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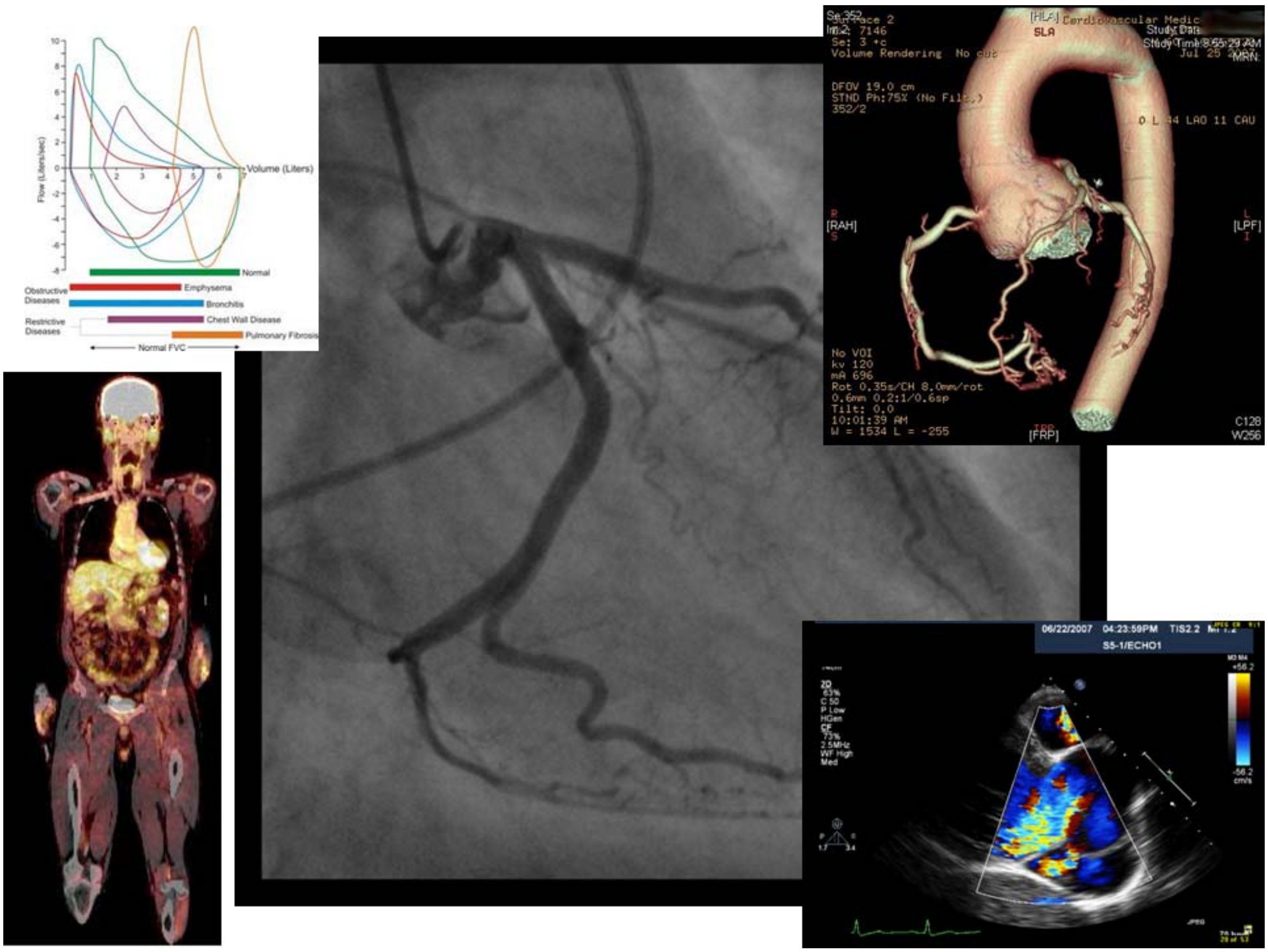
Shades of Gray

Interpretation of Perioperative Imaging

Installment III: Computed Tomography-Chest



This is Installment III of a series on perioperative imaging. Click below for:
Installment I (chest X-rays)
Installment II (abdominal X-rays)

Purpose

"The ability to visualize anatomic and pathologic conditions within the human body by noninvasive means plays a fundamental role for the understanding, diagnosis, and treatment planning of…diseases."[1]
As Advanced Practice Nurses (APNs), we often order and rely on perioperative imaging to guide our decision making and plan our operative interventions. However, almost no BSN, RNFA, or even MSN curricula include interpretation of medical imaging. This forces us to abdicate our autonomy and rely on either the interpreting physician's "read" or our supervising physician's opinion. Learning to interpret medical imaging studies can increase our confidence and autonomy as well as increase our marketability and professional appearance.

Introduction

X-rays are electromagnetic radiation similar in properties to light, with shorter wavelengths than ultraviolet (UV) light. "X-rays are generated by an X-ray tube, a vacuum tube that uses a high voltage to accelerate electrons released by a hot cathode to a high velocity. The high velocity electrons collide with a metal target…creating X-rays."[3] The resulting X-rays are aimed at a target and projected onto a phosporous screen or recording plate and then developed. The "film" is darkened by exposure to photons. The target (patient in our instance) affects the photon "throughput" and results in various shades of white, gray, and black. Denser materials will show up white and less dense materials will be shades of gray or black.

"There are only five categories of opacity visible on a radiograph, though there are varying levels of opacity within the primary categories. These categories are mineral (calcium and phosphorous as seen in bone), soft tissue and fluid (as they have the same radiographic opacity), fat, gas [the most radiolucent opacity on X-ray], and metal [the most radiopaque images on X-ray]."[2]

Computed Tomography

> "In many ways CT scanning works very much like other X-ray examinations. Different body parts absorb the X-rays in varying degrees. In a conventional X-ray exam, a small burst of radiation is aimed at and passes through the body, recording an image on photographic film or a special image recording plate. With CT scanning, numerous X-ray beams and a set of electronic X-ray detectors rotate around you, measuring the amount of radiation being absorbed throughout your body. At the same time, the examination table is moving through the scanner, so that the X-ray beam follows a spiral path. A special computer program processes this series of pictures, or slices of your body, to create two-dimensional cross-sectional images, which are then displayed on a monitor. CT imaging is sometimes compared to looking into a loaf of bread by cutting the loaf into thin slices. When the image slices are reassembled by computer software, the result is a very detailed multidimensional view of the body's interior. Refinements in detector technology allow new CT scanners to obtain multiple slices in a single rotation. These scanners, called "multislice CT" or "multidetector CT," [MDCT] allow thinner slices to be obtained in a shorter period of time, resulting in more detail and additional view capability [with less radiation exposure]."[4]

Older CT scanners contain 16 detectors, while newer generations contain 32, 64, and even 128 detectors allowing for finer resolution and faster imaging examinations. More exotic machines like Imatron's Electron Beam Tomography scanners (there are only 80 worldwide) use ultra-fast spin, 32-slice-per-second scanners that can get resolution to ¼ millimeter between slices.

The injection of contrast media (allowing better visualization of vasculature), timing of the imaging to the bolus, and gating technology will be covered in further installments. Be aware that we will be viewing both CT (without contrast) and CT angiograms (CTA or contrast enhanced CTs) below.

How to Approach Medical Imaging

When approaching any imaging modality it is important to proceed systematically. This requires a firm knowledge of anatomy and physiology and the ability to translate that knowledge into three- and four-dimensional thought. You should cross-check the name, medical record number, and date on the radiograph to your patient and current date. Next, check the position of the patient in relation to space. All medical imaging should be labeled with orientation markers. Orientation plays an important role in how you will mentally evaluate the two-dimensional "shadowgram" in three dimensions. As you begin your radiographic evaluation, it is important to NOT go in with preconceptions of what you will see or "tunnel vision" that will keep you from evaluating the full exam after visualizing the "expected abnormality." Stokell (n.d.)[2] noted that each shadow must be evaluated for four things:

- Is it a feature of normal anatomy?
- Is it a composite structure formed by the superimposition of structures?
- Is it an artifact produced by poor positioning?
- Is it a pathologic lesion?

We are not training to become radiologists so it is not necessary, nor is it conceivable, to know all of the intricacies of radiographic interpretation. There are, however, some standard guidelines to help you get the basics down. First, is everything there that should be there? Secondly, is there anything there that shouldn't be there? Third, is everything there consistent with normal? Symmetry is congruent with health in terms of evolutionary biology. If you see anything on your radiograph that is not symmetrical, you should consider it abnormal. I typically recommend that newcomers to interpretation analyze the "white bits, the gray bits, and the black bits" for features of normal or abnormal anatomy.

Example – Normal

Let's examine a "normal" CT examination of the chest:

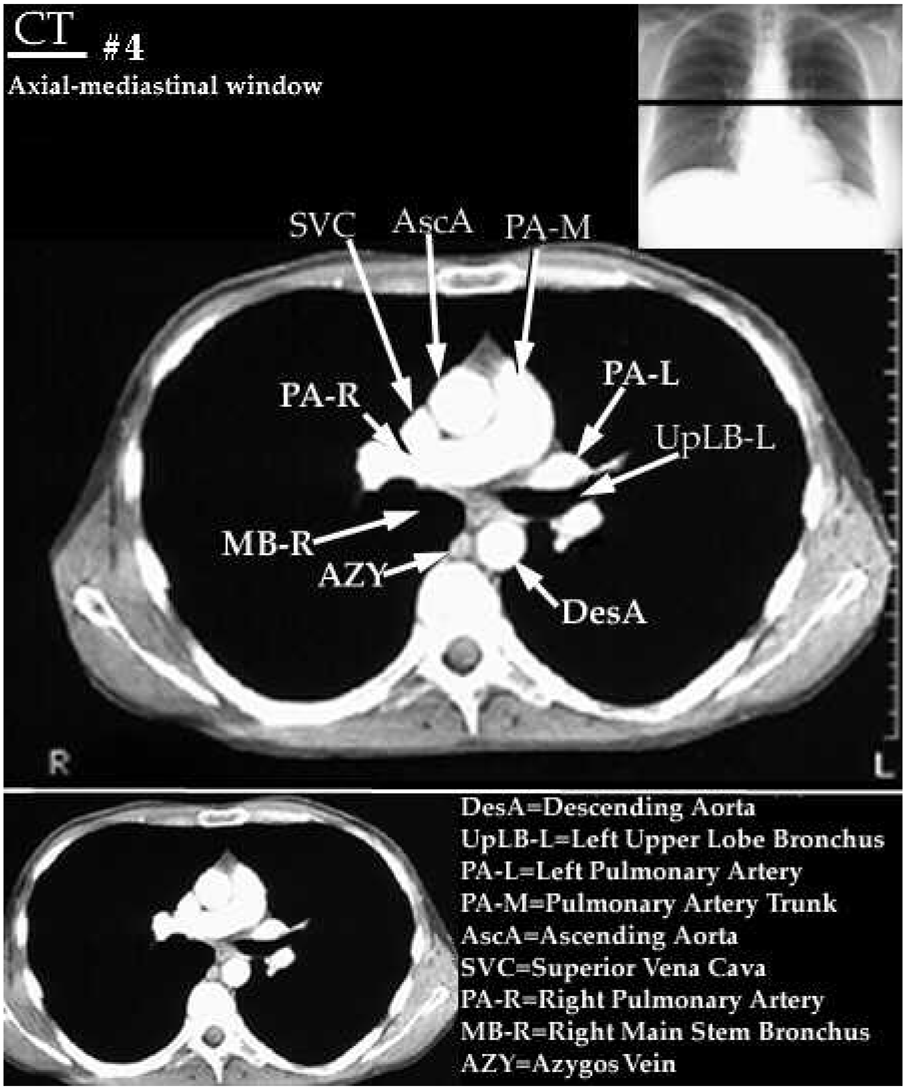


Figure 1
http://www.e-radiography.net/technique/chest/Chest_t4_labelled_mediastinum_ct.jpg

Look at Fig. 1, left. First, is this your patient? Second, how old is your patient? You should try to use the "patient's age to your advantage by making sensible suggestions [i.e., a] 20-year-old is much less likely to have malignancy than someone who is 70."[2] Is the image marked / oriented appropriately? CT scan images will vary in thickness from ¼ millimeter to 10 millimeters per slice. The radiology report or the image will indicate the slice thickness.

I have removed the identifying information from this image so we will assume that this is our 32-year-old male patient. The scout CXR in the right upper corner shows no malrotation (the clavicles are level and horizontal), suboptimal penetration (the thoracic vertebrae are not visible through the heart shadow), good inspiration (hemidiaphragms are curved normally and at appropriate levels), and there are no abnormal lung or vascular markings. The scout CXR also shows you where the "slice" of the CT angiogram (with contrast injected) is taken.

The CT image in the center is clearly marked with right and left orientation markers as well as a scale along the right margin to measure structures. Using our knowledge of anatomy, we can analyze the two-dimensional image in three dimensions. The sternum is the rectangular bone displayed at 12 o'clock. The thoracic vertebral body is displayed at 6 o'clock. You can see the soft gray shadow of the spinal cord within the vertebral column. The ribs emanate out from the origin at the spinal column and wrap around to their insertions along the sternum. The scapulas are located on the right and left at 3 and 7 o'clock, respectively. The lungs are inflated with no gross abnormalities on this image (we will cover lung windowing below). You can see the main pulmonary artery as well as the right pulmonary artery and part of the left pulmonary artery in the center of the image. The superior vena cava and ascending aorta are located anterior to the pulmonary arteries. The descending aorta and azygous vein (as well as the inferior vena cava) are located to the left of midline along the vertebral column.

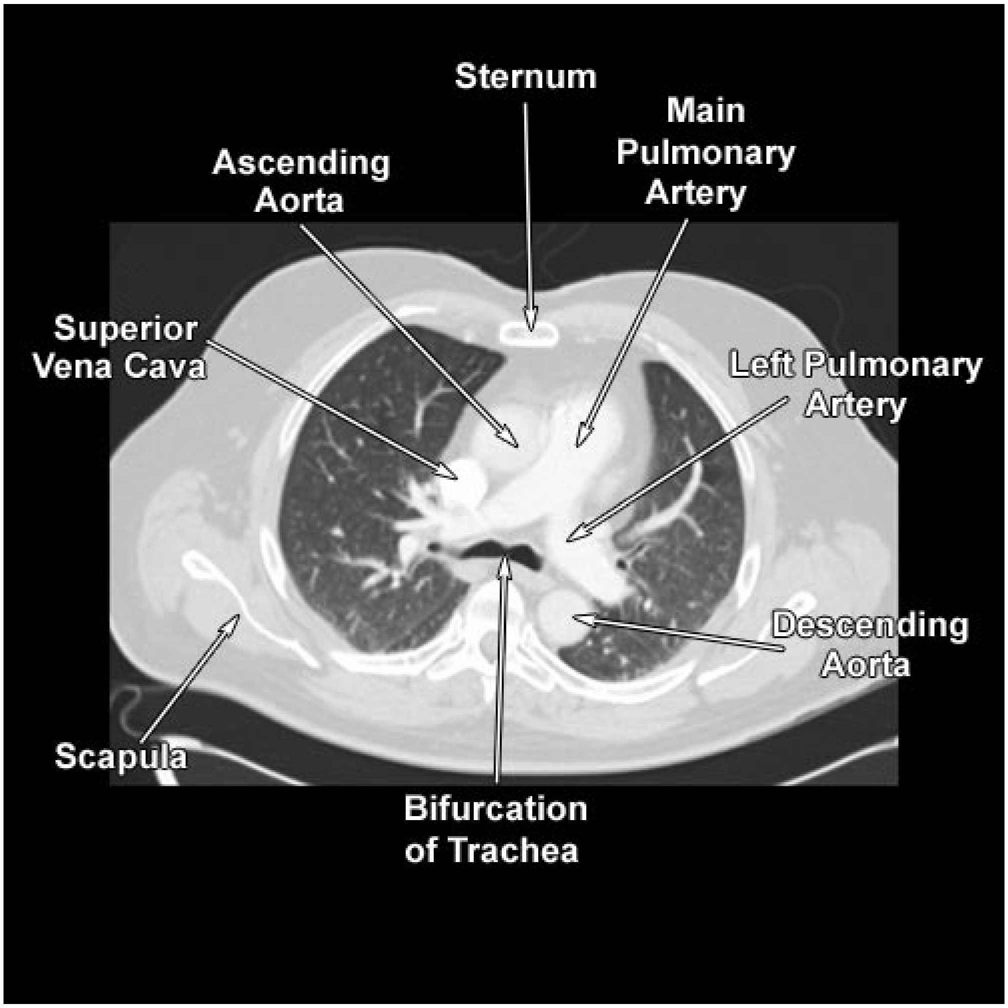


Figure 2, left, is a lung window allowing the viewer to see the lung tissue and is approximately two centimeters above Figure 1. As we learned in installment I, the pulmonary vasculature markings are more pronounced in dependent areas of the lung. The patient is lying on their back so the vascular markings along the posterior side of the image are more clearly visible.

Figure 2
http://images.google.com/imgres?imgurl=http://uuhsc.utah.edu/medstud_radiology/NormalAnatomy/Images/ChestCT1a.jpg&imgrefurl=http://uuhsc.utah.edu/medstud_radiology/NormalAnatomy/NormalCT26.htm&usg=__CvacKAtRJNncwud3IoCilOoxZxE=&h=500&w=500&sz=51&hl=en&start=6&um=1&tbnid=qdsHA3Yw9YwsZM:&tbnh=130&tbnw=&prev=/images%3Fq%3Dnormal%2Bchest%2BCT%26hl%3Den%26rlz%3D1G1GGLQ_NUS254%26sa%3DN%26um%3D1

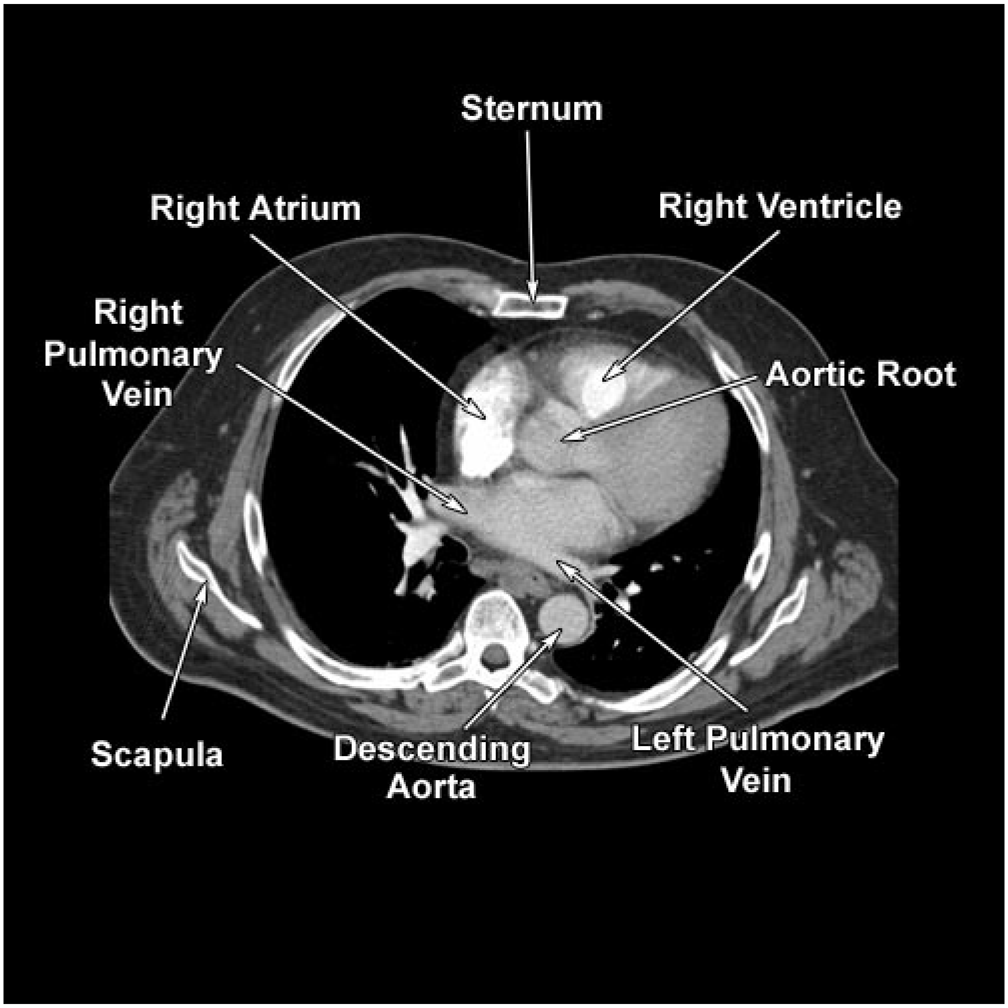


Figure 3
http://images.google.com/imgres?imgurl=http://uuhsc.utah.edu/medstud_radiology/NormalAnatomy/Images/ChestCT1a.jpg&imgrefurl=http://uuhsc.utah.edu/medstud_radiology/NormalAnatomy/NormalCT26.htm&usg=__CvacKAtRJNncwud3IoCilOoxZxE=&h=50&w=500&sz=51&hl=en&start=6&um=1&tbnid=qdsHA3Yw9YwsZM:&tbnh=130&tbnw=&prev=/images%3Fq%3Dnormal%2Bchest%2BCT%26hl%3Den%26rlz%3D1G1GGLQ_NUS254%26sa%3DN%26um%3D1

Figure 3, left, is another slice of a normal CT image of the chest approximately 5-7 centimeters lower than Figure 1. It's important to remember that CT images are volume images and related to as "slices of bread." Imagine that your patient is lying on the exam table and you are moving from top to bottom or vise versa in "X" millimeter increments of anatomy. This image shows the pulmonary veins at the center of the picture. The heart is seen occupying the 12-3 o'clock position. The aortic root (aortic valve, Sinuses of Valsalva, and coronary artery ostia) is shown emanating from the left ventricle in the center of the image with the right coronary artery visible in the 12 o'clock position of the aortic root. The descending thoracic aorta is seen coursing to the left of the vertebral column and the esophagus is located antero-medially to the descending aorta between the pulmonary veins and the vertebral body.

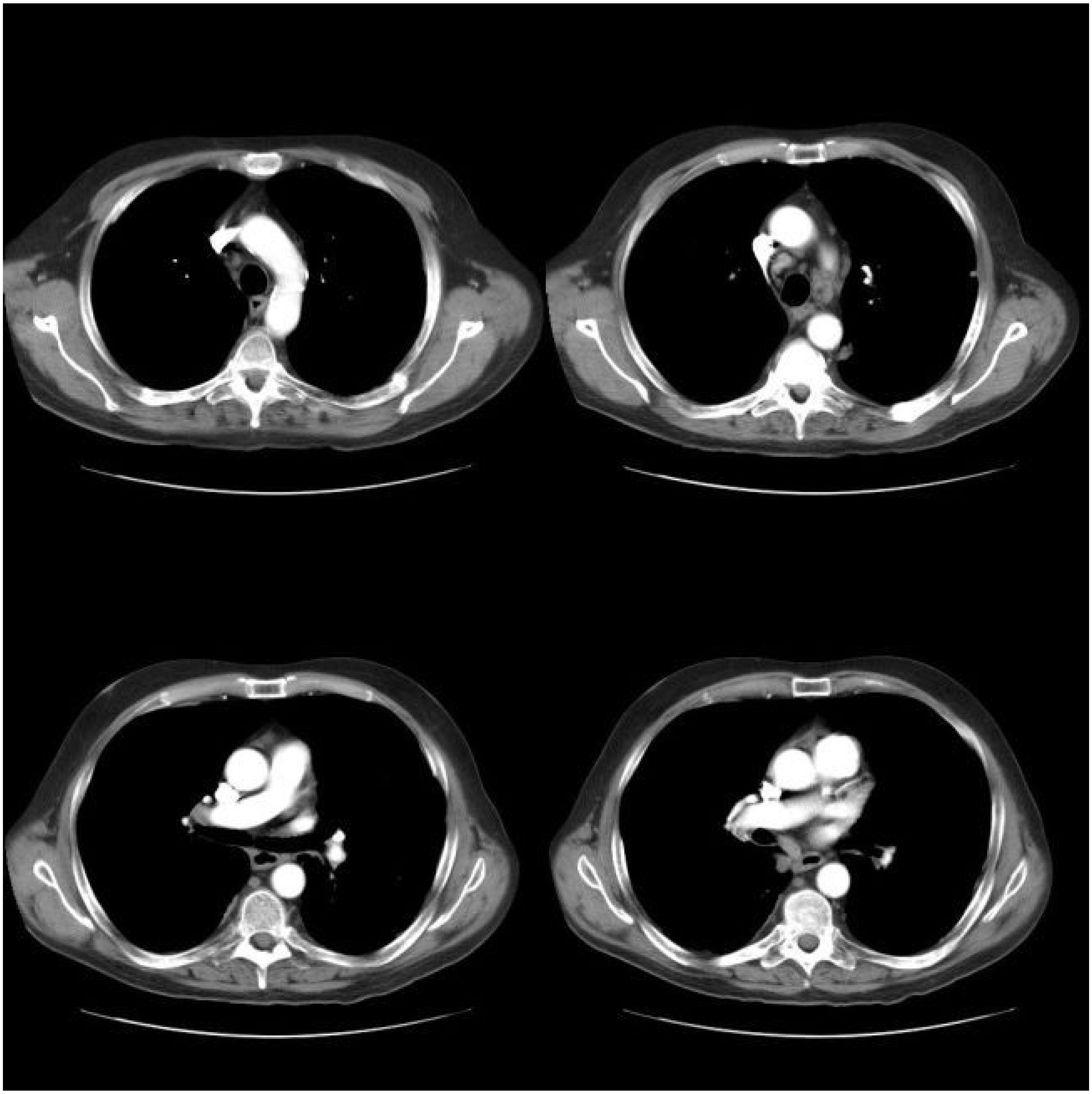


Figure 4
http://images.google.com/imgres?imgurl=http://i90.photobucket.com/albums/k280/keshrad/00%2520HRCT%2520CHEST/sarcoidosis/sarcoidnodularCT1.jpg&imgrefurl=http://radiographics.blogspot.com/2006/09/sarcoidosis.html&usg=__wUqJxhg025FJhTRKhBv7YtoNMMw=&h=650&w=650&sz=42&hl=en&start=108&um=1&tbnid=jvGs5lx_yJK3-M:&tbnh=137&tbnw=137&prev=/images%3Fq%3Dnormal%2Bchest%2BCT%26ndsp%3D18%26hl%3Den%26rlz%3D1G1GGLQ_ENUS254%26sa%3DN%26start%3D90%26um%3D1

Figure 4, above, shows a normal progression of the CT image "slices" starting in the top left, moving to the top right, then to the bottom left, and finally the bottom right. The image in the top right demonstrates enlarged mediastinal nodes in the right paratracheal region seen best in the 11 o'clock position of the "slice" and posterior to the ascending aorta. We will examine the lung windows of this series later as an example showing why it is important to review all the windows and series within a CT data set.

Examples – Abnormal

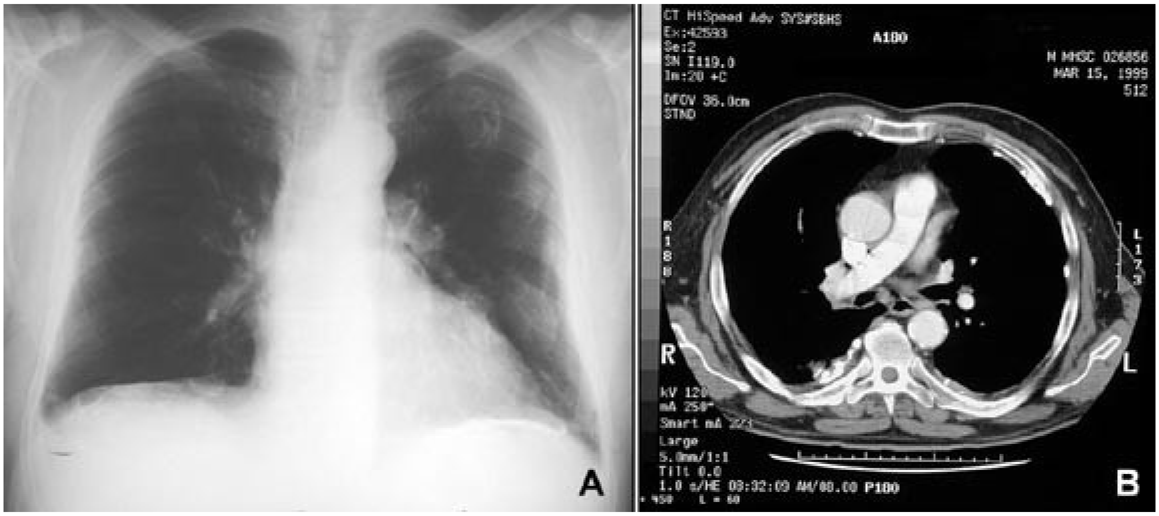


Figure 5

http://www.drguide.mohp.gov.eg/NewSite/E-Learning/Cases/case7.jpg

Look at Fig. 5, above. First, is this your patient? How old is your patient? This is a 68-year-old male presenting with an abnormal CXR on a routine examination. The CXR shows no malrotation and suboptimal penetration. The bony landmarks of the CXR are all normal. The heart is mildly enlarged; mostly in the left ventricular region (left ventricular hypertrophy in a 68-year-old male would normally be due to hypertension or aortic valve disease). The aortic arch is normal. The cephalad extent of the trachea is midline and seen coursing to the right around the aortic arch. The hemidiaphragms are curved normally and at appropriate levels; however, there are abnormal thickenings with calcification along the right and left hemidiaphragms. The CXR also demonstrates abnormal calcification seen in the left lung at the 1 o'clock and 4 o'clock position. The subsequent CT angiogram to rule out neoplasm or inflammatory disease demonstrates raised, calcified, and smooth elevations of the pleura at 2 o'clock, 5 o'clock, and 7 o'clock on the CT image. These pleural plaques are characteristic of asbestos exposure. If they are not associated with intrathoracic findings, they are considered benign.

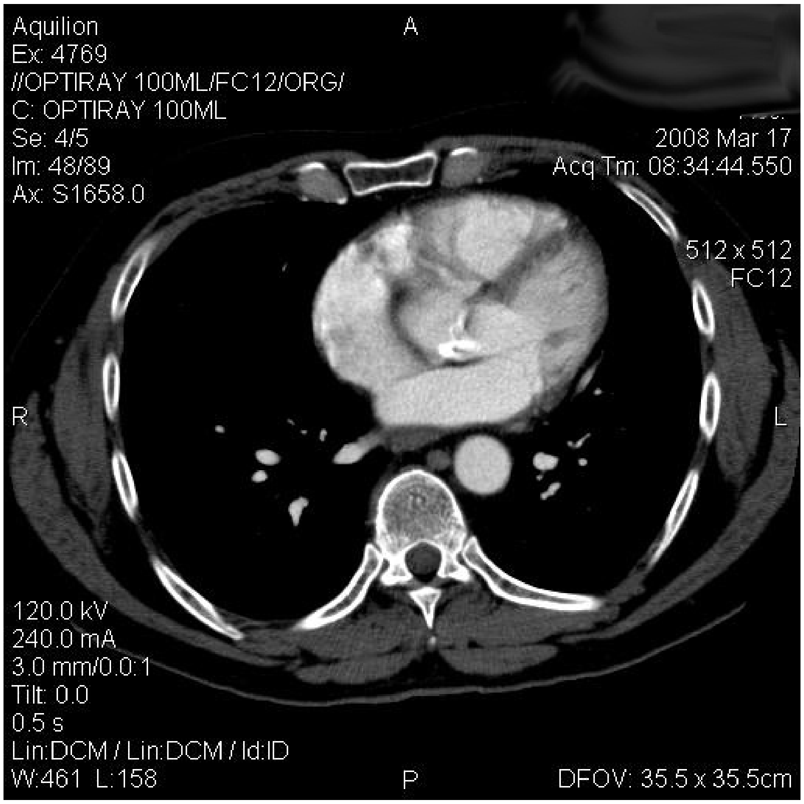


Fig. 6
A patient image from the author's computer.

Look at Fig. 6, above. First, is this your patient? How old is your patient? This is a 48-year-old male presenting with a known bicuspid aortic valve that has been followed by his cardiologist for many years. Recent echocardiographic evaluation demonstrated increasing aortic valve velocities, decreasing aortic valve area, and left ventricular enlargement. The preoperative workup included a CT angiogram of the chest to rule in the aortopathy associated with BAV. The CTA revealed a 5.4x5.4cm ascending aortic aneurysm and a calcified BAV. The CT "slice" above shows the aortic root just above the center of the image. The right coronary artery is visible emanating from the 12 o'clock position off of the aortic root. The aortic valve is noted to be calcified. Bicuspid aortic valves are known to calcify and stenose earlier than a normal tricuspid aortic valve.

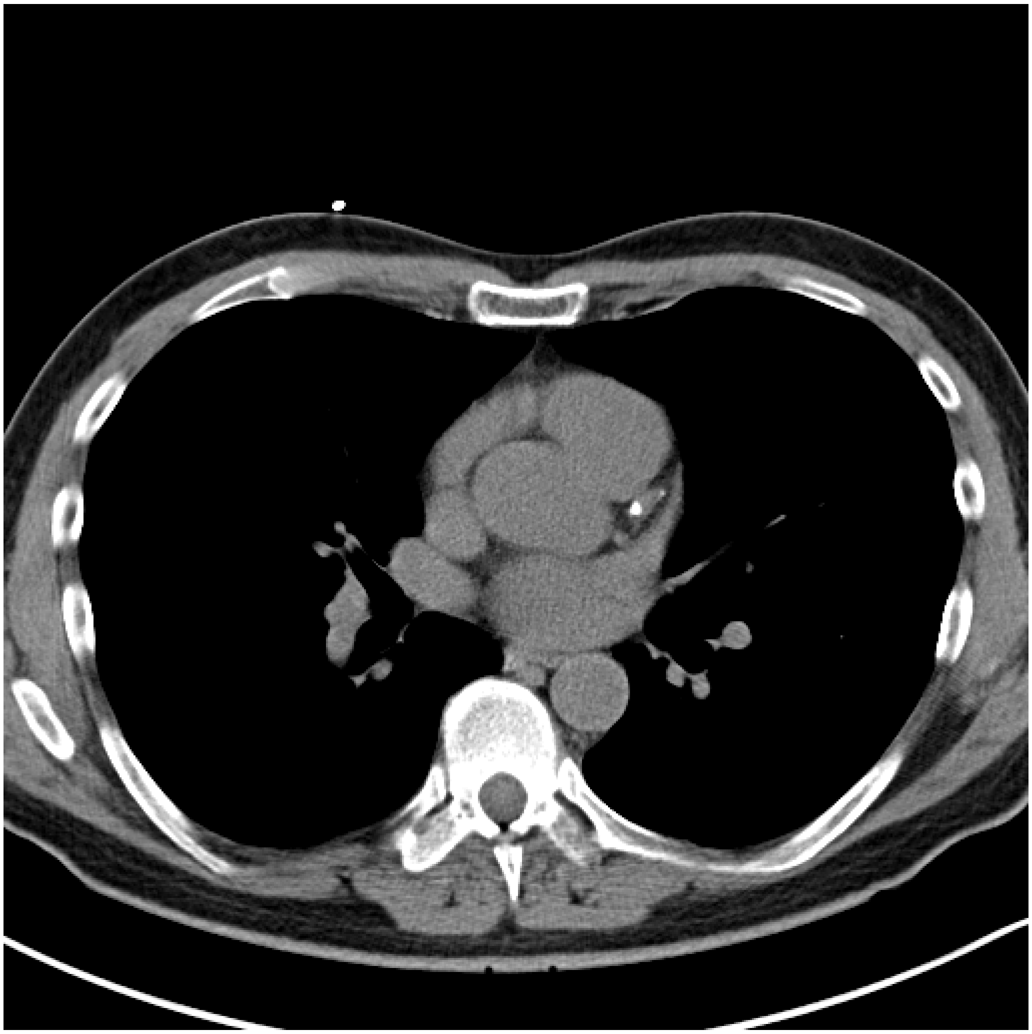


Figure 7

A patient image from the author's computer.

Look at Fig. 7, above. First, is this your patient? How old is your patient? This is a 58-year-old male presenting with a ascending aortic aneurysm that has been followed by his cardiologist for many years. Recent CT evaluation demonstrated a stable tubular ascending aortic dilatation. The aortic root is visualized in the center of the image with the left coronary artery emanating form the 3 o'clock position of the root. The noncontrast image above demonstrates calcification of the left coronary artery seen in the 2 o'clock position from the center of the "slice." Coronary artery disease can be comprised of soft, calcified, or mixed plaques. Calcified plaques and intramural calcium is often seen on the non-contrast enhanced images and is a useful guide in determining patients that should undergo preoperative coronary angiography.

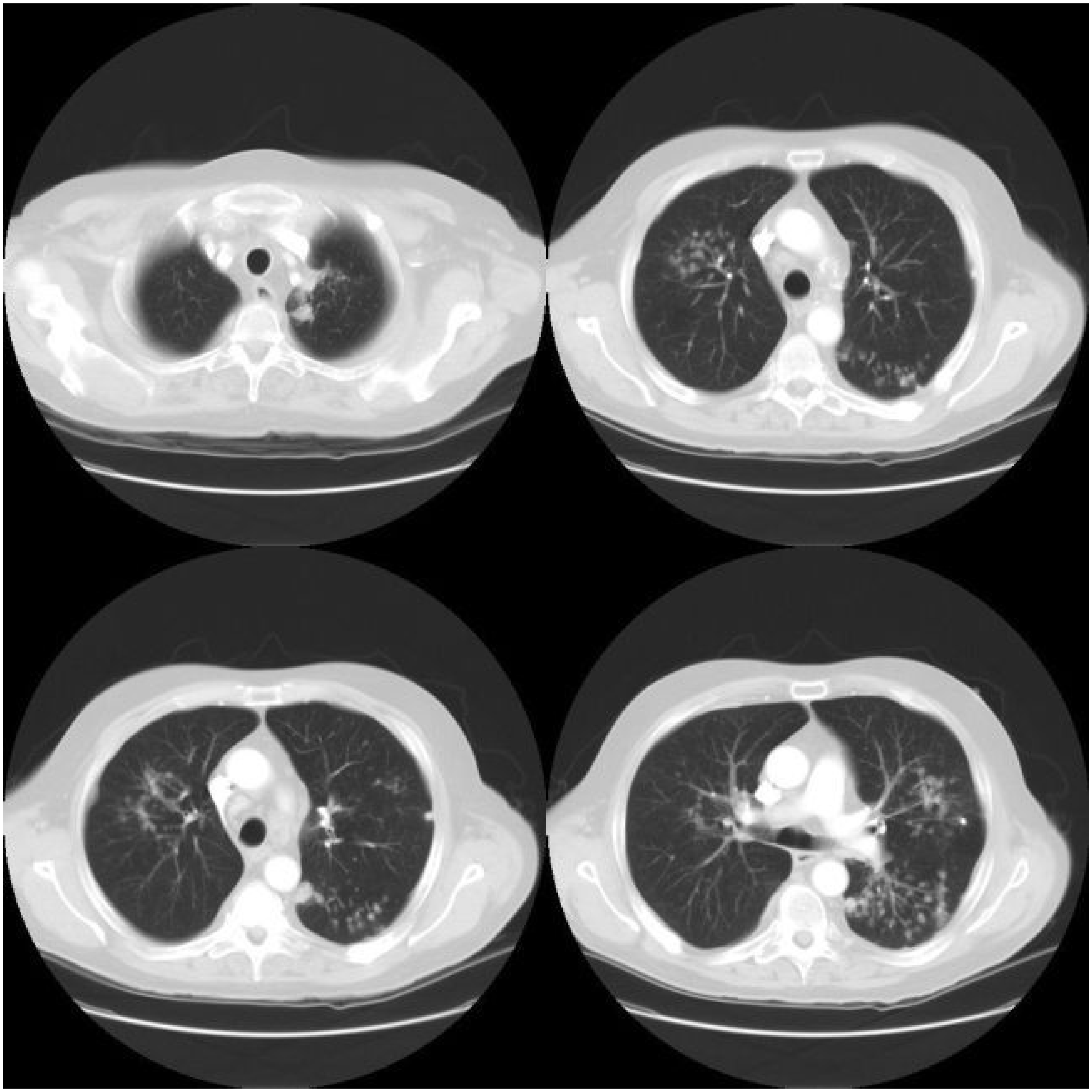


Figure 8

http://images.google.com/imgres?imgurl=http://i90.photobucket.com/albums/k280/keshrad/00%2520HRCT%2520CHEST/sarcoidosis/sarcoidnodularCT1.jpg&imgrefurl=http://radiographics.blogspot.com/2006/09/sarcoidosis.html&usg=__wUqJxhg025FJhTRKhBv7YtoNMMw=&h=650&w=650&s

Figure 8, above, shows us the lung windows associated with Figure 4 of a 27-year-old man presenting with malaise, fatigue, and weight loss. If the reviewer were only to check the images displayed in Figure 4, it would be read as a normal CT scan. However, the lung windows clearly demonstrate enlarged mediastinal nodes in the right paratracheal region described in Figure 4. There are also numerous uniformly shaped pulmonary nodules distributed bilaterally in the upper and mid lung fields and in a perivascular distribution. The lung findings in conjunction with the patient's presentation are consistent with a diagnosis of sarcoidosis.

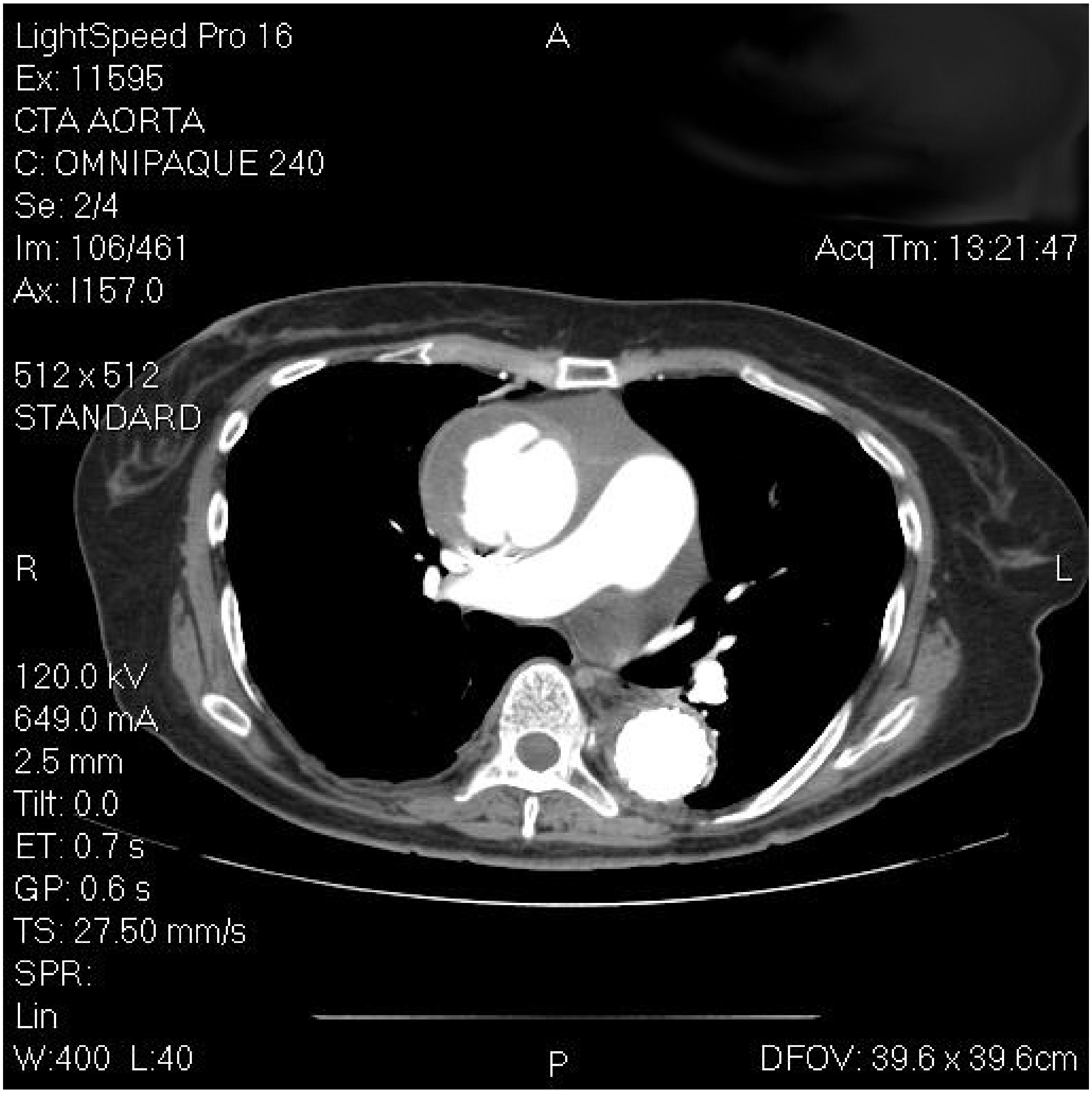


Figure 9
A patient image from the author's computer.

Figure 9, above, is an example of a surgical emergency. The identifying information has been removed so we will assume that this is our 62-year-old female patient (notice the bilateral breast tissue anterior to the chest wall). The upper left hand information lets you know that this is image 106 of 461 images in this series. The information at the bottom left gives you the timing, slice, and physics information. We know from this data that the images are 2.5mm apart. You can identify the sternum in the 12 o'clock position of the image and the vertebral body at the 6 o'clock position. The main and right pulmonary arteries are visualized in the center of the image. The ascending aorta is visualized anterior to the right pulmonary artery. There is a dissection flap and intramural hematoma (aortic bruise as blood leaks into the muscular layers of the aorta). The IMH is the gray crescent occupying the 12-7 o'clock position of the ascending aorta. The dissection flap is the linear abnormality at the 1 and 5 o'clock positions of the ascending aorta. Directly below the sternum and antero-medially to the ascending aorta, you can see some fluid accumulating. The descending thoracic aorta is visualized lateral to the vertebral body and is free of an aortic dissection flap. Traditionally, it has been said that a type A aortic dissection (originating in the ascending aorta or aortic arch) carries a 50% mortality rate at the time of the event and then 1% per hour until treatment. Due to earlier recognition and better treatment, type A aortic dissections have a 30-40% mortality rate initially and a 20-30% operative or in-house mortality rate.

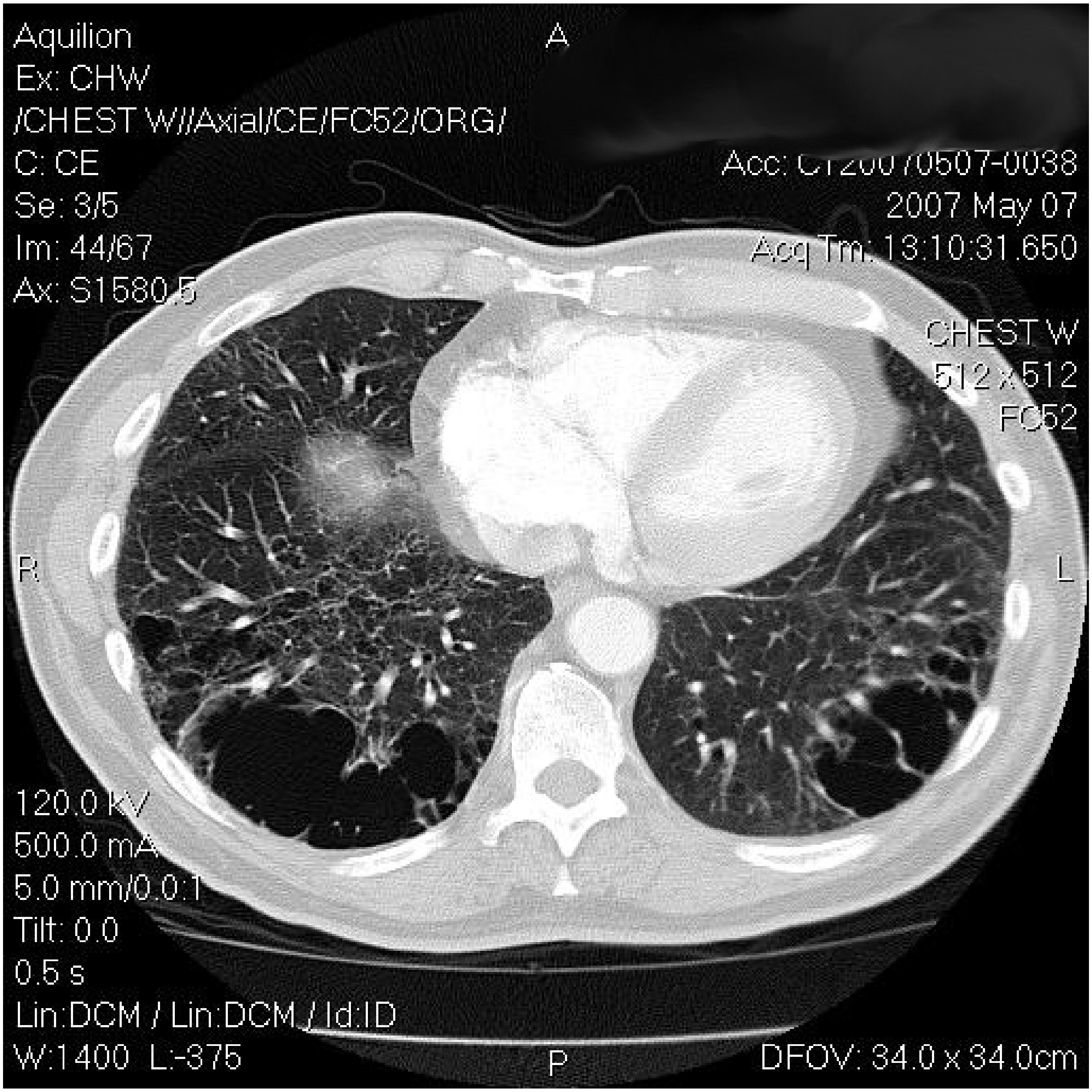


Figure 10
A patient image from the author's computer.

Figure 10, above, is our preoperative CT angiogram on a 73-year-old male who was to undergo a thoracic aortic endovascular stent-graft. We can see from the information at the left that this is image 44 of 67 images and that they are 5mm apart. The lung window of the CTA show severe lung disease. You can see large bullae in the posterior segments of both lungs. The descending thoracic aorta is seen coursing to the left of the vertebral body. The heart is located in the center of the image with the left ventricle in the 2 o'clock position, the right atrium in the 9-10 o'clock position, and a portion of the right ventricle in the 12 o'clock position.

Information for the Patient

Patients often suffer anxiety regarding any medical procedure. As the APRN, we can reduce stress by providing current information regarding any diagnostic imaging. Here are some points to make for your patients' education:

- All women who are or may be pregnant should tell their technologist as radiation can cause teratogenic effects.
- You should wear loose-fitting and comfortable clothes to your examination and should remove all metal objects.
- You may be asked to not eat or drink anything for a few hours prior to the examination, especially if contrast material will be injected.
- If you will be having a contrast-enhanced CT scan, a nurse or technologist will start an IV.
- You may be asked to hold your breath at different times during the scanning.
- A CT scan may take 15-25 minutes to perform in its entirety.
- A CT scan of the chest will traditionally expose you to 5-10mSv of radiation, or slightly higher than the average person would be exposed to background radiation over the course of a year (6-8mSv).

Images of Interest

Please see below for a collection of interesting images. Some of these 3-dimensional reconstructions are normal variants, others are post-surgical changes, and others are 3-dimensional reconstructions that will be used to create 4-dimensional images (Figure 13) on an AquariusNet TeraRecon station. (A 4-dimensional image adds the fourth dimension of time to the existing three dimensions; X, Y, and Z, creating motion images of raw CT data..)

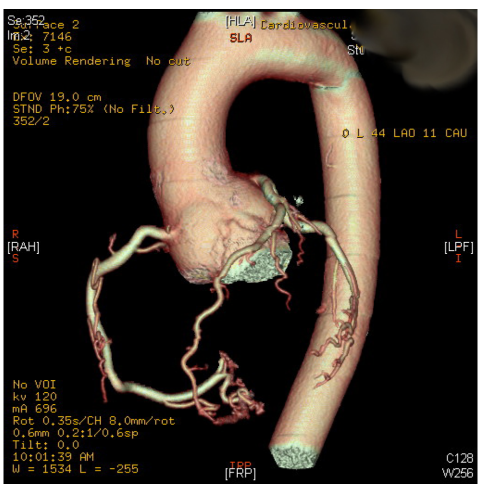


Figure 11

This 3D volume-rendered image shows the patient's aortic root, the coronary arteries, and the ascending, transverse, and descending thoracic aorta. This was a gated, coronary CT angiogram with IV beta-blockers given to slow the heart and image the coronaries fully.

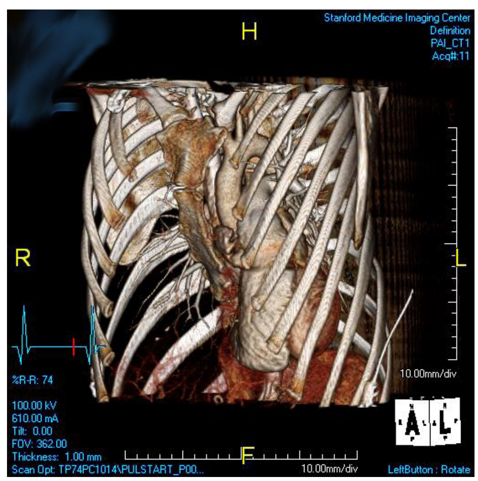


Figure 12

This 3D volume-rendered image shows a severe pectus excavatum in a young patient with the Marfan Syndrome prior to her valve sparing aortic root replacement.

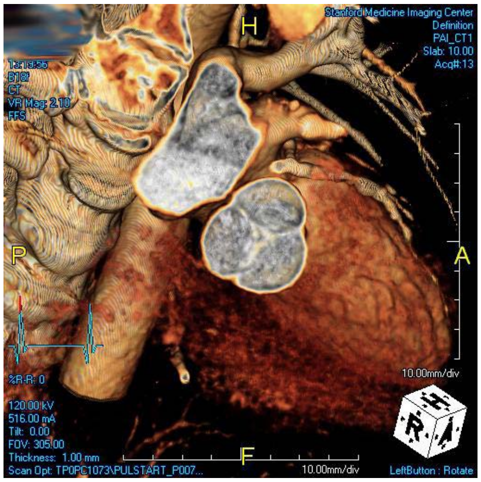


Figure 13

This 3D image shows a short axis view of the aortic valve of a patient undergoing evaluation for mild aortic root dilatation and moderate aortic regurgitation. You can see a small to moderate coaptation defect in the middle of the "Mercedes benz" sign where the leak originates. This image was later used as the basis for 4-dimensional imaging on an AquariusNet TeraRecon station.

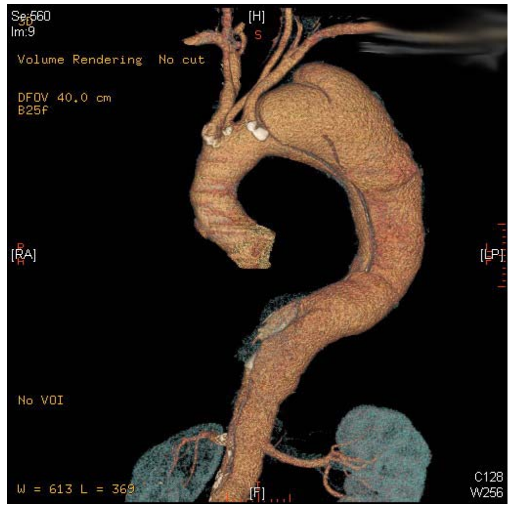


Figure 14

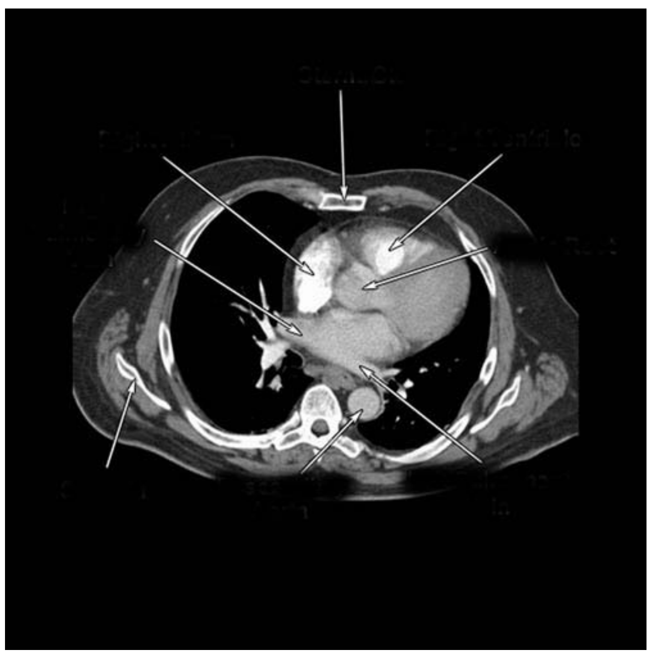
This 3D volume rendered image shows a 65-year-old male with a known chronic type B (beginning beyond the left subclavian artery) aortic dissection that suffered an acute on top of a chronic dissection while in Australia. You can see the 2 dissection flaps in the Proximal descending thoracic aorta at 1 o'clock.

Figures 15, 16, and 17

This 3D volume-rendered series shows the staged operation of a 38-year-old male who had undergone previous aortic valvuloplasties as a child and a subsequent mechanical aortic valve replacement at age 19 for a congenital uni- or bicuspid aortic valve. Due to the known but poorly characterized aortopathy of BAV, the patient had dilatation of the aortic root (with calcification), ascending, and transverse aorta (all seen to the far left). The patient's mechanical AV was function well; however, he had massive left ventricular hypertrophy with next to no LV cavity size. The decision was made to stage the operation to address his AV and his aortic dilatation separately. The image in the middle was taken after stage 1 of the operation. A valved LV to aortic conduit was built intraoperatively. The proximal end was sewn directly to the patient's left ventricle after a myomectomy was performed to make a large ventriculostomy. The distal end was sewn to the patient's descending thoracic aorta. When the LV contracts, blood is sent in an antegrade *and* retrograde fashion. The image to the right was taken after stage 2 of the operation. The aneurysmal segment of the ascending and transverse aorta was replaced with a Dacron interposition graft and the brachiocephalic vessels were reimplanted into the graft. The decision was made to leave the previous AV and aortic root in place due to extensive scarring and calcification.

Review Quiz

1. What does CT stand for?
2. What does CTA stand for?
3. How are the two studies different?
4. Looking at CT images is likened to looking at what?
5. How much radiation is your patient exposed to with a standard CT of the chest?
6. What four markers should you look for on every CT image?
7. How thick are average CT "slices"?
8. Starting in the lower left hand corner and proceeding clockwise, label what each arrow is pointing to in the image below:



Answers

1. Computed tomography
2. Computed tomography angiogram
3. A CTA uses injectable contrast dye to illustrate the vascular anatomy more fully
4. A loaf of bread
5. 10mSv or the equivalent of background radiation over the course of a year
6. Right, left, anterior, posterior, image slice thickness, patient name, date
7. 5mm (0.25-10mm)
8. Scapula, right pulmonary vein, right atrium, sternum, right ventricle, aortic root, left pulmonary vein, descending aorta

References

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