purple arrow).

Knowing the operative details becomes essential in patients who have complex or multiple procedures. They allow separation of pathology from normal postoperative appearance.

Thoracic Aorta Imaging:

There is a large body of literature regarding the pre-operative diagnosis of aortic aneurysms, dissections, and other pathology. There have been far fewer studies looking at normal post-operative appearance of aortic repairs and grafts.

Debate exists whether MR or CT should be the standard of care for post-operative imaging. Currently, CT is the most frequently used imaging modality given its accessibility and relatively low cost. Multidetector-row CT (MDCT) scanners are a newer type of scanner that acquires images more rapidly than older technology. MDCT eliminates motion artifact that distorted cardiac images on older CT scans. As MR becomes more accessible, it may be used more frequently. MR has the added advantages of being radiation free and ability to assess for aortic insufficiency and thrombus presence.[28]

Standards for postoperative imaging protocols and frequency of imaging have not been established. Contrast use and the length of scanned aortic vary. During the 1980s, patients were scanned every 6-12 months to assess for the development of complications.[29] The current protocol at Yale-New Haven Hospital is for patients to be scanned at 2-3 months following initial surgery, at 1 year and then every 2 years following their operation.

Several studies have attempted to analyze post-operative imaging for findings indicative of pathology. Perigraft collections are very common and have been observed between 29-33% of the time in MR studies[23,30] and reported in up to 82% in CT studies[6]. The collections can persist as long-term fixture in CT studies with 55% patients having perigraft fluid after 1 year post-op.[6] With MR imaging, pathologic collections are usually heterogeneous, asymmetrical and nonenhancing with gadolinium administration.[31] Others have reported that the size of perigraft collections is a potentially important indicator of underlying pathology. Gaubert et al wrote that perigraft hematoma was normal as long as it was concentric and less than 10mm in diameter.[32] Moore showed that perigraft fluid greater than 15mm at the time of first post-operative MR led to an increased rate of pseudoaneurysm formation.[33]

Pseudoaneurysms are a rare complication that occur in less than 0.5% of all cardiac surgeries.[34] These are classically described as an abnormal dilatation in the inner two layers of a blood vessel (intima and media). In the postoperative patient with dilatation at suture line, it can difficult to determine the number of wall layers involved in the dilation. A postoperative pseudoaneurysm may involve all three layers of the arterial wall, but be controlled by clot or graft from unconstrained expansion.

Several other findings have been frequently reported. Pleural effusions were common, especially on the left side. Attili noted that these were usually self-limiting, but may be worrisome for infections when they increased in size between exams.[35] In one MR series of patients with type A dissection, there were new dissections in 47% of abdominal aortas, dilation of the native aorta in 58% of patients and extension of the dissection in 10%.[30] Patients with dissections were noted to have a patent false lumen 76-80% of the time.[36,37]

HYPOTHESIS

The majorities of simple fluid collections seen on CT scans following thoracic aortic surgery are benign and can be managed conservatively.

AIM

- To correlate imaging findings of fluid collections with post-operative course and complications in patients undergoing thoracic aortic surgery.

METHODS

We retrospectively reviewed the medical records of 200 consecutive patients in the Yale Center for Thoracic Aortic Disease database. All operations were performed by a single surgeon, Dr. John A. Elefteriades, and took place between January 1998 and December 2002. Patients were included in the study if they had available post-operative chest CT examinations in the Yale-New Haven Hospital PACS system. Additional imaging modalities, such as plain film or MR, were not included in the analysis. Patients also needed to have a medical record available for clinical correlation (discharge summary, office notes, etc). The final study group was comprised of 102 patients, 61 men and 41 women. The average age was 62 years old (range, 21-88 years).

There were 98 patients excluded from the study. 90 patients did not have post-operative CT scans in the Yale-New Haven PACS system. 8 patients did not have available post-operative medical records. There were 51 men and 39 women disqualified.

Any repair along the length of the thoracic aorta was included in the study. 7 patients had multiple operations on their thoracic aorta. This resulted in a final study population of 102 patients with 109 surgeries in the study group. The study group consisted of 48 repairs in the ascending aorta, 20 in ascending aorta and arch, 3 in the arch alone, 6 in the arch and descending aorta, 26 in the descending aorta, and 6 in thoracoabdominal aorta (Figure 15)**.** Thirty-seven patients had concomitant aortic valve replacements. Ten patients had coronary artery bypass grafts during their thoracic aorta surgeries. Four patients had lung biopsies or lobe removal during aortic repair.

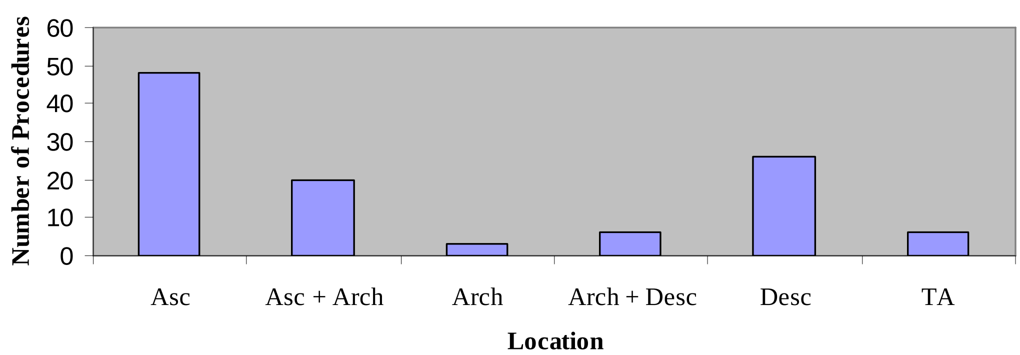

Figure 15. Number of thoracic aortic procedures by location. *Asc* = ascending aorta, *Asc + Arch* = ascending aorta and aortic arch, *Arch* = aortic arch, *Arch + Desc* = aortic arch and descending aorta, *Desc* = descending aorta, *TA* = thoracoabdominal aorta.

Patients were also classified in terms of necessity of their operations. 7 patients had emergent surgeries that occurred within 24 hours of presentation. 26 patients needed urgent repairs within 48 hours of admission. 71 patients had scheduled procedures. 4 aortic surgeries were of an indeterminate necessity.

Patients had surgery for a variety of reasons. The most common reason for surgery was aortic aneurysm with 64 procedures. 10 operations were performed for aneurysm and dissection, 14 operations were for dissection, 7 operations were for intramural hematomas, 3 operations were performed for cystic medial necrosis. 8 operations were performed for other causes: 2 pseudoaneurysms, 2 aortic stenosis, 2 unknown with only discharge summary available, 1 aortitis, and 1 aneurysm with ulcerated arch (Figure 16).

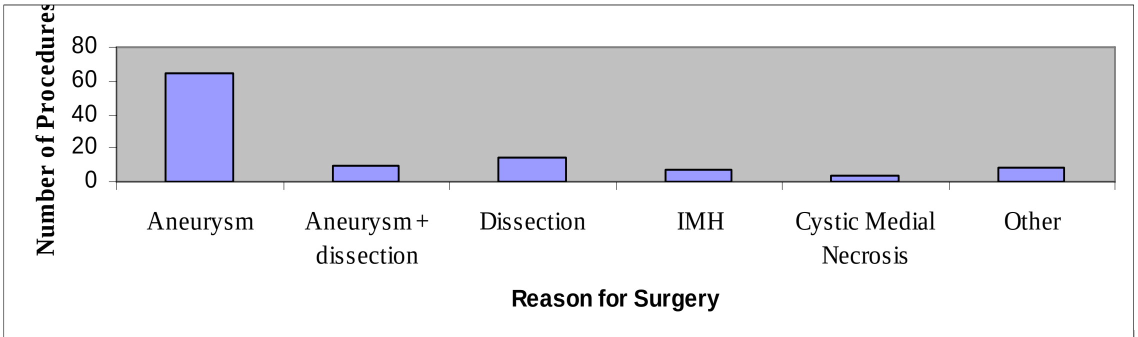

Figure 16. Number of thoracic aorta procedures by reason for surgery. *IMH* = intramural hematoma.

CT scans in all patients were obtained at Yale New Haven Hospital. Protocol varied by clinical indication and studies were done with and without contrast. All available scans, whether clinically urgent or routine follow-up, were retrospectively analyzed. CTs ordered by non-cardiothoracic personnel for unrelated causes in these patients (e.g. cancer staging) were also reviewed. A total of 188 CT scans were available for review for an average of 1.8 scans per patient (range 1, 5). Patients' first post-operative CT scans were performed an average of 113 days after surgery (range 3, 1125).

For study purposes, the CT findings were divided into three categories. First, the CTs were evaluated for the presence or absence of fluid near the graft site. If fluid was present, the density was measured using standard Hounsfield units. Second, lung fields were evaluated for the presence of pleural effusions. Location and density of effusions was noted. Finally, other interesting findings such as the presence of pseudoaneurysms or new lung nodule were noted. The graphs themselves and aortic contours were also evaluated.

RESULTS

The vast majority of the study patients survived to hospital discharge. Three of 102 patients (2.9%) died while in house.

Immediate post-operative complications caused 5 patients (4.9%) to return to the OR on post-operative day 0 or 1. These were due to hemodynamic instability or sternal oozing. Seven patients (6.9%) had delayed wound healing or late dehiscence that required surgical correction after hospital discharge. Only nine patients (8.8%) required 11 additional procedures during their initial hospital stay (4 thoracenteses, 3 tracheostomies, 1 pacer insertion, 1 PEG, 1 sigmoidoscopy, 1 TURP).

Perigraft fluid was a very common finding at the time of initial CT scan. Fifty-seven of 102 patients (56%) had perigraft fluid at the time of their first postoperative CT scan.

Time since surgery is negatively correlated with the presence of perigraft fluid. In the first post-operative month, 23 patients had 28 CT scans. Twenty-three of 28 scans (82%) showed perigraft fluid. In post-operative months 1-3, 41 patients had 53 CT scans. Thirty-two of 53 scans (60%) showed perigraft fluid. In post-operative months 3-6, 21 patients had 21 scans. Eleven of 21 scans (52%) showed perigraft fluid. In post-operative months 6-12, 12 patients had 13 scans. Seven of 13 scans (54%) showed perigraft fluid. In post-operative months 12-24, 28 patients had 30 scans. Seven of 30 scans (23%) showed perigraft fluid. At post-operative months greater than 24, 24 patients had 32 scans. Seven of the 32 scans (22%) showed perigraft fluid (Table 1, Figure 17).

	0-1 Month	1-3 months	3-6 months	6-12 months	12-24 months	>24 months
Presence of perigraft fluid	23/28 scans (82%)	32/53 scans (60%)	11/21 scans (52%)	7/13 scans (54%)	7/30 scans (23%)	7/32 scans (22%)
Presence of pleural effusion	24/28 scans (86%)	16/53 scans (30%)	5/21 scans (24%)	3/13 scans (23%)	2/30 scans (6%)	1/32 scans (3%)

Table 1. Presence of perigraft fluid and pleural effusions over time.

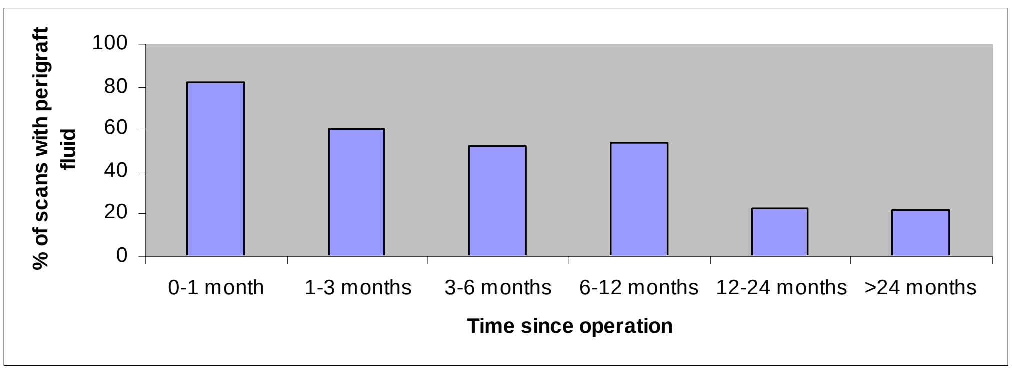

Figure 17. Percent of CT scans with perigraft fluid over time.

Time since surgery is also negatively correlated with presence of pleural effusions. In the first post-operative month, 23 patients had 28 CT scans. Twenty-four of 28 scans (86%) showed pleural effusions. In post-operative months 1-3, 41 patients had 53 CT scans. Sixteen of 53 scans (30%) showed pleural effusions. In post-operative months 3-6, 21 patients had 21 scans. Five of 21 scans (24%) showed pleural effusions. In post-operative months 6-12, 12 patients had 13 scans. Three of 13 scans (23%)

showed pleural effusions. In post-operative months 12-24, 28 patients had 30 scans. Two of 30 scans (6%) showed pleural effusions. At post-operative months greater than 24, 24 patients had 32 scans. One of the 32 scans (3%) showed pleural effusion (Table 1, Figure 18).

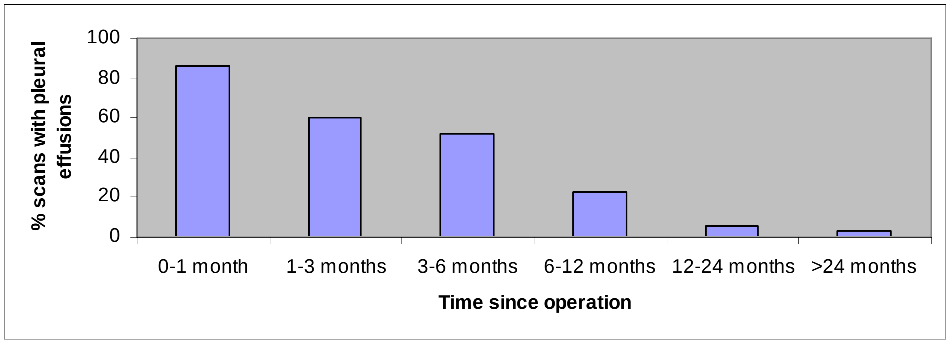

Figure 18. Percent of CT scans with pleural effusions over time.

Pleural effusions occurred predominantly in the left lung field or, if bilateral effusions present, larger in the left than right lung fields. In the first postoperative month, 24 patients had pleural effusions. Twenty-one of 24 (88%) of these effusions were left sided predominant. In post-operative months 1-3, 15 patients had pleural effusions. Fifteen of sixteen (93%) were left sided predominant. In post-operative months 3-6, 5 patients had pleural effusions. Five of 5 (100%) were left sided predominant. In post operative months -12, three patients had pleural effusion. Three of 3 (100%) were left sided predominant. In post-operative months 12-24, 2 patients had pleural effusions. Two of 2 (100%) were left sided predominant. Beyond 2 years, only 1 patient had a pleural effusion and this was on the right.

Pseudoaneurysms were a relatively rare complication that occurred in 7 of 102 patients (6.9%) and 8 of 107 surgeries (7.5%). Three pseudoaneurysms occurred in the ascending aorta out of a total of 48 ascending aortic procedures (6.2%). Four pseudoaneurysms occurred in the descending aorta out of a total of 38 descending aortic procedures (10.5%). One pseudoaneurysm occurred at the left ventricle-graft interface for a thromboexclusion procedure. Pseudoaneurysm did not appear to be correlated with a particular type of surgery or with the urgency with which it was performed. The patient's initial surgeries occurred for a variety of reasons: 2 known aneurysms with additional dissection, 1 aneurysm, 1 dissection, 1 ruptured intramural hematoma, 1 stenosis and 1 aorta-pulmonary fistula. Pseudoaneurysm patients also included a spectrum of clinical urgency on their initial operations. One patient was classified as an emergent procedure, out of a total of 7 emergent procedures in the clinical sample (14%). Two patients were classified as urgent procedures, out of a total of 26 urgent cases (7.7%). Four patients were classified as scheduled on their initial surgeries, out of a total of 71 scheduled cases (5.6%).

No patients developed aortobronchopulmonary fistulas.

DISCUSSION

This study was undertaken to delineate the normal post-operative anatomy and course of recovery for patients undergoing thoracic aorta surgery. An appreciation of the normal post-operative appearances allows recognition of the postoperative abnormalities and complications.[38] Post-operative CTs usually show perigraft fluid collections and pleural effusions, which may appear worrisome but are part of the normal recovery process.

CT scans are very effective identifying medium to long-term complications. No perioperative complications within the first 72 hours required CT imaging and decisions to return to the OR were made on clinical grounds. None of the five patients who returned to the OR for hemodynamic instability or sternal bleeding had CT scans prior to their second surgery.

Perigraft fluid collections were very frequent in the study population as has been noted in previous studies. More than half the patients had perigraft fluid at the time of initial CT evaluation. The fluid collections resolved with time, with 82% of scans showing a collection in the first month and only 22% scans after 1 year (Figure 19). Prior studies have shown similar results.[6,30] We did not evaluate the size of the perigraft fluid collections and are unable to confirm or disprove the findings of Moore and Gaubert et al. that larger collections predispose to pseudoaneurysm formation.[32,33] The small number of complications makes identification of predisposing factors very difficult.

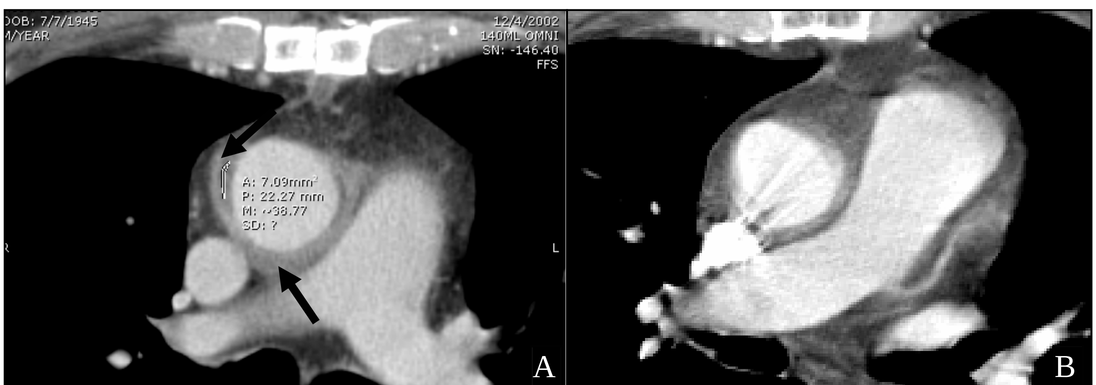

Figure 19. Perigraft fluid resolution over time. The patient had an ascending aorta aneurysm repair and aortic valve replacement. A, 1 month post-operatively. B, 13 months post-operatively with fluid collection much diminished.

Pleural effusions also decreased with time, present on 86% of scans in the first post-operative month and only 9% of scans after 1 year (Figure 20). The vast majority of these were located in the left chest which likely reflects greater manipulation of the contents of the left hemithorax than those on the right. These results are consistent with other reports of post-operative pleural effusions.[6]

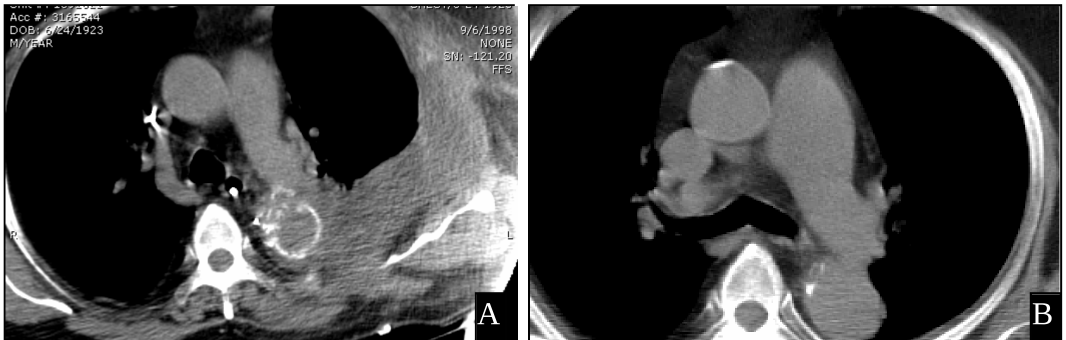

Figure 20. Resolution of left pleural effusion over time. The patient had a descending aneurysm repair. A, 1 month post-operatively. B, 9 months post-operatively.

Pseudoaneurysms are a relatively rare but worrisome complication (Figure 21). There is no consensus in the literature about predisposing risk factors on post-operative CT for pseudoaneurysm development. Ascending pseudoaneurysms occurred in 6.2% of patients in this study group. This rate was similar to the incidence of 4.3% described by Quint.[6] In comparison, Mathieu's study of ascending aortic dissections found no pseudoaneurysm in 52 patients.[36] This rate difference is especially striking given that pseudoaneurysms most frequently occur with aneurysm repair and deserves additional follow-up.[39] Given that Mathieu's study was published in 1986, older scanning techniques and larger axial slices may have missed small pseudoaneurysms that are detected today.

Pseudoaneurysms of the descending aorta occurred at a rate of 10.5% in this study population. This is much higher than that reported by Quint. One possible explanation is that Quint's study involved interposition grafts only, while this study had both interposition and inclusion grafts. Inclusion grafts have been shown to have higher rates of pseudoaneurysm formation and are used less frequently today.[24]

Figure 21. Coronal reformatting of ascending pseudoaneurysm (white arrow) that occurred after ascending aorta reconstruction and aortic valve replacement for dissection. White arrowhead: ascending aorta. Black arrows: pulmonary artery.

Pseudoaneurysms may develop into an aortobronchopulmonary fistula. Aortobronchopulmonary fistulas are very rare, with fewer than 100 cases reported in the literature and are usually associated with surgical procedures on the thoracic aorta.. Classically, they develop from pseudoaneurysms and are uniformly fatal without treatment. The time course for the development of aortobronchopulmonary fistula varies from 3 weeks to 25 years.[40] One patient in our study population merits discussion. The patient presented with hemoptysis and a pseudoaneurysm diagnosed by outside imaging. His inclusion surgery was for an aortobronchopulmonary fistula involving the descending thoracic aorta.. The patient had had three prior procedures to repair both ascending and descending thoracic aorta aneurysms as well as a prior ascending aorta-pulmonary artery fistula repair.

Pleural effusions were frequently observed during the postoperative period, left more often than right. No patient developed empyema. One patient was reported to have empyema at 6 months when air bubbles were noted in the left pleural space (Figure 22). Unknown to the reporting radiologist was a recent wound closure procedure with muscle and omental flap. This underscores the need for close cooperation between surgeon and radiologist for proper image interpretation.

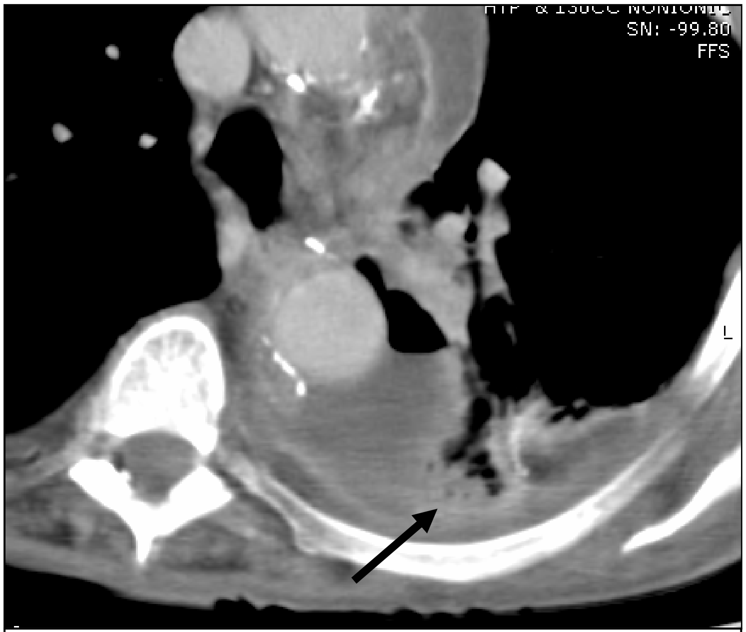

Figure 22. CT scan of patient 6 months status-post repair of the aortic arch and descending aorta, and additionally 2 days post wound repair. Black arrow points to air bubbles in pleural effusion, normally worrisome for empyema. However, the recent procedure make the air likely postoperative in character.

While interpreting anatomy and checking for graft complications, radiologists must also be aware of issues occurring away aorta. Seven percent of patients had wound complications that required return to the operating room (Figure 23). Analyzing incision sites for changes or signs of infection is important, as new fluid collections may indicate possible infection or abscess formation. Also, radiologists can play a role the detection of incidental findings which may range from subsegmental atelectasis to pulmonary emboli and clinically undetected lung cancers (Figure 24).

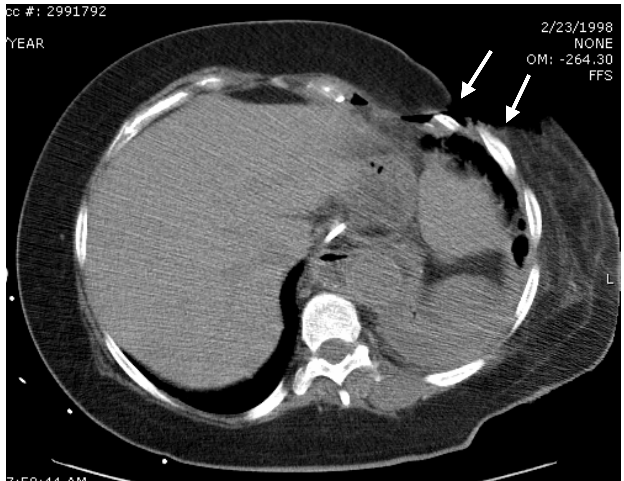

Figure 23. A patient with significant wound defect (white arrows) that necessitated operative repair.

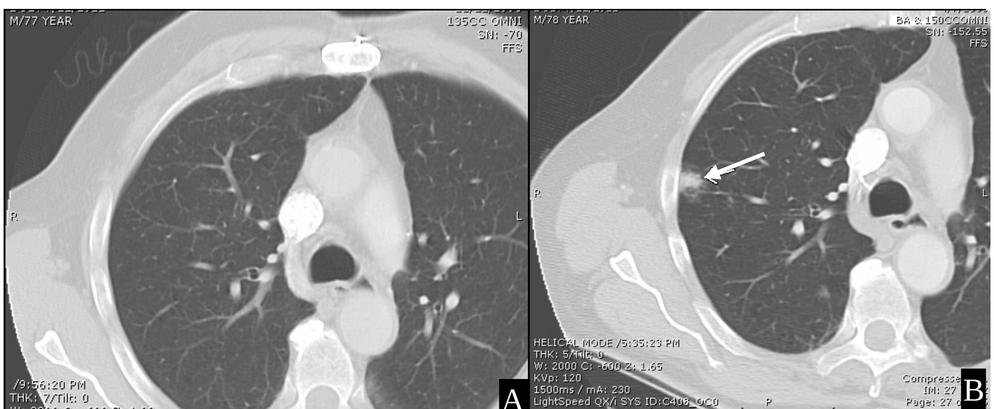

Figure 24. Incidental finding of new lung cancer. A, Patient 17 months post-repair of ascending aorta dissection. No cancer visible in right lung field. B, 21 months post-repair, patient now has new lesion in the distal lung (arrow).

There was difficulty interpreting cobrahead or sidearm grafts. In one example, a cobrahead graft in the descending aorta was reported as an aortic ulcer (Figure 25). Another case commented on an outpouching of descending aorta as “cobra head vs. pseudoaneurysm” and remarked that it was unchanged from prior CT (Figure 26). More frequently, however, grafts were not commented on in radiolographic reports. If these secondary grafts were remarked on, it was rarely mentioned whether grafts were patent or if collaterals had developed.

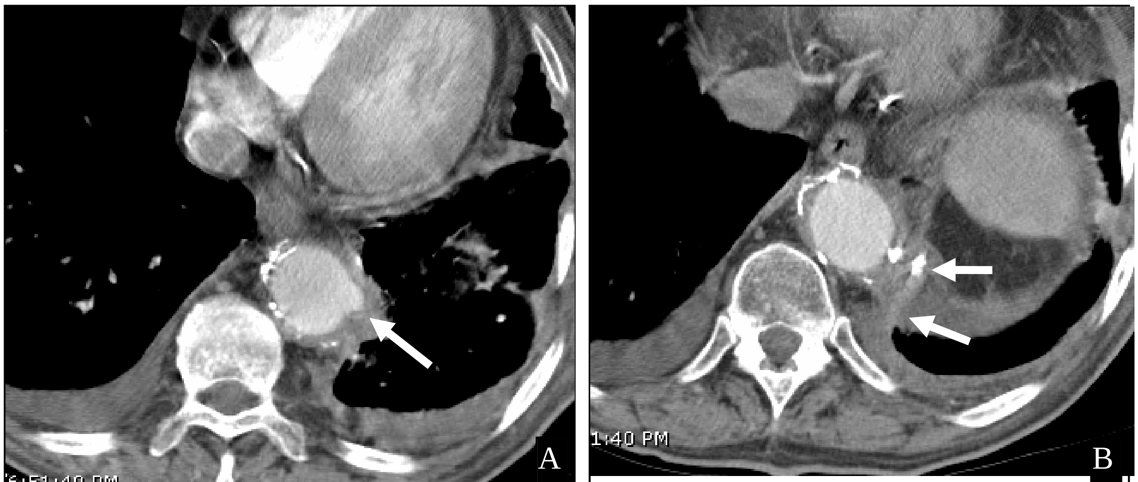

Figure 25. Patient had CT scan worrisome for descending aortic ulcer, A Cobrahead graft(arrow) could be mistaken for aortic ulcer Slightly caudal, B, shows course of graft.

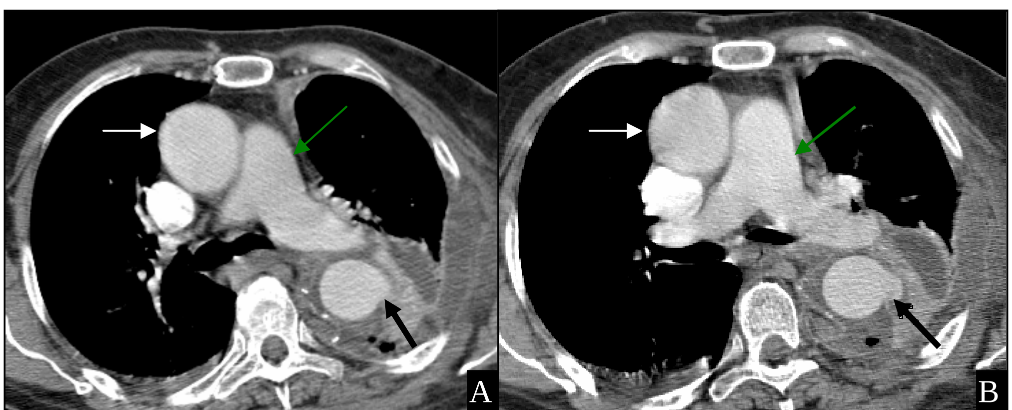

Figure 26. Patient is 2 weeks status post repair of a thoracoabdominal aneurysm. CT scan was interpreted as pseudoaneurysm versus cobrahead graft (black arrow) in the descending aorta. Post-operative changes present near the graft. White arrow = ascending aorta. Green arrow = pulmonary artery near the level of the bifurcation.

As patients return to the operating room for additional thoracic surgeries, anatomic relationships can become very complex. Accessibility to operative reports is mandatory to interpret some examinations correctly. However, surgical details can become imperative to avoid missed calls. One example is a patient with severe aortic valve stenosis and a heavily calcified aorta which made direct valve replacement and aortic resection impossible. Instead, a graft with a porcine valve was inserted directly into the left ventricle and the distal end of the graft was connected to the descending aorta thus bypassing the ascending aorta and arch. The coronary arteries and cerebral vessels were perfused in a retrograde fashion. The radiology report described the valve of the conduit as the site of a prior left ventricle assist device. A pseudoaneurysm at the site of graft insertion not observed or described (Figure 27). With an operative report available while evaluating this scan for the study, it was easier to interpret actual anatomy and pathology.

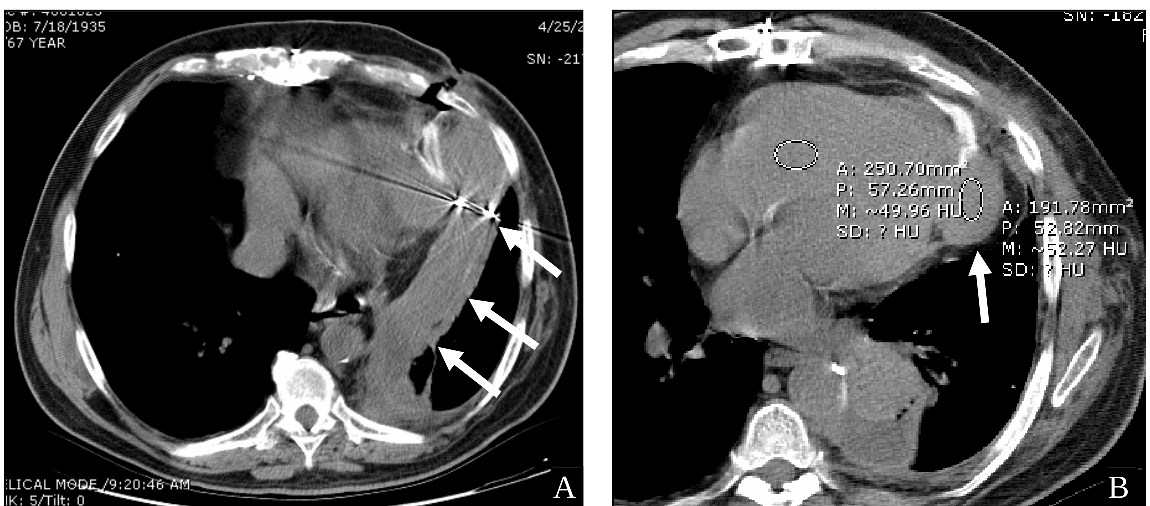

Figure 27. Patient with exclusion graft from left ventricle to descending aorta. White arrows illustrate conduit in A. Complex anatomy contributed to missed pseudoaneurysm seen in B. Hounsfield units shown for right ventricle and pseudoaneurysm.

Errors of interpretation can be avoided using 3D reformatting. While all of the imaging information is available on the axial images, 3D reformats are useful for radiologists and clinicians in particular. 3D reformats can facilitate subsequent evaluations. Improvement in technology has allowed this resource to be available at many workstations. With complex surgical procedures, 3D reformats can give an anatomic overview (Figure 28). Additionally, radiologists on this project experienced increased ease in following vascular anatomy throughout the thorax. Reformatting of vessels that are in the axial plane, such as the transverse aortic arch, is useful in identifying aneurismal dilatation (Figure 29).

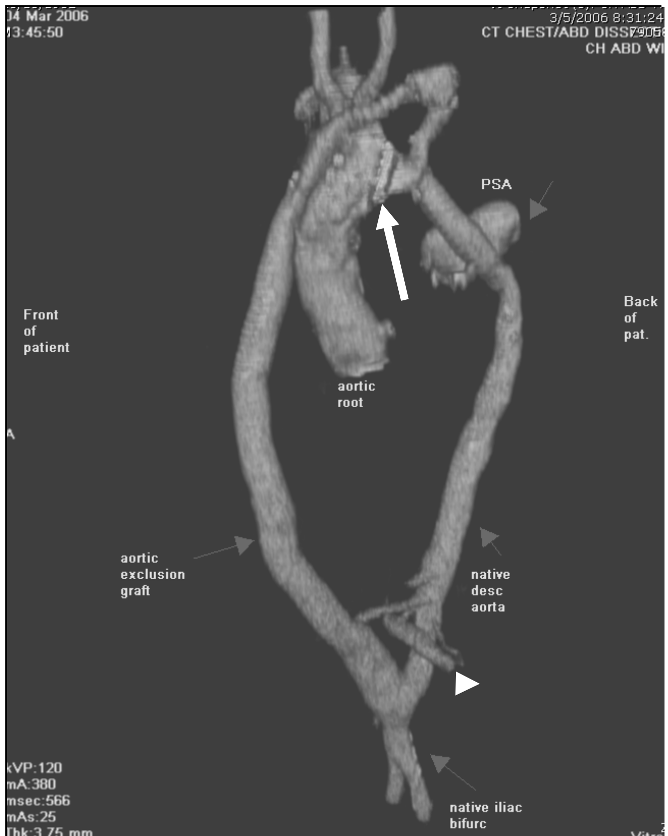

Figure 28. A. Three dimensional image created at the workstation. Patient three prior thoracic vascular interventions prior to the complicated thromboexclusion procedure with results shown here. Aortic exclusion graft connects the innominate artery to the infrarenal aorta. An “E”clamp transects the aortic arch between the innominate artery and the left coronary carotid, visible with white arrow. Left common carotid reattached to the innominate artery and left subclavian artery ligated and grafted to the aortic exclusion material. Pseudoaneurysm (PSA) present on descending aorta. A second clamp (white arrowhead) is visible at the abdominal aorta.

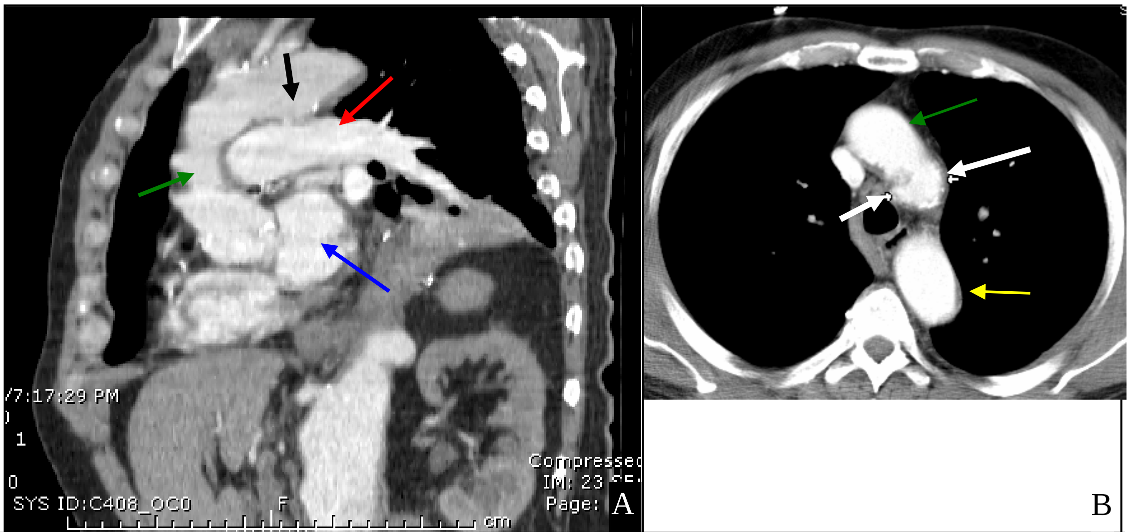

Figure 29. *A*. Reformatted images of a patient with a secular aneurysm along the caudal surface of the transverse arch. Black arrow = transverse arch aneurysm. Green arrow = ascending aorta. Blue arrow = left ventricle. Red arrow = pulmonary artery. *B.* Standard axial slices of the same patient. The aneurysm is very subtle (white arrows) and difficult to interpret given the frequent ovoid cross-sections through the transverse arch. Green arrow = ascending aorta. Yellow arrow = descending aorta.

This discussion has pointed out several occurrences of misinterpretation by radiologists. None of these led to adverse clinical outcomes for patients. Cardiothoracic surgeons who have hands-on experience with aortic anatomy serve as a second check for potential pathology. These misreads do serve an important role as a guide to weaknesses in radiologists' knowledge and can be used in future educational programs.

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