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The Medical Student's Guide to the Plain Chest Film

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Introduction

There are no great textbooks out there for medical students (and, for that matter, interns) who want to learn the basics of chest film interpretation. Most chest radiologists balk at the thought of trying to teach such a huge topic to a group that cannot devote a significant amount of time to this one area. Of course, not everyone can do a residency in Radiology and a fellowship in Thoracic Radiology. The reality, though, is that as medical students and interns you will be caring for a great number of patients on whom you will be ordering these studies. While most films will ultimately be interpreted by a Radiologist, you will nevertheless be expected to look at any film you order and you should have some comfort in making general diagnoses off of these films without having to wait the "official read." In addition, many chest films are obtained at night, both in the Emergency Department and in the hospital. These films may have abnormalities that are immediately life-threatening. You responsibility is to the patient, and the sooner you can make the diagnosis, the better off the patient will be.

The true secret to understanding these films is that it is not always as difficult as some would have you believe. Many of the more difficult and confusing diagnoses can wait for the radiologists. You do not need to worry about the subtle differences in findings between different chronic interstitial diseases. These cases can wait for the

Radiologist. In addition, if you miss a solitary pulmonary nodule and it is not seen until the next morning by the Radiologist, then there really has been no harm done to the patient. Many of the more subtle findings, although extremely important, are not as time sensitive as those affecting an acutely ill patient. Nevertheless, as you practice looking at these studies your skills will improve and you may find yourself making findings that even the Radiologist misses.

The goal of this guide, therefore, is to attempt to simplify the process of looking at and interpreting chest films. I will ignore some of the subtle details in the interest of compacting the information into an easily-digested format. In addition, I will focus primarily on those findings which you may encounter at night, when a Radiologist may not be available to you, and on those findings which are particularly time-sensitive. In an effort to make some of the concepts easier to understand, I have included images from CT scans.

Quick Flow Chart

Preliminary Steps

1. I am sure this is the right patient?
2. Is this a good film?

Systematically Evaluate the Film

3. Check all life support devices
4. Look for pneumothorax and pleural effusion.
5. Go through the anatomy (*Bones, Soft Tissues* and *Airways/Lungs*)

Think About What You See

6. Consider the vascular status: *Normal vs. Abnormal*
    - Vascular Volume
    - Pulmonary Vasculature
    - Is There Pulmonary Edema
7. Evaluate the lung parenchyma: *Normal vs. Abnormal*
    - Alveolar Flooding
    - Volume Loss (atelectasis)
    - Interstitial

Look For Don't Miss Lesions

Normal Anatomy

Chapter I

A normal frontal chest radiograph is shown in Figure 1.1, and a normal lateral chest radiograph is shown in Figure 1.2. The frontal film is always presented as if the patient were standing in front of you, so that the patient's left is your right and vice versa. Notice that in general there are three different densities which are seen – bone, soft tissue and air. Bone shows up as the "densest" (meaning whitest), then soft tissue, then air (which is almost always pure black). Because the degree of whiteness seen on a film is a function not only of the material (bone, soft tissue, air) but also of the amount of the material, soft tissue structures such as the heart usually appear whiter than bones such as the ribs. While fat is often cited as a fourth density seen on plain films, in general it will rarely be distinguishable from soft tissue in most *chest* films.

Bone Anatomy

The bone anatomy on the chest film is fairly straight-forward. Unlike some other areas of the body, the bones in the chest appear on the chest film much as you would expect them to. Briefly I will discuss the major bone anatomy that is visible on the chest film.

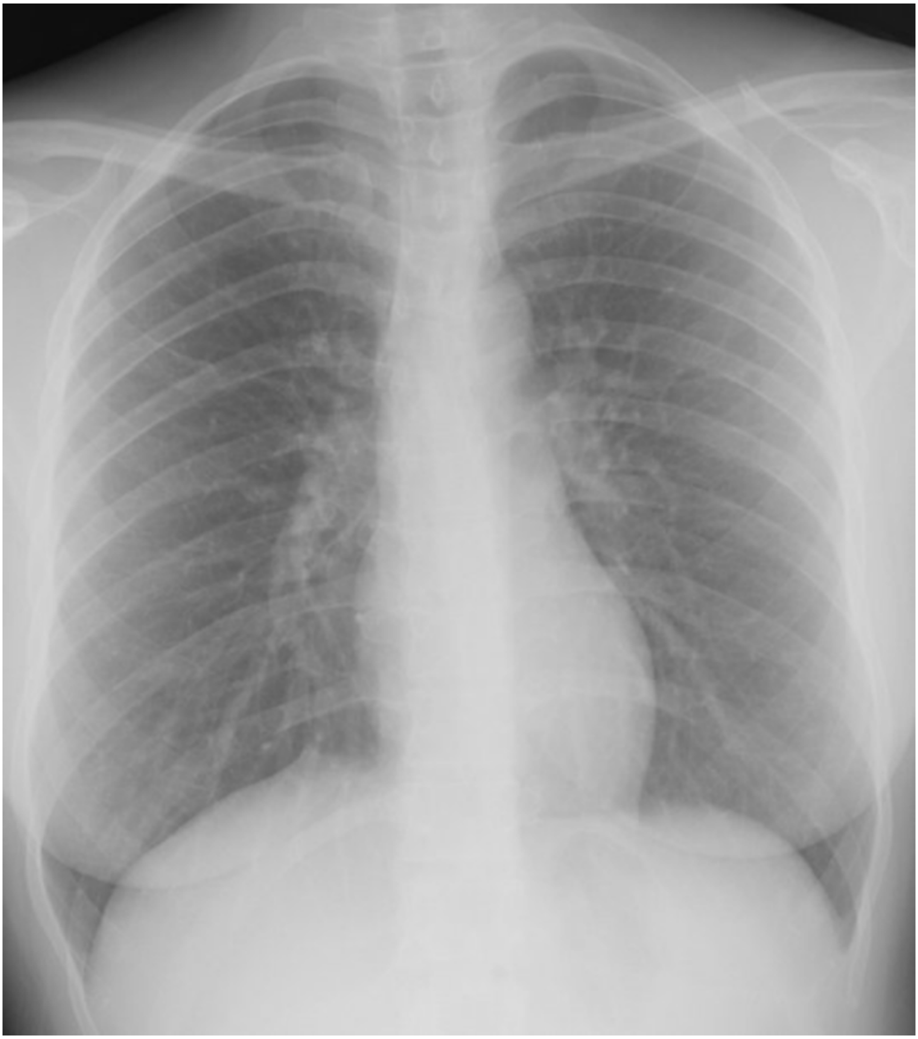

Figure 1.1 – Normal frontal chest radiograph.

Figure 1.2 – Normal lateral chest radiograph.

The sternum sits anteriorly and in the midline. Because so many structures overly the midline on the frontal film, it is usually difficult to see any detail within the sternum itself. Figure 1.3 shows a volume-rendered CT scan of the sternum in the same orientation in which it sits on a frontal chest radiograph, while Figure 1.4 shows the same oriented for the lateral view.

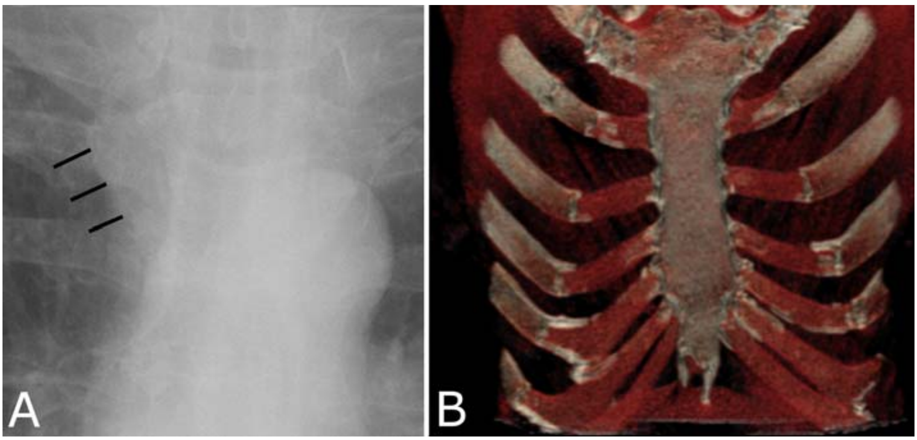

Figure 1.3 – A. Frontal radiograph showing that only part of the manubrium (black lines) is well seen. B. Volume rendered CT image of the sternum showing the sternum in the same configuration that it is in on a frontal radiograph. The red areas represent the cartilage joining the anterior ribs to the sternum. This cartilage will be visible to different degrees in different patients depending upon the degree of calcification within the cartilage.

The spine sits posteriorly but also along the midline. In a properly-penetrated frontal film the vertebral bodies should be just discernable through the heart. Again, because of the overlying structures in the midline, spine abnormalities will generally be easier to see on the lateral, rather than the frontal, view. Figure 1.5 shows the spine from a volume-rendered CT scan as it lies on both frontal (A) and lateral (B) radiographs.

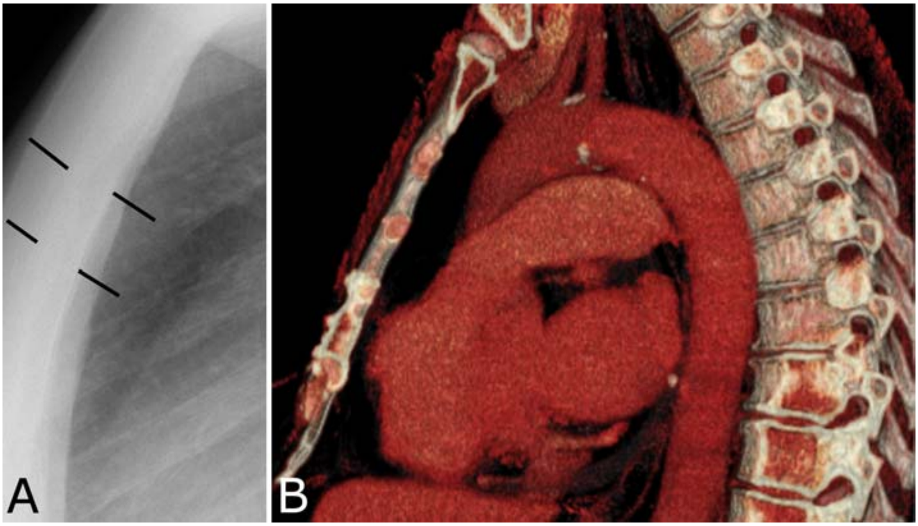

Figure 1.4 – A. Lateral radiograph shows the sternum (black lines) better. B. Volume rendered CT image of the sternum showing the sternum as it is seen on the lateral radiograph. Sternal abnormalities are more likely to be visible on the lateral view that on the frontal view because fewer objects overlap the sternum when viewed from the side.

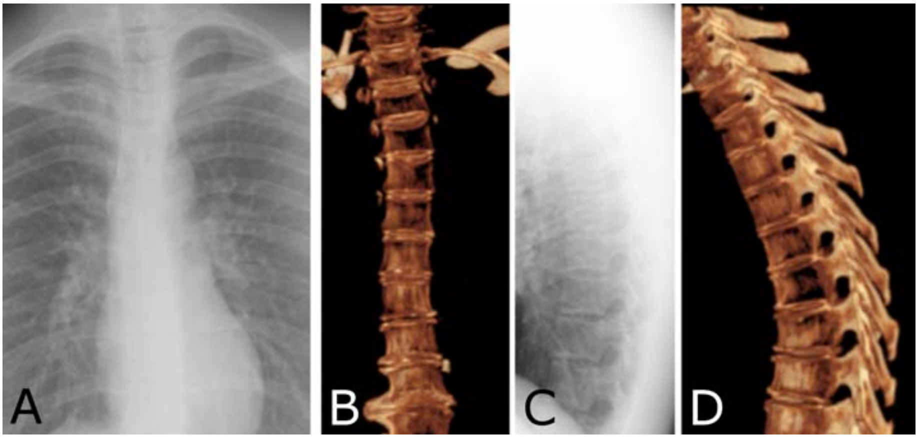

Figure 1.5 – Spine. A. Frontal radiograph shows that the vertebral bodies are just visible through shadow of the heart. B. Volume rendered CT of the spine in the same orientation. C. Lateral chest radiograph shows the vertebral bodies better than the frontal view. D. Volume rendered CT image of the spine as seen on the lateral projection for comparison.

The ribs can be seen on both the frontal and lateral radiographs. On the frontal radiograph, the posterior portions of the ribs have a relatively horizontal course from the spine as they travel out laterally. The anterior ribs are generally seen less well, and they tend to slop inferiorly as they move from lateral to anterior. On the lateral view, right and left ribs overlap and have a general downward slope as they travel from posterior to anterior. Figures 1.6 and 1.7 illustrate the course of the ribs on frontal and lateral radiographs.

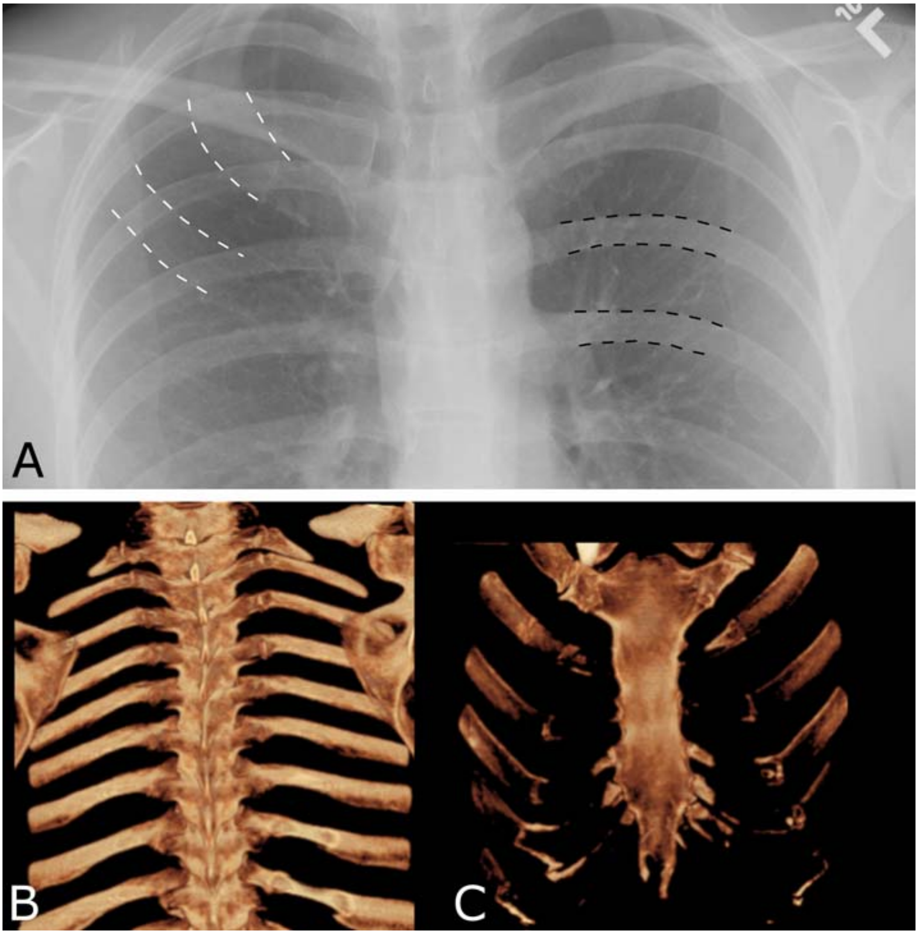

Figure 1.6 – Ribs. A. Frontal radiograph shows that the posterior ribs (outlined in black) have a horizontal course, while the anterior ribs (outlined in white) have a more sloping course as the move medially. The anterior ribs are generally not seen as well as the posterior ribs. B. Posterior ribs on volume rendered CT. C. Anterior ribs on volume rendered CT.

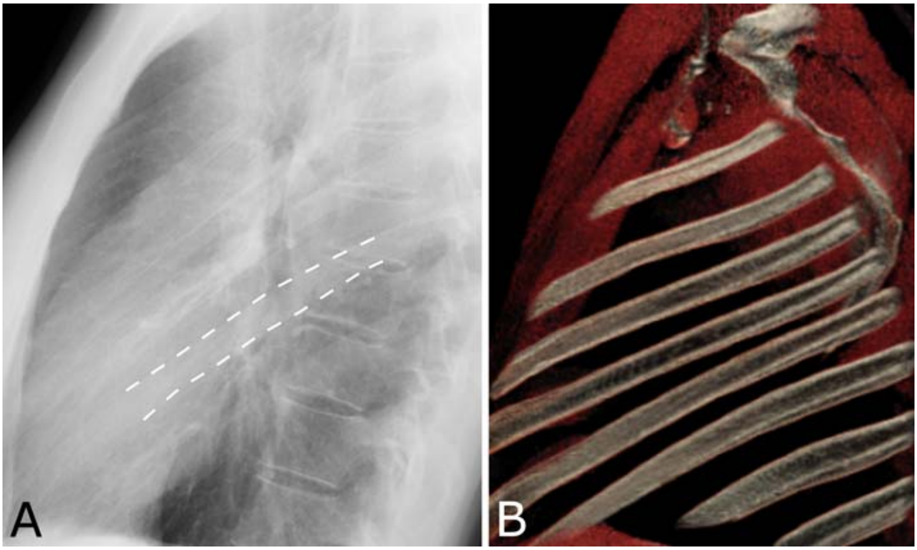

Figure 1.7 – A. Lateral radiograph shows the course of the lateral ribs (outlined in white). B. Volume rendered CT scan shows the ribs as they are seen on a lateral radiograph. This view shows only one side (in this case, the left) but on the actual radiograph, the left and right ribs overlap. Notice that the ribs generally slop downward as they course from posterior (right side of the image) to anterior (left side of the image).

In general, the scapula will overlie part of the lung field on the frontal view. It is important to recognize the borders of the scapula because occasionally a novice chest reader will mistake the outline of the clavicle for a pneumothorax. On the lateral view, the patient has his or her arms raised and the scapulae will overlie each other as well as the apices of the lungs. Figure 1.8 illustrates the positioning of the scapula on the frontal radiograph.

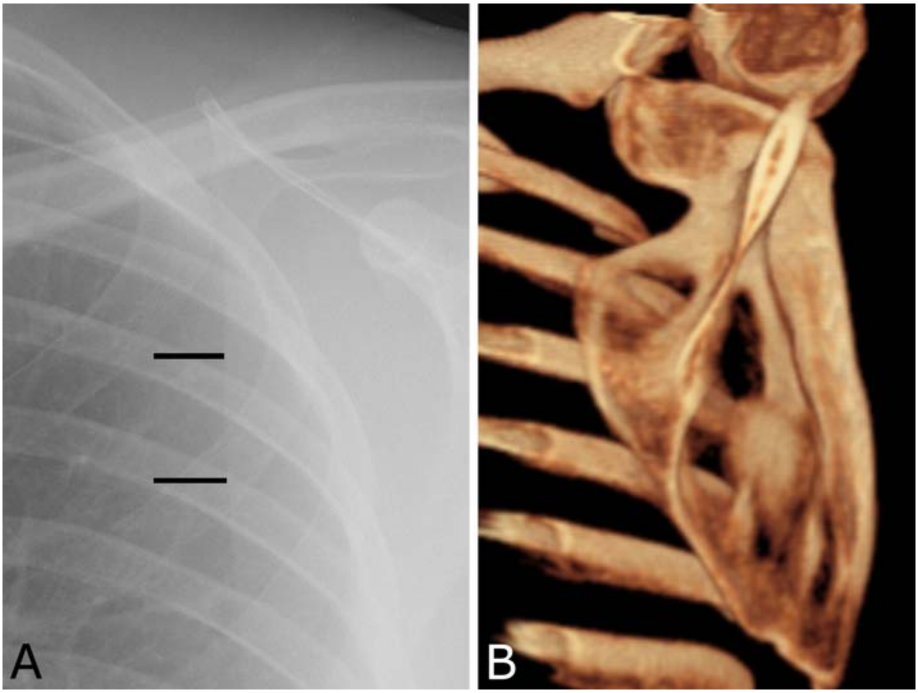

Figure 1.8 – Scapula. A. Frontal radiograph. The scapula will overlie the lung field to various degrees depending upon how the patient has been positioned. Recognize the medial border of the scapula (black lines). B. Volume rendered CT shows the scapula in relationship to the adjacent ribs.

Mediastinal Anatomy

The anatomy of the mediastinum can only be seen on the chest radiograph when it is surrounded by air. Thus, internal structures such as the chambers of the heart, the great vessels, etc. all blend into a single shadow except when they abut the lung. It is thus customary to consider the mediastinal "borders" – the lateral portions of the mediastinum that sit next to the lung.

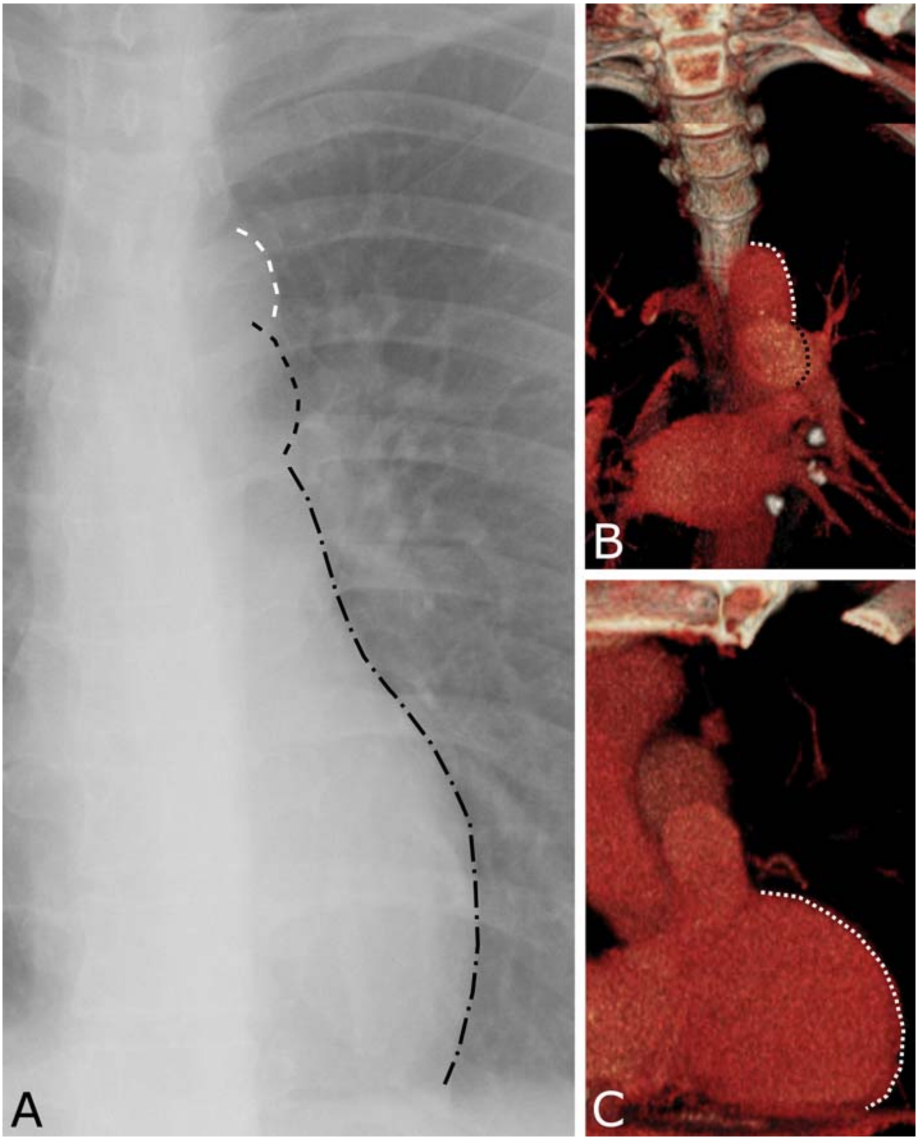

Figure 1.9 – Left mediastinal border. A. Frontal radiograph shows aortic knob (white dashes), main pulmonary artery (black dashes) and left ventricle (black dot-dash). B and C. Volume rendered CT images to show the same structures. B. Aortic knob (white dots) and main pulmonary artery (black dots). C. Left ventricle (white dots).

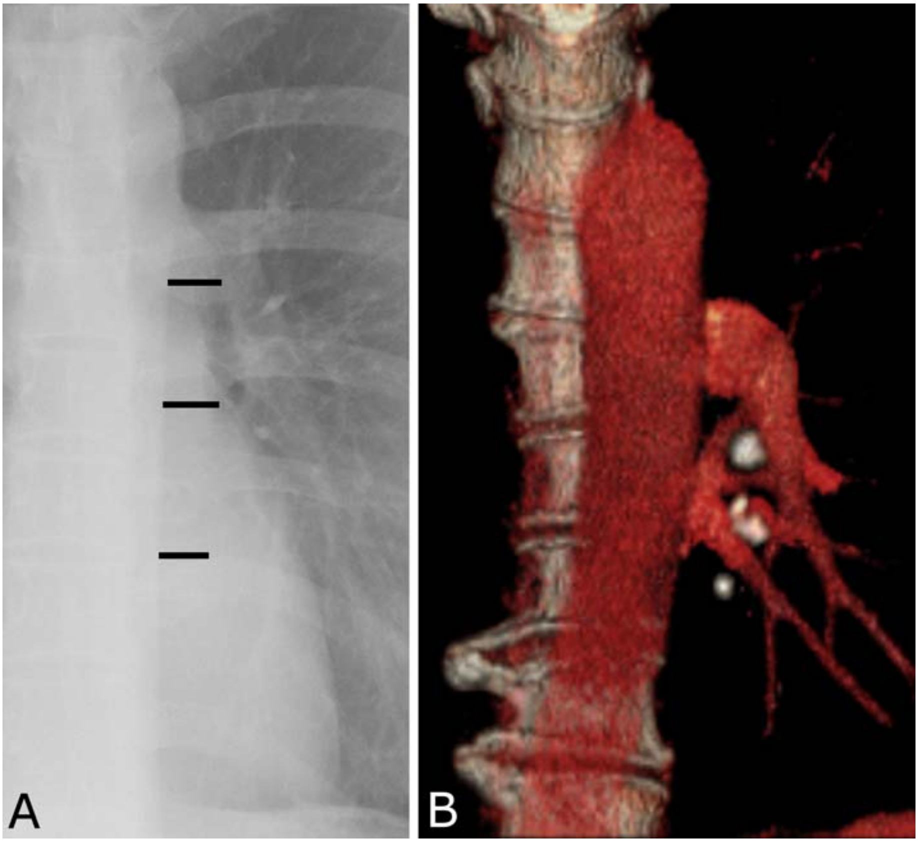

Figure 1.10 – Descending aorta. A. Frontal radiograph shows that the descending aorta is well seen (because it is bordered by air) even though it is posterior to the heart. B. Volume rendered CT scan shows the descending aorta coursing posteriorly along the spine.

On the frontal film, the left and right sides of the mediastinum can be considered separately. Starting with the left side, from superior to inferiorly, the major border forming structures that should be recognized are (1) the aorta (sometimes called the "aortic knob"), (2) the main pulmonary artery and (3) the left ventricle. Figure 1.9 shows theses structures. It should also be noted that the descending aorta, though behind the heart, can usually be seen quite well on a frontal film, as demonstrated in Figure 1.10.

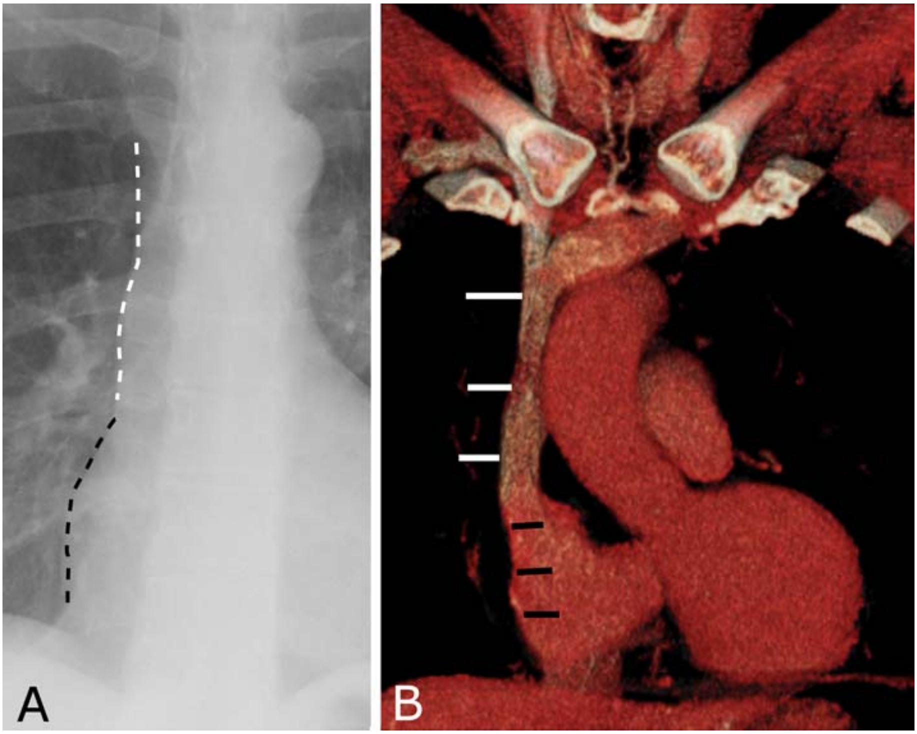

Figure 1.11 – Right mediastinal border. A. Frontal radiograph shows the superior vena cave (white dashes) descending and joining with the right atrium (black dashes). B. Volume rendered CT shows the same structures with white and black lines, respectively. Notice that the ascending aorta does not contribute to the right heart border in normal patients (though in patients with a very ecstatic or aneurysmal aorta it can extend lateral to the SVC and form the right mediastinal border).

The right side of the mediastinum is primarily formed by the superior vena cava and the right atrium of the heart. Generally the superior vena cava will fade superiorly. Figure 1.11 shows these structures.

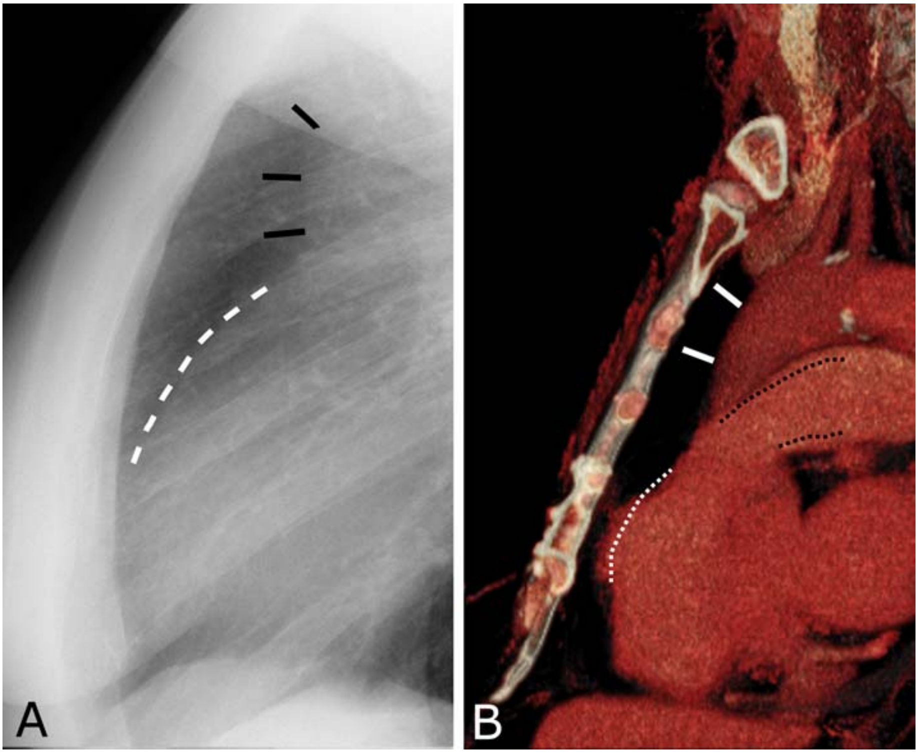

Figure 1.12 – Anterior mediastinal border. A. Lateral radiograph shows the anterior margin of the heart, which is formed by the right ventricle (white dashes). The structure arching superiorly (black lines) is the ascending aorta. B. Volume rendered CT image showing the anterior mediastinal anatomy as it is seen on a lateral radiograph. The right ventricle (RV) is the anterior border. The ascending aorta (white lines) is also seen, though usually not as well. The main pulmonary artery (black dots) is not surrounded by air at this level and thus is not seen on the lateral radiograph.

On the lateral view, it is appropriate to consider the anterior and posterior borders of the mediastinum. The anterior chamber of the heart is the right ventricle. This chamber forms the anterior border of the mediastinum on the lateral chest radiograph, as shown in Figure 1.12. Note that the main pulmonary artery, as it comes off of the right ventricle, is not surrounded by air and thus is not border-forming on the lateral. Often, however, the ascending aorta will be seen, coming just anterior and superior to the pulmonary artery.

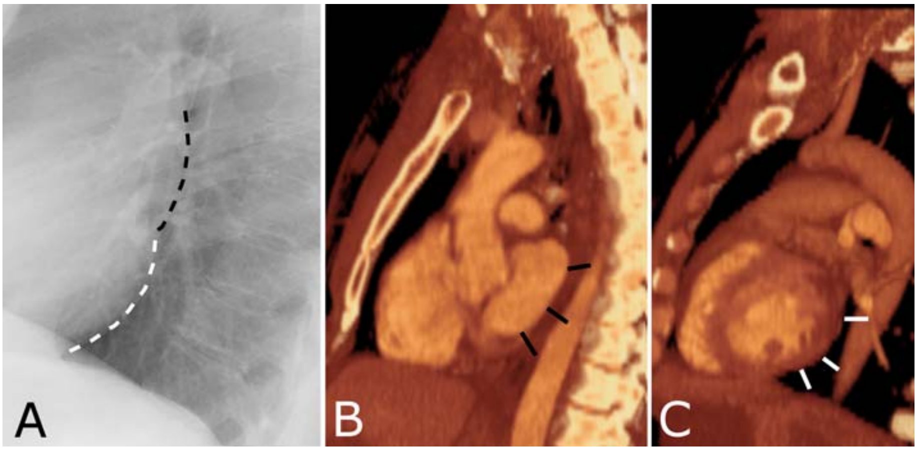

Figure 1.13 – Posterior mediastinal border. A. Lateral chest radiograph shows posterior margins of both the left atrium (black dashes) and left ventricle (white dashes). B. Volume rendered CT scan shows the left atrium in the same projection. C. Volume rendered CT scan shows the left ventricle as it lies on a lateral chest radiograph.

The posterior border of the mediastinum is composed of both the left atrium (superiorly) and the left ventricle (inferiorly). Figure 1.13 shows these structures. It should also be noted that the descending aorta is usually seen rather well on the lateral radiograph, as well. The degree of tortuosity varies from patient to patient, but a typical example is seen in Figure 1.14.

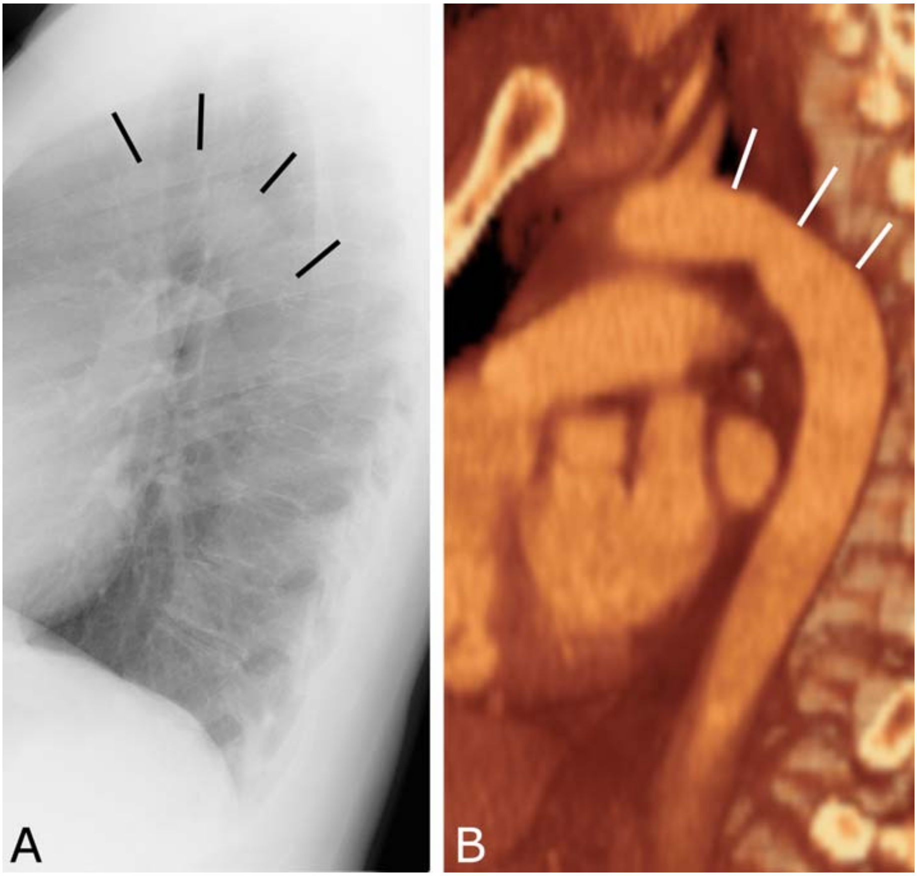

Figure 1.14 – Descending aorta. A. Lateral radiograph shows the arch of the aorta continuing inferiorly as the descending aorta. Generally, the descending aorta becomes gradually less apparent when looking from superior to inferior. B. Volume rendered CT scan shows the same structure.

Airway and Lung Anatomy

The central airways can be well seen on both the frontal and lateral radiographs. It is always important to look for them and to evaluate both their patency and course. The trachea, carina and main stem bronchi can be well seen through the mediastinum because they represent air-filled structures surrounded by soft tissue density. Figures 1.15 and 1.16 illustrate the anatomy of the central airways on the frontal and lateral chest radiographs respectively.

The lungs themselves are divided into five lobes, each supplied by a bronchus with the same name as the lobe. On the right, there are three lobes: the upper, middle and lower, while on the left there are two: the upper and lower. The upper and middle lobes of the right lung sit anteriorly and are separated from each other by the minor fissure. The minor fissure runs horizontal from the hilum and is usually seen well on the frontal radiograph. Figure 1.17 illustrates this fissure.

In both lungs the lower lobes sit posteriorly, behind the major fissure. On the right, both the upper and middle lobes sit in front of the major fissure, while on the left there is only and upper lobe (which includes the lingula) to sit in front of the major fissure. The major fissures are not seen on the frontal radiograph, but both can be seen on the lateral radiograph. The major fissures run obliquely, parallel to the lateral rib shadows, as shown in Figure 1.18. It is not always possible to tell the left from right major fissure because in the normal individual they overlie each other on the lateral radiograph. In some cases the minor fissure will also be visible on the lateral radiograph, running anterior to the major fissure. These relationships are shown in Figure 1.18.

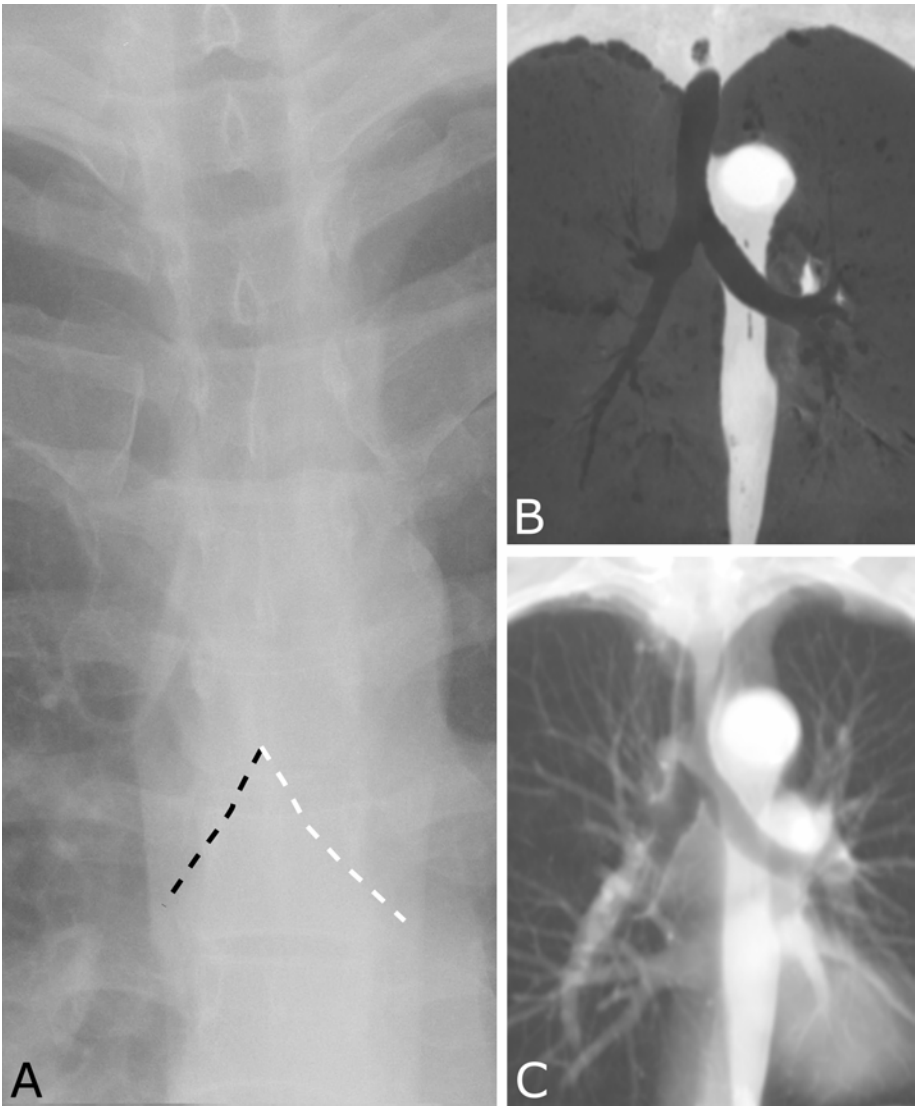

Figure 1.15 – Central airways. A. Frontal chest radiograph shows the trachea splitting into the left (white dashes) and right (black dashes) mainstem bronchi. The carina is an important landmark that should be identified on every film. B. Coronal CT image rendered as a minimum-intensity (MinIP) slab. The course of the central airways is shown. C. The same slab as B, but rendered using average intensity to better illustrate the relationship of the central airways to the adjacent soft tissue structures.

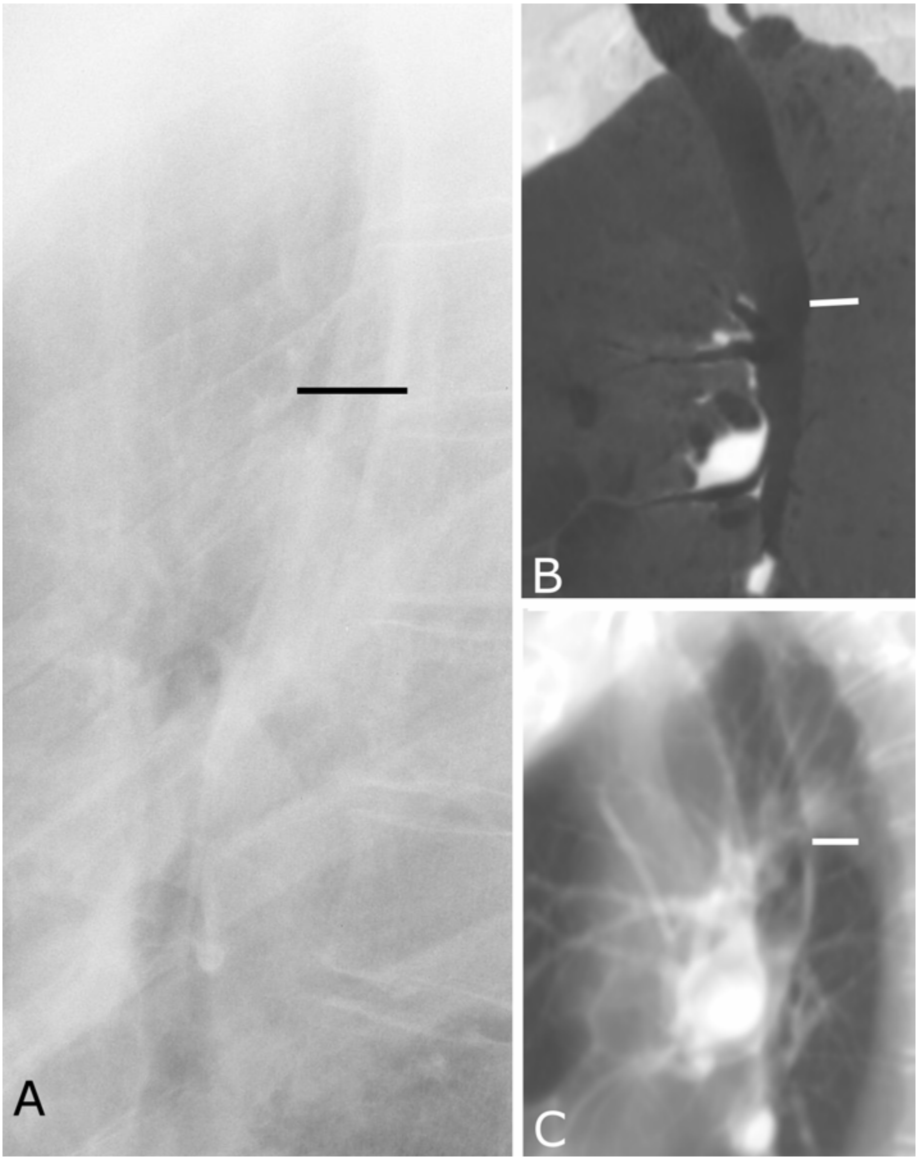

Figure 1.16 – Central airways. A. Lateral radiograph of the chest showing the trachea. The carina can only be identified as an apparent decrease in diameter of the airway on the lateral radiograph. B. MinIP and C. Average intensity projection CT slab to show the anatomy in the same configuration as A.

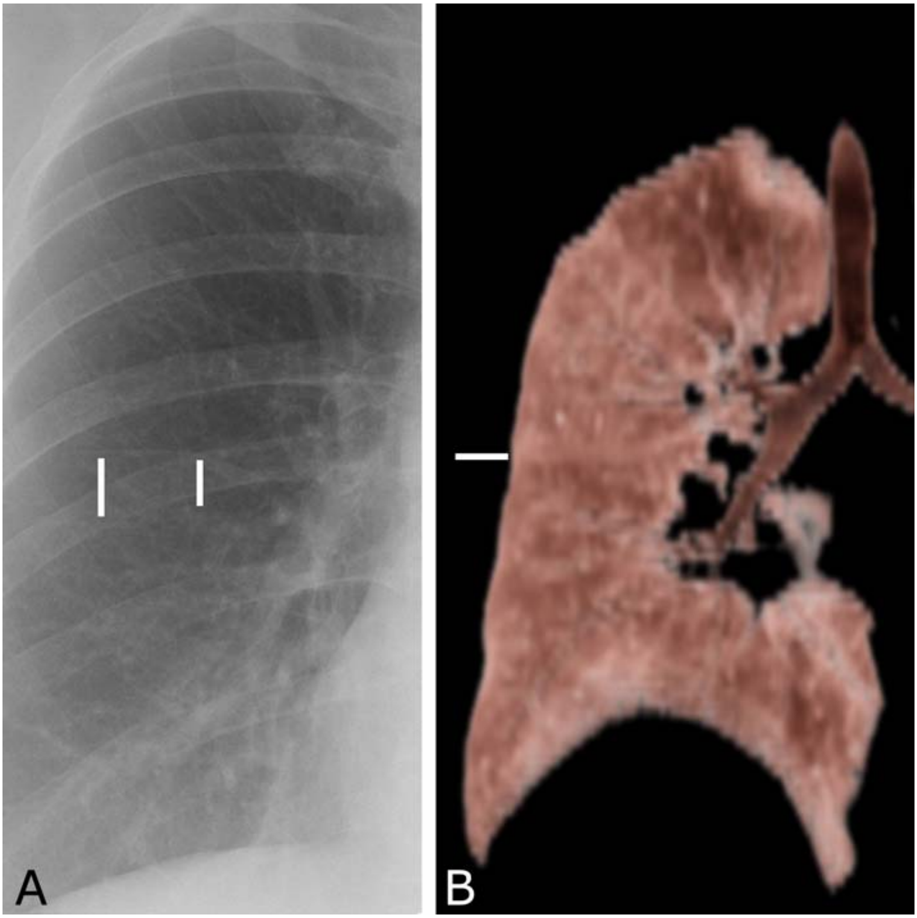

Figure 1.17 – Lungs. A. Frontal chest radiograph shows the minor fissure which separates the right upper lobe from the right middle lobe. B. Volume rendered CT image of the right lung shows the same structure.

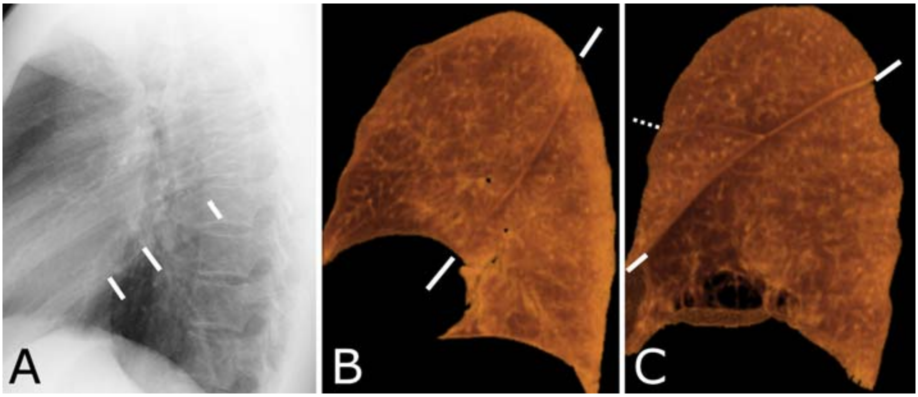

Figure 1.18 – Lungs. A. Lateral radiograph shows the major fissures (white lines). The lower lobes sit below this fissure, while the upper (and on the right middle) lobes sit anterior to this fissure. B (left lung) and C (right lung) volume rendered CT images to show the course of the major fissures (white lines) as seen on a lateral chest radiograph. Note that in the right lung the minor fissure is also identified (white dotted line).

Approach to the Plain Film

Chapter II

Preliminary Issues

The first thing you should do whenever you look at a chest film is assure yourself that you are looking at the correct patient's film. This process requires two steps. The first is to make sure that the label on the film corresponds to the name of the patient. For images on actual film, the patient's name and medical record number will be “flashed” onto one of the corners of the film. Films get into the wrong jacket and get hung on the wrong boards. Unfortunately, the modern digital films (on a PACS, picture archive and communication system) can actually suffer the same problems. Here the name and medical record number are electronically attached to the film, but computers behave in strange ways sometimes. It is not uncommon to click on one patient's name, only to have the films of several different patients appear. You need to look at the name associated with the image to make sure it is correct.

The second step in verifying that you are looking at the correct film involves a more sinister, though thankfully less common, problem. Sometimes the technologist will image the wrong patient, or accidentally switch the cassettes of two patients after doing a series of portable films.

In this case, the identifying information appears to be correct, but in fact it is a different patient's image that you are seeing. While this problem will often go unnoticed, you should at least look for any obvious signs that something is not correct. Are there sternal wires in your patient who has never had surgery? Breast shadows where there should not be? Old films, if they are present, can be very helpful here. This possibility of the wrong patient being imaged should always be considered whenever there has been a dramatic but clinically unexpected change in the appearance of the chest. In all cases it is prudent to be alert and use common sense.

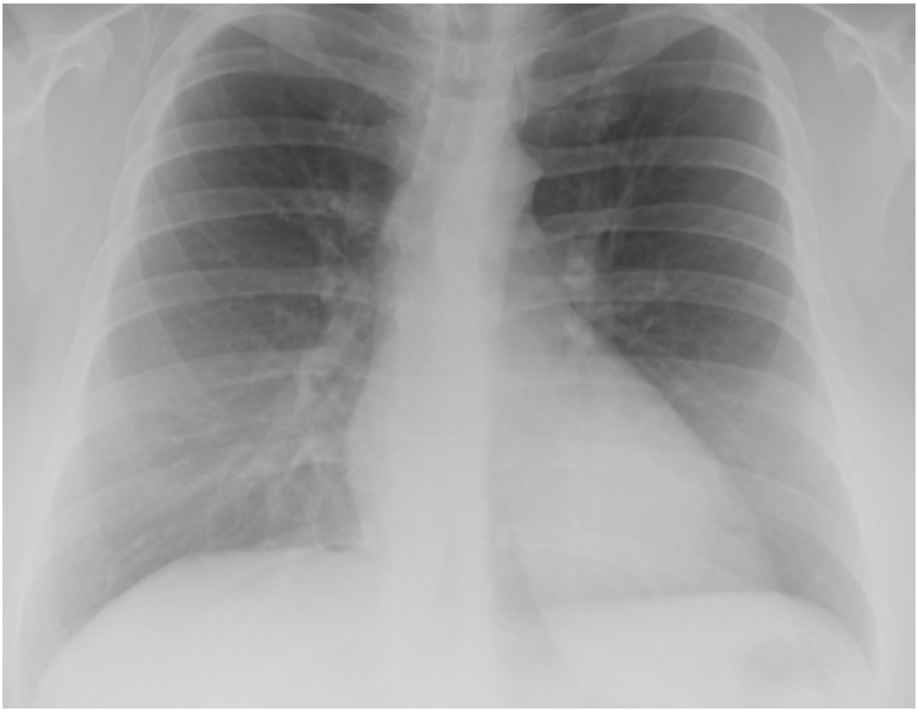

Figure 2.1 – Frontal radiograph of the chest where the apices of the lungs have been missed. A small pneumothorax may not be seen in such a case.

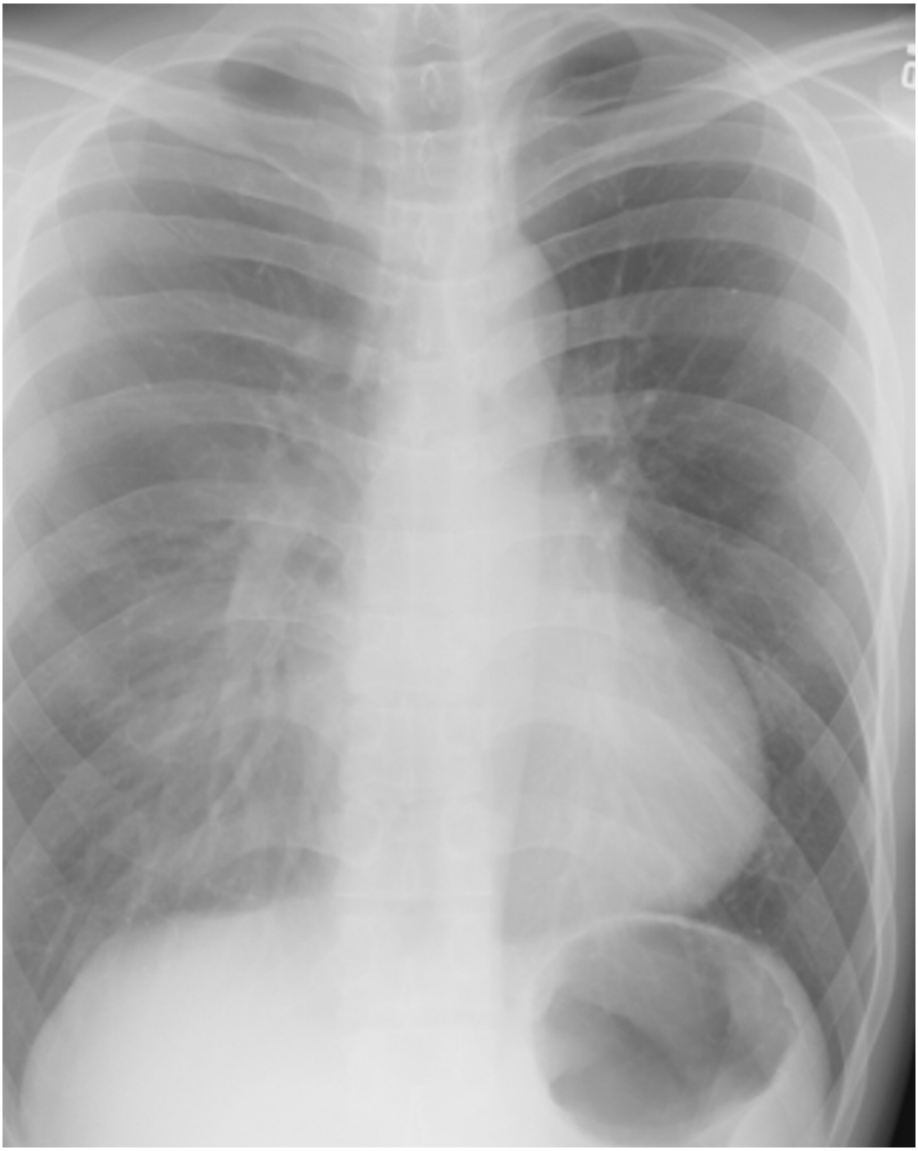

Figure 2.2 – Frontal radiograph of the chest where the right costophrenic angle has been excluded. Often this will be the only location where small pleural effusions will be seen. When this region is left off of the film, these effusions may be missed.

When first looking at a chest film, it is also useful to make a quick assessment about the overall quality of the film. A poor quality film may mask abnormalities that would have otherwise been seen on a high quality film. First, you should make sure that the entire region of interest is included on the film. For the chest, this generally means including all of the lungs. If the apices are not on the film, small pneumothoraces or even tumors may be missed (Figure 2.1). If the costophrenic angles (the lateral, inferior portions of the lungs) are not included, you may be missing your best shot at identifying a pleural effusion (Figure 2.2).

It is also vital that the patient be positioned properly when the film is taken. A patient who is rotated will have a different appearance than one seen straight on. Rotation causes the greatest problem in the evaluation of the mediastinal borders and vascular status of the patient.

The final aspects of image quality that I will discuss are the concepts of exposure and penetration. With modern equipment, it is much less common to encounter problems in these areas. Nevertheless, it is still often talked about (especially on Medicine rounds!) so it is worth understanding. *Penetration* is determined by the voltage setting on the x-ray tube. Penetration determines how well x-rays travel through the body. In a well-penetrated chest radiograph the vertebral bodies will be just discernable through the heart on the frontal film. In an under-penetrated film the vertebral bodies will not be visible. In an over-penetrated film the vertebral bodies will be seen too well. Over penetration is a problem because it means that pathology in the lungs will likely be missed.

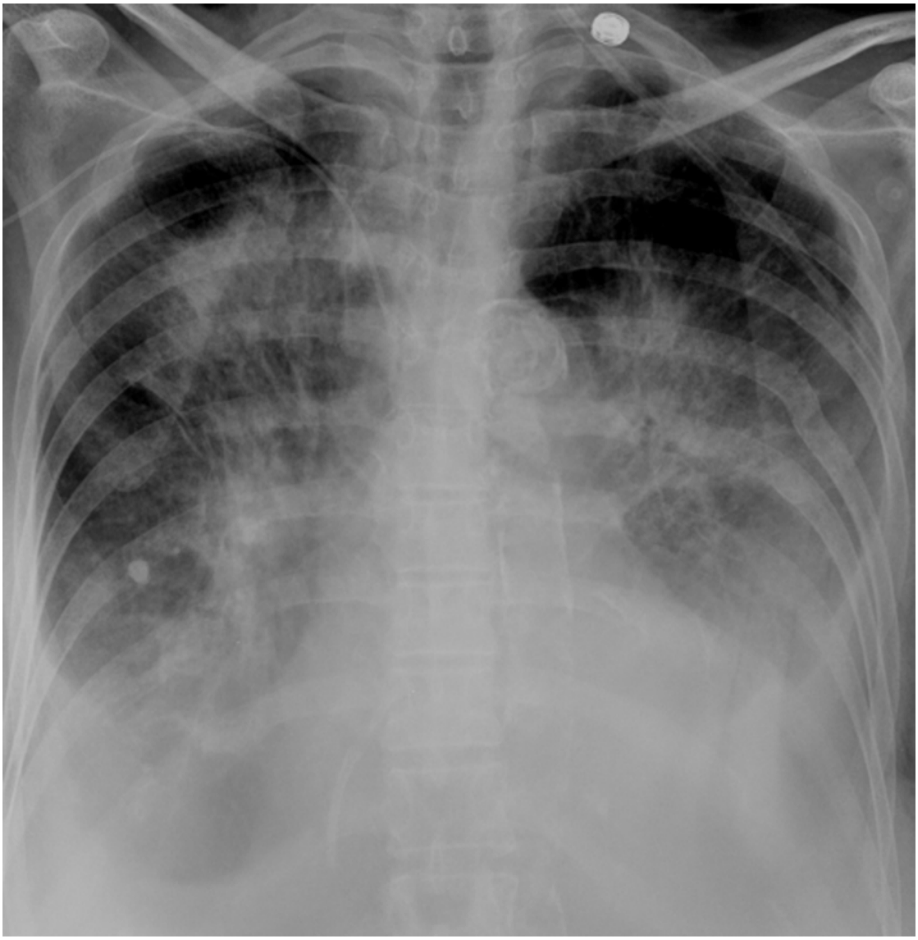

Figure 2.3 – Over-penetrated radiograph. Notice how unusually well the vertebral bodies are seen through the heart. The problem with over-penetration is evident in the lung fields, where detail of the parenchymal process is lost because of the poor technique.

Figure 2.4 – Under-penetrated radiograph. Notice that the overall degree of blackening in the lungs is appropriate (exposure) but there is essentially no detail visible through the heart (indicating poor penetration).

Exposure is determined by how many x-rays reach the film or detector. In general it is determined by the current and time settings (mAs) on the x-ray tube. Since x-rays cause a film to turn black, a well-exposed film will have dark areas where there is pure air (airways, outside the patient, etc.) but the non-air regions will be lighter shades of gray. In an under-exposed film, the film looks too white and it is difficult to determine whether there is pathology in the lungs. In an over-exposed film the film looks too black and all of the lung markings are lost. It should be noted that most over-*penetrated* films will also be over-exposed (because setting the voltage too high causes both problems), though most over-*exposed* films will not necessarily be over-penetrated (because setting the mAs too high does not affect penetration). There are other issues that impair image quality, including some related to the developing/fixing process (for film) and the digital read-out and A/D conversion (digital systems) but these are beyond the scope of this work.

Figure 2.5 – Over-exposed radiograph. Notice that the lung fields appear far too black and almost all detail is lost, though the penetration is correct (the vertebral bodies are just discernable through the heart).

Figure 2.6 – Under-exposed radiograph. Much like Figure 2.4 the soft tissues in the image appear too white. The problem is clearly one of exposure, though, because the vertebral bodies are discernable through the heart (unlike Figure 2.4).

Systematically Evaluating the Film

The absolute worst way to look at film is to use what I call the "Rorchach" method (named for the famous ink blot test used in Psychiatry). In this method, you look at the film and see what diagnosis comes to you. Unfortunately, this method is probably the most commonly used among inexperienced film readers. This method causes many problems and needs to be avoided. Reasons to avoid this method include:

1. Subtle findings will be missed if they are not specifically looked for.

2. Secondary findings will be missed. Once one finding has been made, it is easy to start thinking about it. This phenomenon is called satisfaction of search. Once you find one thing you are looking for, you stop looking for other findings.

3. Complicated films cannot be evaluated because no single diagnosis "jumps out" at you.

4. It takes longer. Novice readers generally find this statement hard to believe, and most who resist using a systematic system do so because they mistakenly think that being systematic is necessarily slow. In fact, with practice, a systematic approach will allow you to interpret films not only more accurately but also more rapidly.

Instead, a systematic approach should be used to evaluate every film. There are many different systematic approaches out there, and I do not favor one over the other. The most important thing is that you pick a method, practice it, and use it on absolutely every chest film you look at. I will describe one method that seems to be relatively easy to adopt. As a side note, though, let me add that no matter what system you ultimately choose to use, the first thing you must do is evaluate the life support devices and look for potential complications. This step is covered in the next chapter.

A Systematic Approach to the Chest Film

Step 1: *Evaluate any life support devices* and look for potential complications including pneumothorax. It is also at this time that I look for pleural effusions, since I can lump pneumothorax and pleural effusion easily together in my mind. Foreign bodies should also be identified at this point. Life support devices and their complications are discussed in the next chapter.

Step 2: *Evaluate the anatomy of the chest* by evaluating each of the structures discussed in the last chapter. I organize this step the same way I organized the previous chapter. First I look at all the bones. Then I look at the soft tissue structures and all of the mediastinal borders. Then I evaluate the central airways and the lungs. This process will allow you to identify most of the findings on the film.

Once you have made most of the findings on the film (through your careful and deliberate evaluation) it is time to think about the significance of what you see. Some findings, such as pulmonary nodules and broken bones, by their very nature trigger an easy differential diagnosis. But there are two areas where you need pay particular attention to pattern and detail:

Step 3: *Evaluate the vascular status of the patient.* The chest film gives a great deal of information about the vascular status of the patient. I will discuss the process of deciphering this information in Chapter IV.

Step 4: *Evaluate the lung parenchyma.* Findings in the lung parenchyma can be difficult to understand for the inexperienced reader. When there is a visible abnormality within the lung parenchyma, it is important that it be classified correctly so that the correct diagnosis can be made. I will discuss the process of classifying parenchymal patterns in Chapter V.

Life Support Devices

Chapter III

Many patients have indwelling life support hardware devices. While these are most common in hospitalized patients, they are becoming increasingly common in outpatients as well. It is always important to evaluate every life support device on every film. You must make sure (1) that the device is where you expect it to be and (2) there has not been a complication related to that device. Since malpositioned life support devices and complications from life support devices can be immediately life-threatening, it is important that any abnormalities be identified as quickly as possible. I will discuss the major types of life support hardware, its proper positioning, and the complications you need to specifically look for.

Endotracheal Tubes

Endotracheal tubes (ETT), like several other life support devices, usually contain a "stripe" along their wall to make them easier to identify on a radiograph. In general, however, the entire tube can be seen. The tip of the tube should be located 4 or 5 cm above the carina (Figure 3.1). This position corresponds to the level of the clavicular heads and thus can easily be identified even when the carina is poorly seen. If the tube is in too far then it may begin to migrate into one of the mainstem bronchi when the patient's neck is flexed. In the extreme case, it may be seen to actually travel down one of the mainstem bronchi on the film itself. An ETT down a mainstem bronchus (Figure 3.2) causes one lung to be under-ventilated (or even obstructed completely) while the other lung is over-ventilated. When the tube is in too far it needs to be retracted and the distance to retract the tube can simply be measured from the film. Many inexperienced readers have difficulty seeing the carina (the key landmark to which the ETT tip is measured) so it is worth practicing this skill by looking for the carina on every patient, regardless of whether there is an ETT or not. The carina is most easily found by locating the left mainstem bronchus (which is generally easier to find) and tracing it proximally to the carina.

An endotracheal tube that is not in far enough is a problem as well (Figure 3.3). First, the patient is at risk of that tube coming out (thus "losing the airway"). The other problem from a too-shallow tube results from the inflatable cuff that surrounds the ETT. In a properly-positioned ETT, the inflated cuff will reside below the vocal folds (which can be found near the C4/5 level). But if the ETT is not in far enough, this cuff may be inflated at the level of the vocal folds, causing irritation and possible future problems for the patient. A tube that is not in far enough needs to be advanced, and again the proper distance can be measured on the film.

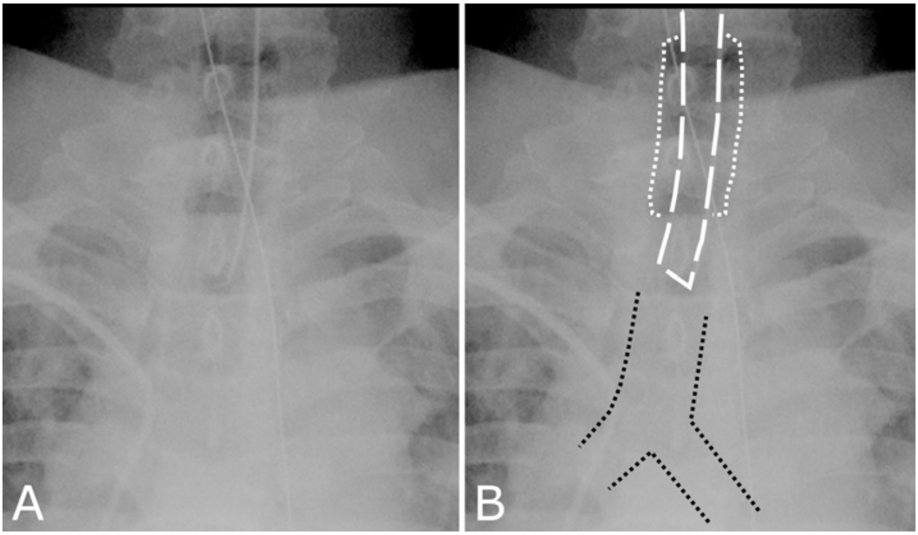

Figure 3.1 – Well-positioned endotracheal tube. A. Unmarked film. B. Marked film to outline the endotracheal tube itself (white dashes) and the airway (black dots). Note also that the inflated cuff can be seen (white dots) and it nicely parallels the wall of the trachea.

The cuff of the ETT is usually well-seen on the chest film. This cuff should nicely parallel the wall of the trachea. An over-inflated cuff can irritate the trachea and may result in the patient developing a tracheal stenosis later on. You should always look for the cuff whenever you evaluate the position of the ETT.

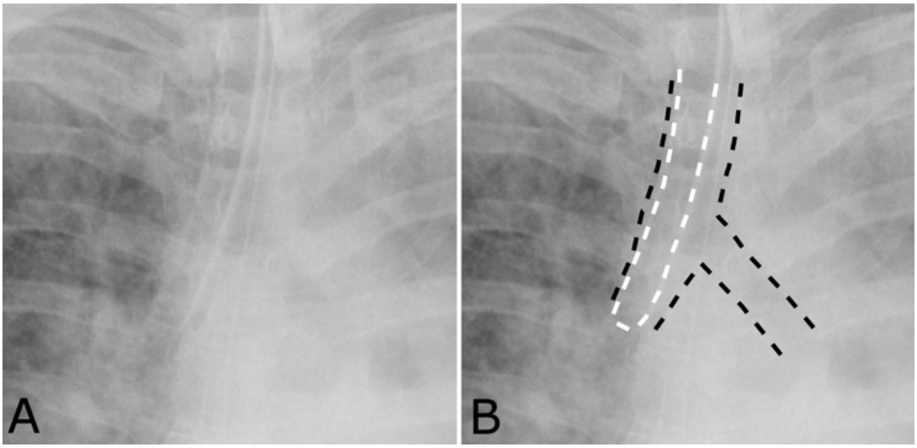

Figure 3.2 – Endotracheal tube into the right mainstem bronchus. A. Unmarked film. B. Marked film to show the endotracheal tube (white dashes) as well as the airway (black dashes). It is often said that tubes migrate down the right mainstem bronchus more frequently than the left because of the straighter path, but be aware that both conditions do occur.

The major complications to look for when evaluating an endotracheal tube are (1) malpositioning and (2) pneumothorax. Besides being in too far or not far enough, it is also possible that the tube is not in the airway at all. In most cases this will mean that the tube is in the esophagus. The best clue to an esophageal intubation is that the course of the ETT will lie outside of the trachea. It is also common to see excessive air in both the esophagus and stomach. Pneumothoraces are discussed at the end of this chapter.

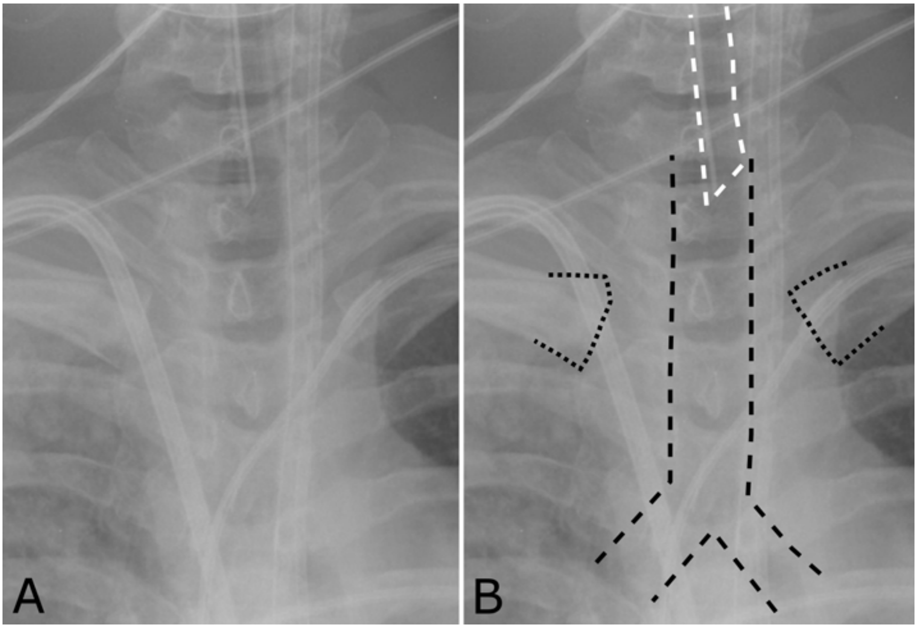

Figure 3.3 – Endotracheal tube too high. A. Unmarked film. B. Marked film to show endotracheal tube (white dashes) and airway (black dashes). Also notice the tip of the endotracheal tube is well above the level of the clavicular heads (black dots).

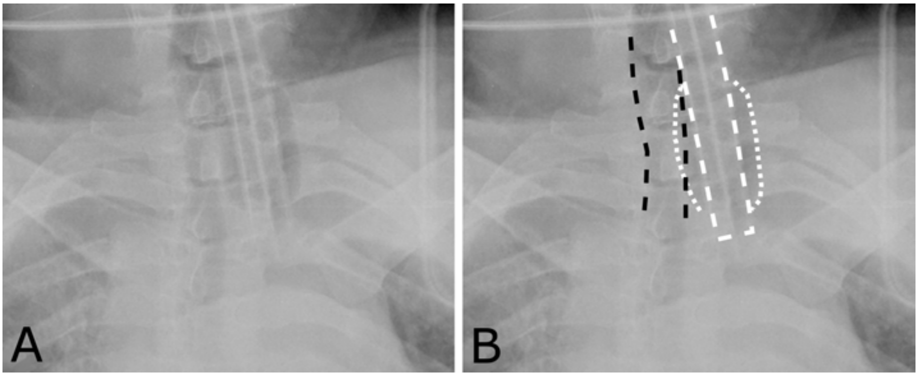

Figure 3.4 – Esophageal intubation. A. Unmarked film. B. Marked film to show that the endotracheal tube (white dashes) does not lie within the trachea (black dashes). Also note that the inflated cuff is well seen (white dots).

Central Lines

There are many different types of central lines in use. Most of the central lines seen on a chest film will enter either through a subclavian vein (Figure 3.5) or an internal jugular vein (Figure 3.6). In most cases the desired location for the tip is the superior vena cava. Because of the decreased risk of clot formation, so lines, especially those placed for long-term access, perform better with the tip in the right atrium of the heart. In either case, the key to understanding the actual location of the tip is to identify the point at which the superior vena cava joins with the right atrium (the venoatrial junction).

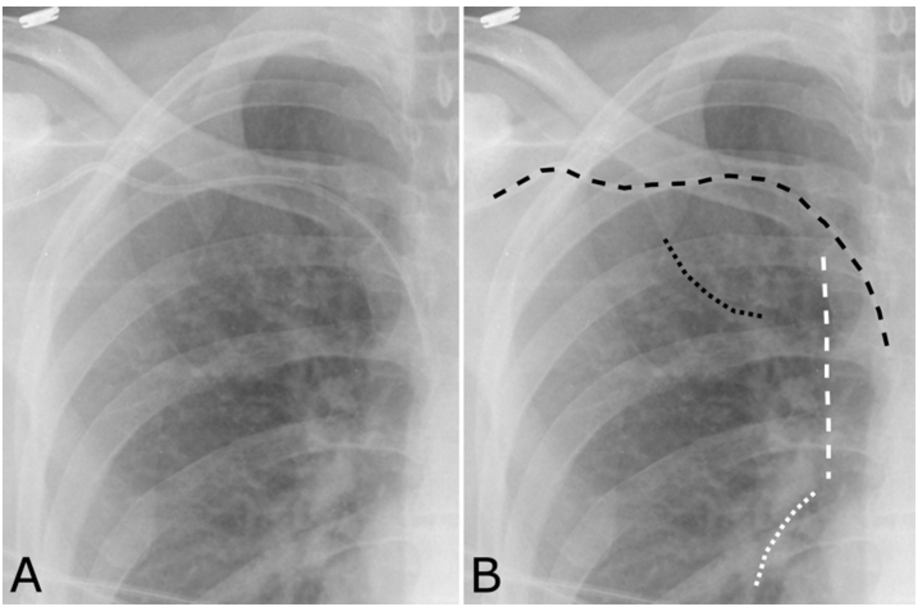

Figure 3.5 – Normal right subclavian line. A. Unmarked film. B. Marked film to show that the central line (black dashes) courses into the SVC, which lies between the inferior margin of the right first rib (black dots) and the venoatrial junction (where the SVC, white dashes, reaches the right atrium, white dots).

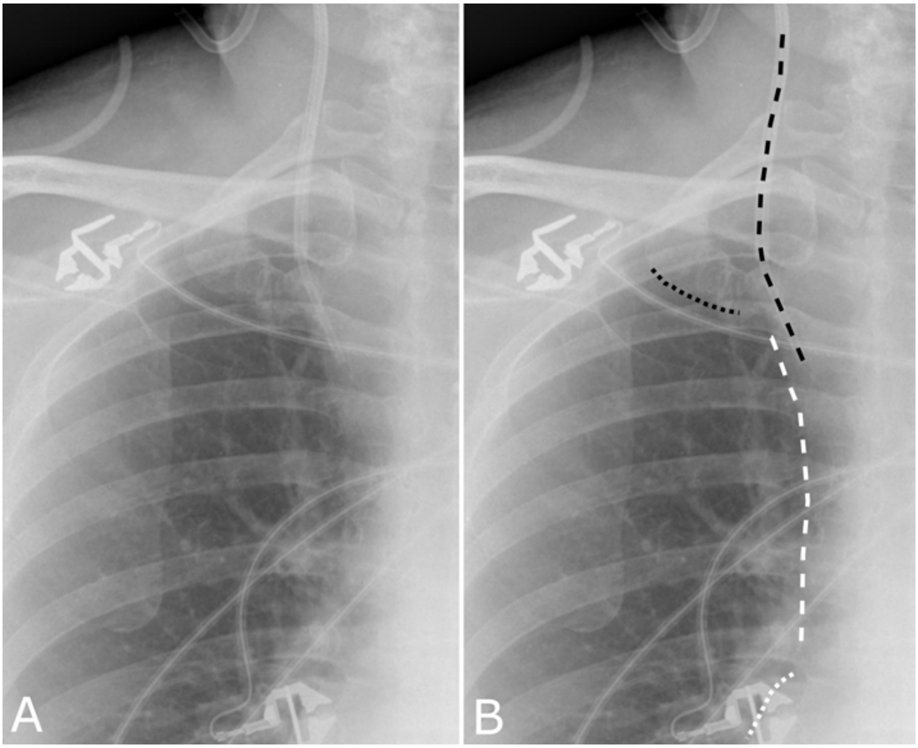

Figure 3.6 – Normal right internal jugular line. A. Unmarked film. B. Marked film to show the line (black dashes), SVC (white dashes) and right atrium (white dots). Also note the inferior margin of the right first rib (black dots) which lies at the superior extent of the SVC.

As you recall from the anatomy, the right heart border forms the curve of the lower part of the mediastinal border on the right. More superiorly, the superior vena cava forms a generally straight vertical line. The point at which the straight line of the SVC comes in contact with the curve of the right atrium represents the venoatrial junction. Lines above this point are in the SVC while those below it are in the right atrium.

Occasionally it is important to know if a line is in "far enough." Usually this question comes up when the line is going to be used to deliver either chemotherapy or TPN or some other substance that by policy can only be delivered to the SVC. The best landmark for identifying the superior extent of the SVC is the inferior margin of the right first rib. A tip below this point is in the SVC, while one proximal to it is in one of the brachiocephalic veins. Occasionally lines follow an unintended course. Figure 3.7 shows an example of a subclavian line that courses erroneously into the internal jugular vein.

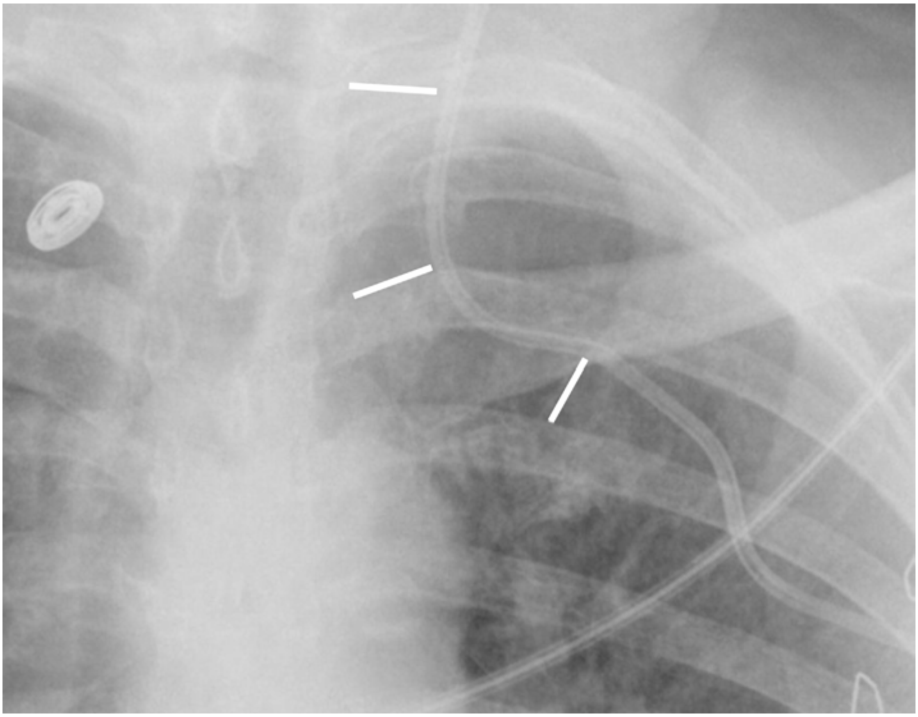

Figure 3.7 – Malpositioned left subclavian line. The line courses from the left subclavian vein into the left internal jugular vein.

Other than being in too far or not far enough, lines may also be in the wrong vessel, or they may be extravascular. These types of malpositionings must be identified and corrected quickly. It also occasionally happens that a line breaks, and a fragment of the line will then travel through the venous system until it gets stuck at either the heart or pulmonary arteries. Figure 3.8 shows two examples of catheter emboli. Another major complication that can result from line placements are pneumothorax and hematoma, both discussed at the end of this chapter.

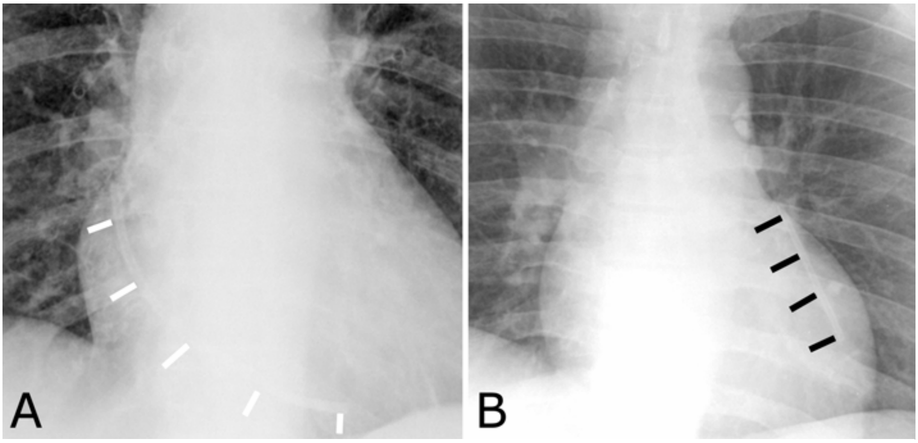

Figure 3.8 – Catheter fragment emboli. In both cases a piece of a central venous catheter broke off and traveled through the venous system. A. Fragment stopped at the heart, where it sits partly in the right atrium and partly in the right ventricle. B. Fragment traveled through the heart and got stuck in a pulmonary artery branch. In both cases the diagnosis should be made quickly so that the fragment may be removed by an Interventional Radiologist before excessive clot and fibrin formation prevent easy retrieval.

Pulmonary artery catheters ("Swann-Ganz" lines) are designed to have the tip in the pulmonary artery, of course. The proximal portion of these lines looks similar to a standard central line. The difference is that the line then continues through the right atrium, through the right ventricle and into the pulmonary arterial system. Figure 3.9 shows the normal course of a pulmonary artery catheter. The tip ought to be near the point at which the line crosses itself. If the line goes too far out into the pulmonary arteries (when it is not being used to take "wedge" pressures) it may occlude blood flow to a portion of the lung and lead to pulmonary infarction. Figure 3.10 shows another problem that may result when placing these lines.

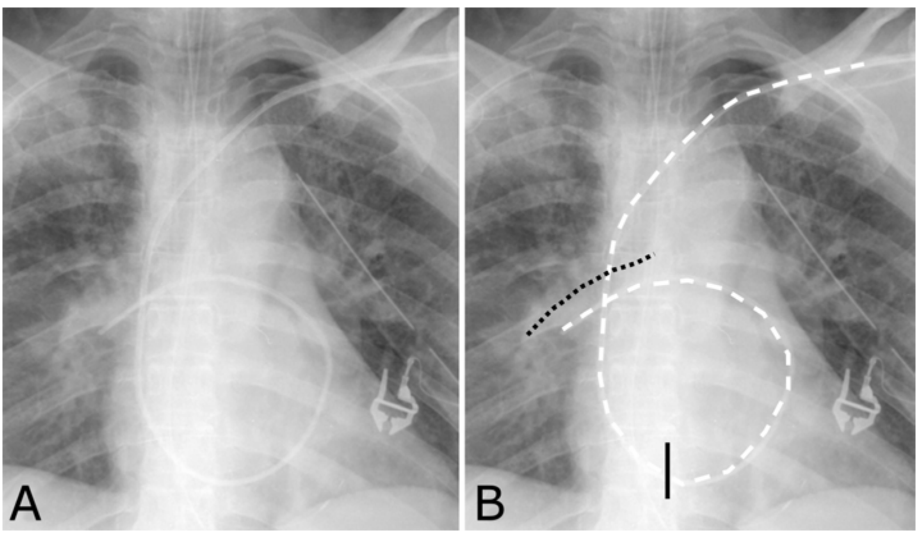

Figure 3.9 – Normal pulmonary artery catheter. A. Unmarked image. B. Marked image to show the catheter (white dashes) and the range of normal positioning for the tip (black dots). The approximate location of the tricuspid valve is indicated by the black line.

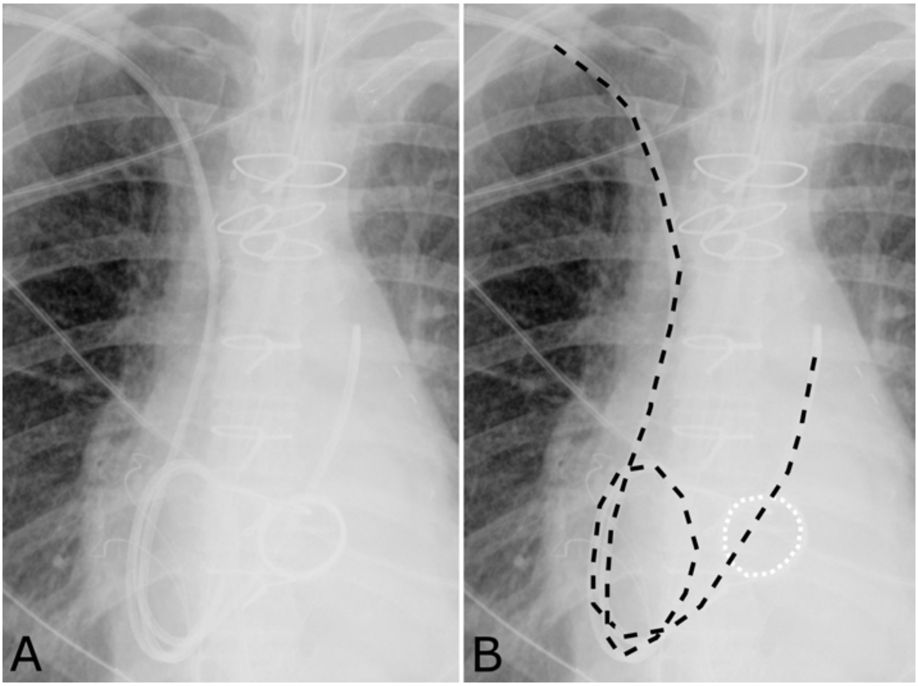

Figure 3.10 – Malpositioned pulmonary artery catheter. A. Unmarked film. B. Marked film to show that the catheter (black dashes) loops in the right atrium before completing its journey through the right ventricle and into the pulmonary arterial system. A prosthetic aortic valve (white dots) is also present. The line does not go through this valve, it merely overlies it.

Nasogastric and Feeding Tubes

The term "nasogastric (NG) tube" will be used generically here to refer to the suction tubing that is placed either from the mouth or nose into the stomach. These tubes have two holes, one at the end of the tube and another, more proximal, on the side of the tube. These two holes communicate with the same lumen of the NG tube and allow suctioning to occur properly. Thus, it is important that both the end hole and the side port of these tubes extend beyond the GE junction. Otherwise, not only will suctioning not work properly, but it also will open a pathway for the free flow of gastric contents into the esophagus, thus putting the patient at an increased risk of aspiration. NG tubes have a dense stripe along their side which is visible on the chest film. There is an interruption in this stripe at the level of the side port so that its position may be known. Feeding tubes, on the other hand, generally have just a single end hole, or if there is a side port it is so close to the end hole that it can virtually never create a bridge across the gastroesophageal junction.

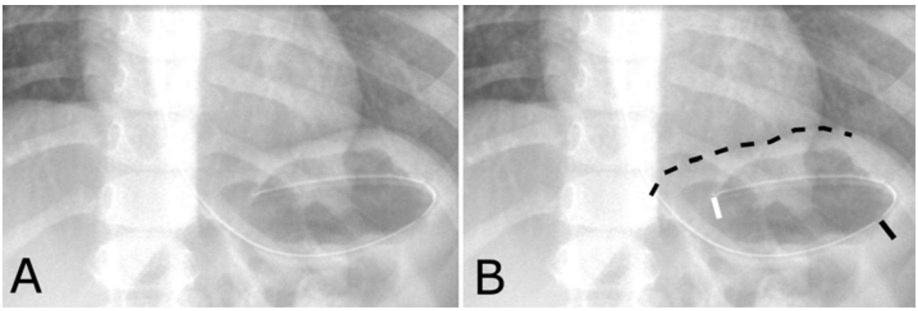

Figure 3.11 – Normal nasogastric tube placement. A. Unmarked image. B. Marked image to show the tip (white line) and side port (black line) of the NG tube. The location of the left hemidiaphragm is shown with the black dashes. Both the tip and side port of the NG need to be distal to the left hemidiaphragm.

One common complication seen with both nasogastric tubes and feeding tubes is that they may coil either in the hypopharynx or in the esophagus. A coiled tube irritates the throat and its presence makes it more difficult for the epiglottis to protect the airway, thus increasing the risk of aspiration for the patient. Coils in the tubes are often missed by novice readers who instinctively look for the end of the tube without evaluating the entire course of the tube. A coiled NG tube is shown in Figure 3.12.

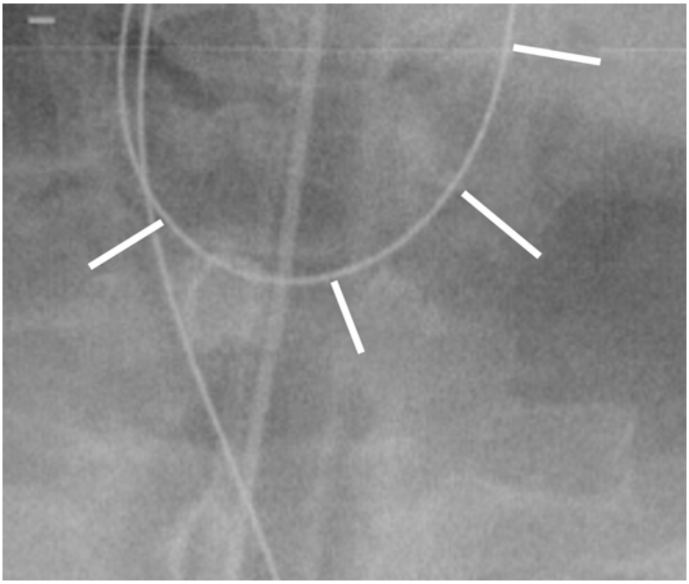

Figure 3.12 – Coiled nasogastric tube. There is a large loop (white lines) in the nasogastric tube as it courses through the cervical esophagus. This loop extends off the superior end of the film, but it likely is impairing the epiglottis' ability to protect the airway. Coils such as this one are easy to overlook because they occur up high on the film, but they should be identified and corrected quickly. It should always be remembered that aspiration can occur even in a patient with an endotracheal tube (such as in this case).

Another common problem with both feeding tubes and nasogastric tubes is placement of the tube into the airway. For nasogastric tubes, there are two problems: (1) the patient's stomach is not getting the suction that it needs and (2) there is a large foreign body in the airway. This situation is a setup for aspiration. In the case of the feeding tube, it is even worse. Tube feeds into the airway can be rapidly fatal to the patient. In either situation the error needs to be identified and corrected quickly. Figure 3.13 shows an example of a feeding tube in the airway.

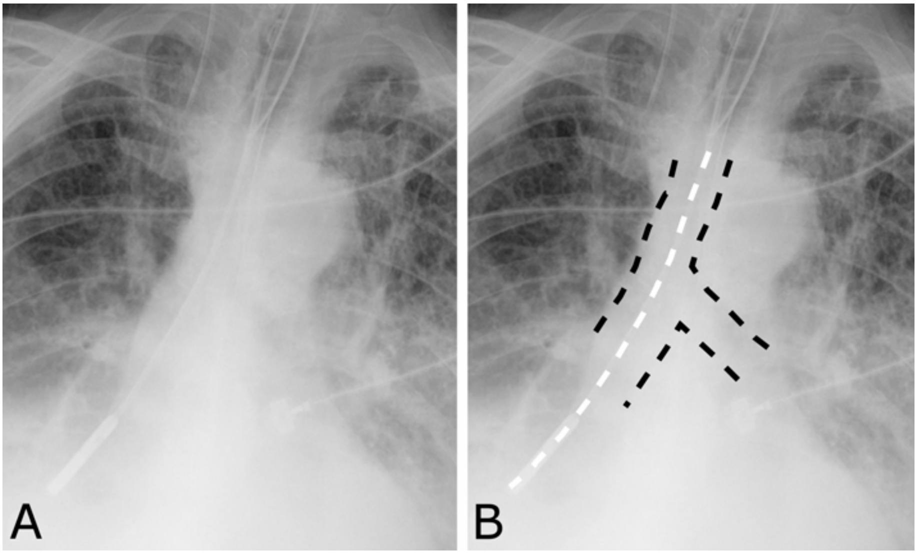

Figure 3.13 – Feeding tube in right mainstem bronchus. A. Unmarked image. B. Marked image to show the course of the tube (white dashes) in relationship to the airway (black dashes). Notice that both the tubing itself and the tip of the tube appear different from nasogastric tubes.

Chest Tubes

Chest tubes have a radiographic appearance that is similar to that of the nasogastric tube. Both tubes have a dense stripe that is visible on the plain film. Like NG tubes, chest tubes also have an interruption in this stripe. The interruption is termed the "sentinel eye" by some for it marks the point of the proximal-most side hole in the tube (chest tubes have numerous side holes). This side hole should be within the pleural space (Figure 3.14). When tubes are misplaced or inadvertently retracted, the proximal side port may be outside of the pleural space, causing a communication between the pleural space and the surrounding tissues (or even room air in the extreme case). Figure 3.15 shows a chest tube with its proximal side port outside of the pleural space. Figure 1.16 shows a malpostitioned chest tube which never enters the pleural space.

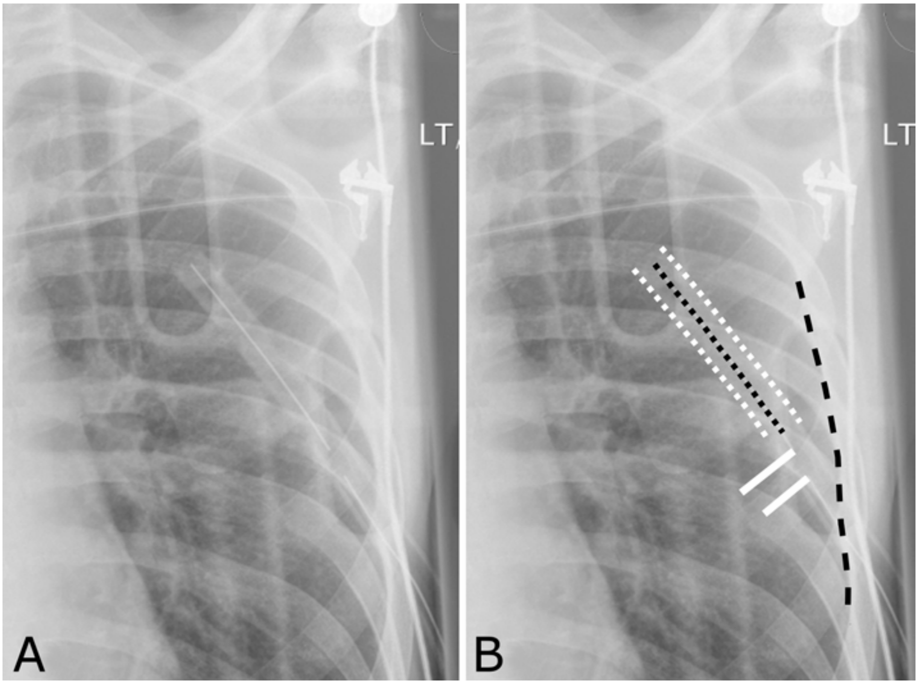

Figure 3.14 – Normal position for a chest tube. A. Unmarked film. B. Marked film to show the chest tube itself (white dots), the visible stripe (black dots) and the interruption in the stripe to signal the location of the proximal side port. The lateral extent of the pleural space is shown with the black dashes. The side port should be medial to this location (as it is in this case).

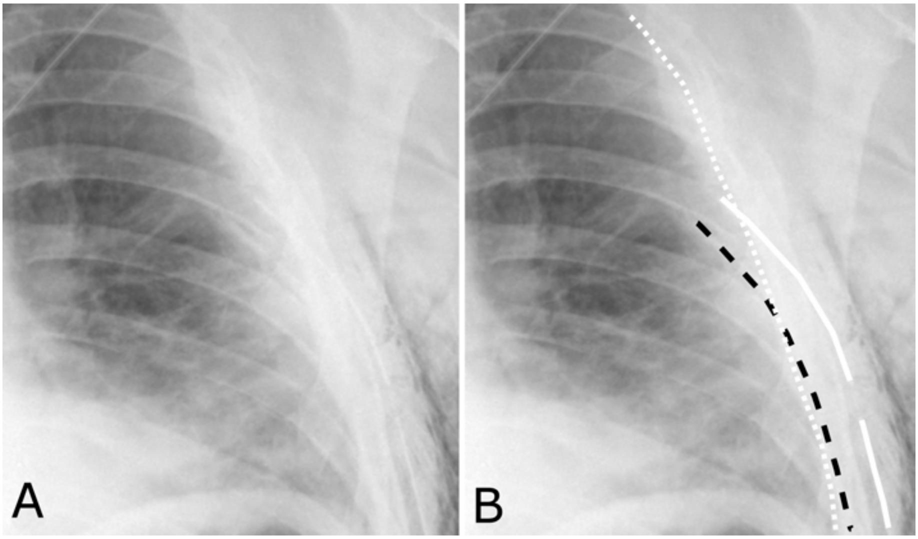

Figure 3.15 – Chest tube with proximal side port outside of pleural space. A. Unmarked film. B. Marked film to show the strip (white line) and opposite wall of the chest tube (black dashes). The lateral margin of the pleura is shown with white dots.

Important Complications

There are many important complications of almost any life support devices that should always be looked for (even in the absence of life support hardware because these problems have other causes as well). It is easiest to remember to look for these problems when you actually evaluate the life support hardware itself, and that is why I discuss these complications here.

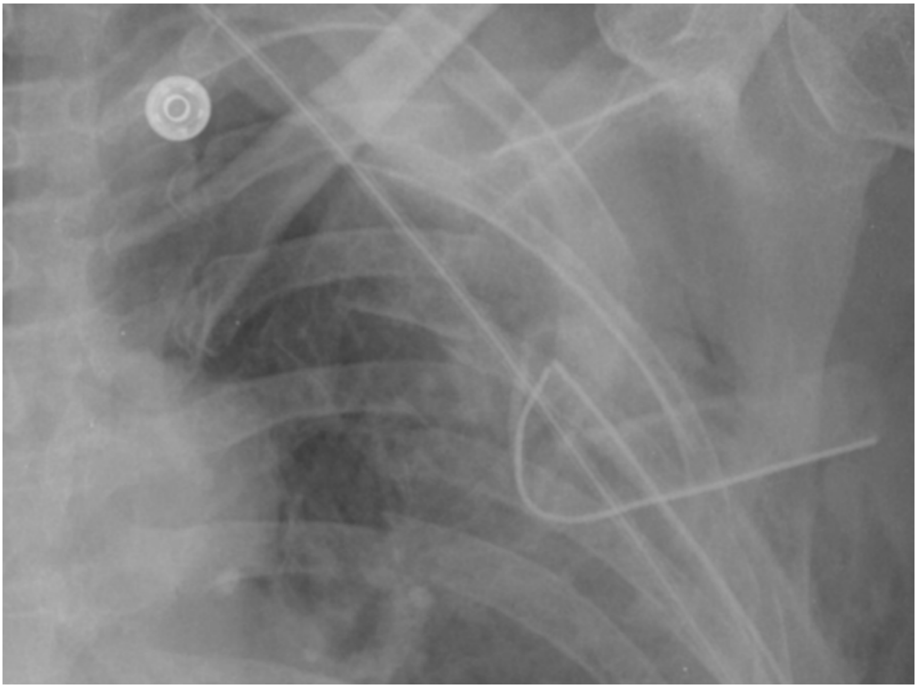

Figure 3.16 – Malpositioned chest tube. In this case, the chest tube has coiled in the soft tissues and though it overlies the pleural space (at least partially) it never actually enters the pleural space.

One of the most common complications is that of a pneumothorax. In the case of a pneumothorax, air enters the pleural space. Chest radiographs can give a gross estimation of how much air is in the pleural space (i.e., how big the pneumothorax is) but generally percent sizes should never be determined from chest films. (In fact, it is strongly suggested that they not be used at all, since management of the patient with a pneumothorax should be based upon your clinical assessment and not some number you obtained from a Radiologist). The key to identifying a pneumothorax is to find a thin, white line. This pleural line stands out because it has air on either side of it. Figure 3.17 shows a typical pneumothorax.

The most difficult decision some novice film readers have when looking for a pneumothorax is whether a line they see represents a pleural line (and thus a pneumothorax) of if it represents a skin fold overlying the chest. Skin folds are very common and they occur when the cassette used to take a portable chest film presses against the back of the patient. Many skin folds extend beyond the rib cage (something a pleural line can never do) but many do not. In most cases, though, a skin fold will appear as a thicker, less sharp, black line. A typical skin fold is shown in Figure 3.18.

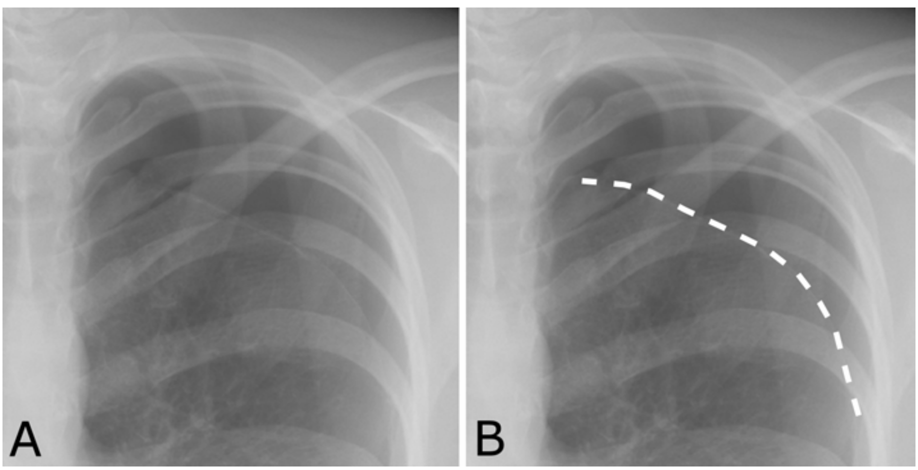

Figure 3.17 – Pneumothorax. A. Unmarked image. B. Marked image to show the thin white pleural line (white dashes). Everything seen above this line represents air in the pleural space (i.e., pneumothorax).

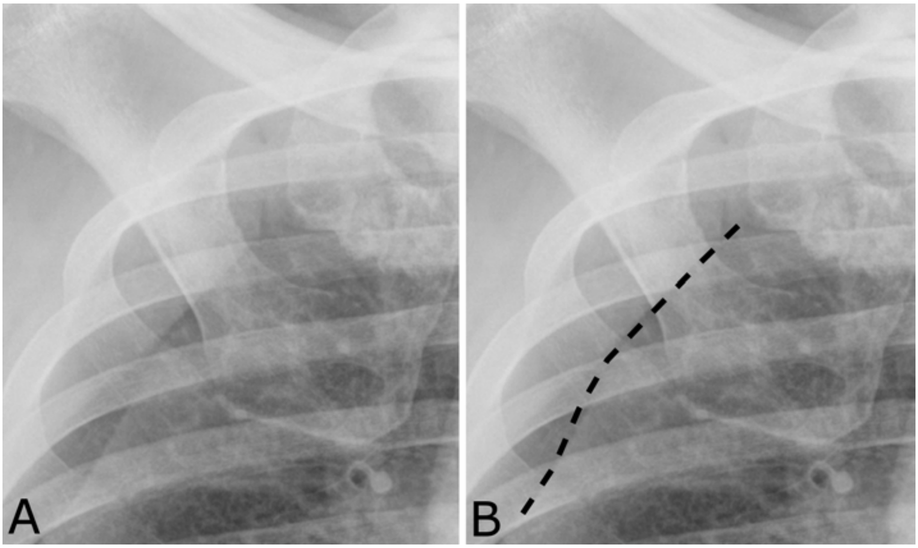

Figure 3.18 – Skin fold. A. Unmarked image. B. Marked image to show the skin fold (black dashes). The line from the skin fold is neither sharp nor white like that seen in the case of pneumothorax (Figure 3.17).

There is a common and insidious myth about pneumothoraces that will be discussed here, and I warn you that sometime in your career someone will give you this bogus advice. That myth is that when you see a line that may be a pleural line or a skin fold, you should look for lung markings on the other side of that line. *Do not make this mistake.* It will lead you astray as often as it will help you. Pneumothoraces are three-dimensional phenomena that may lie in front of (or behind) lung. It is quite common to see lung markings "through" a pneumothorax because of expanded lung behind (or in front of) the pneumothorax itself. In addition, at the very periphery of the lung, you should not see lung markings anyway, so once again that "sign" will lead you astray.

Occasionally clinicians will talk about a "tension pneumothorax." This is a diagnosis that requires some knowledge about the clinical situation of the patient (specifically, whether there is compromise of the blood return to the heart). Thus, a Radiologist cannot make that diagnosis off of the film. Nevertheless, there are some signs that make us worry that a patient has a tension pneumothorax. A tension pneumothorax will be large and will usually result in near complete collapse of the ipsilateral lung with shift of the mediastinum away from the pneumothorax. It should be noted that whenever a tension pneumothorax is suspected clinically, it is prudent to treat the patient rather than wait for an x-ray to be taken. Thus, it is commonly said that the standard radiographic appearance of a tension pneumothorax is really a patient who already has a chest tube. Figure 3.19 shows an example of a large pneumothorax in a patient that required an emergent chest tube placement.

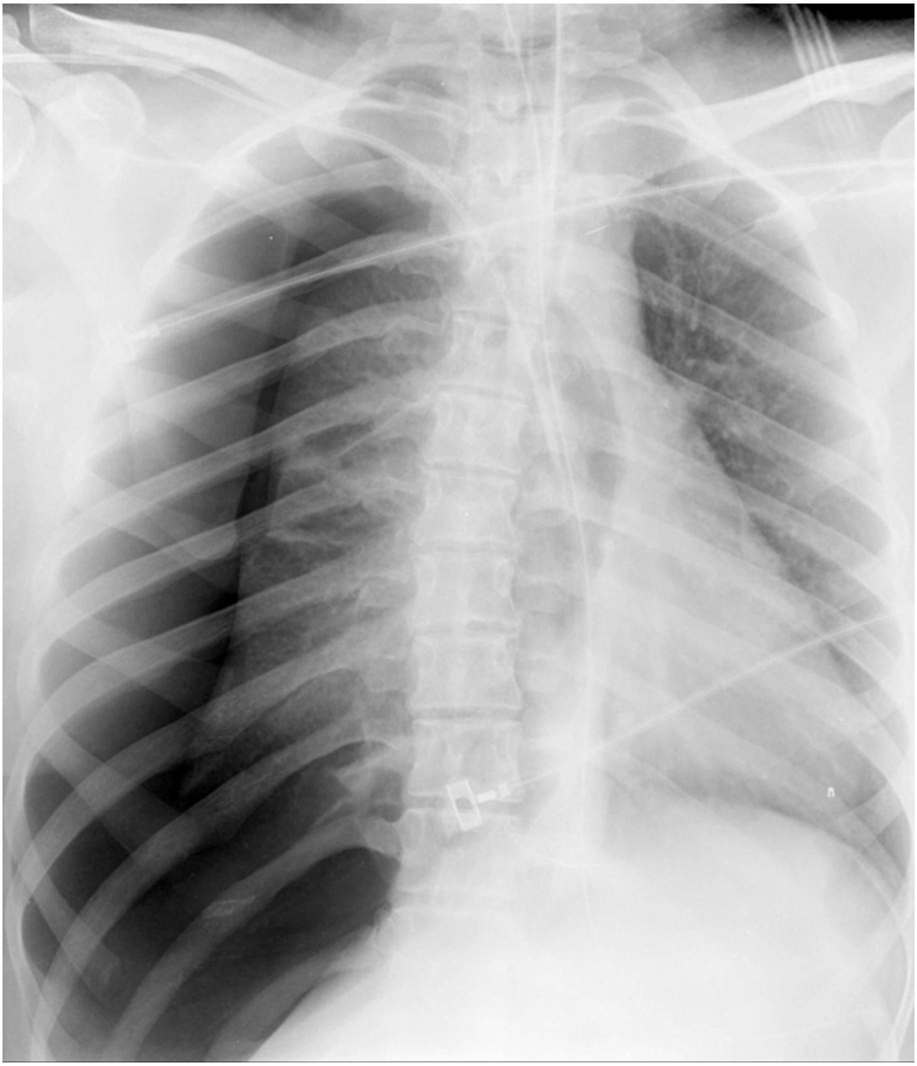

Figure 3.19 – Very large pneumothorax. There is a very large pneumothorax on the right side. The right lung is almost completely compressed by the pneumothorax and there is shift of the heart towards the left side of the chest. It is rather rare to see films in patients with pneumothoraces this large because the diagnosis of tension pneumothorax is usually made clinically and the patient is treated well before a film is obtained.

Sometimes there is not only air but also fluid in the pleural space. In this situation, the term hydropneumothorax is used. When a patient with a hydopneumothorax gets an upright film, an air-fluid level can be seen because of the result of gravity. When the patient is supine, however, and the x-ray beam travels perpendicular to gravity, the air fluid level will not be visible on the film. An example of a hydropneumothorax is shown in Figure 3.20.

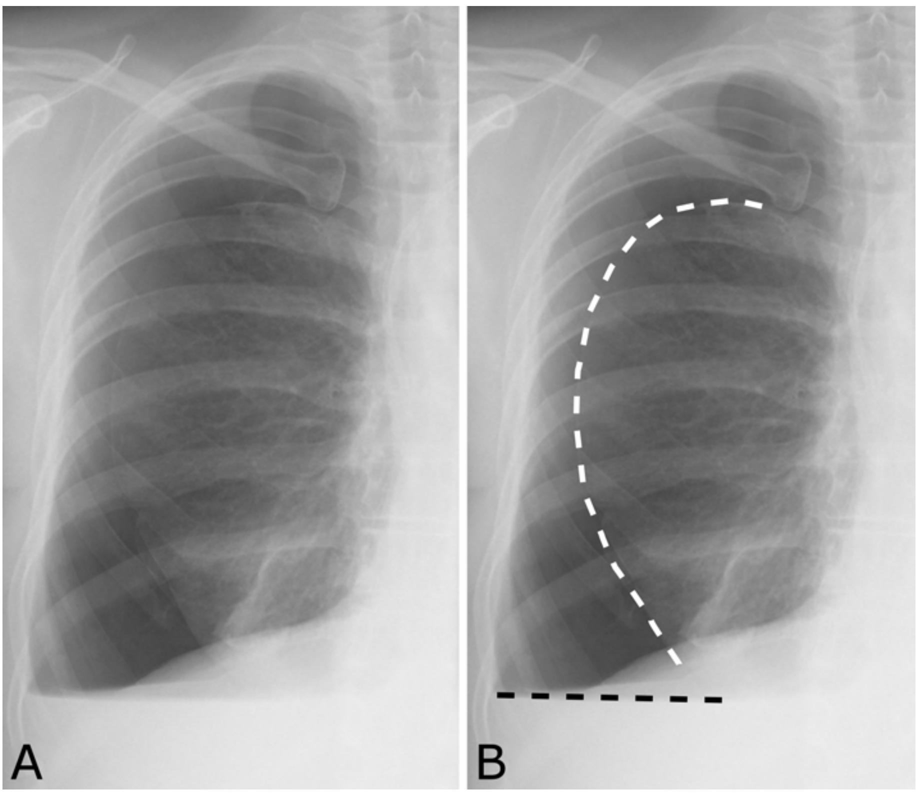

Figure 3.20 – Hydropneumothorax. A. Unmarked film. B. Marked film to show both the thin white pleural line (white dashes) and the air-fluid level (black dashes) that indicates both air and fluid must be present in the pleural space.

The concept of the pleural effusion (fluid in the pleural space) is usually not one that is discussed in the context of life support devices and their complications. While it is possible to get bleeding into the pleural space, the overwhelming majority of pleural effusions are completely unrelated to any hardware that may be within the patient. Nevertheless, when evaluating a film systematically, I find it easiest to look for both pneumothoraces and pleural effusions immediately after I evaluate the life support devices, and thus I include the discussion of pleural effusion here.

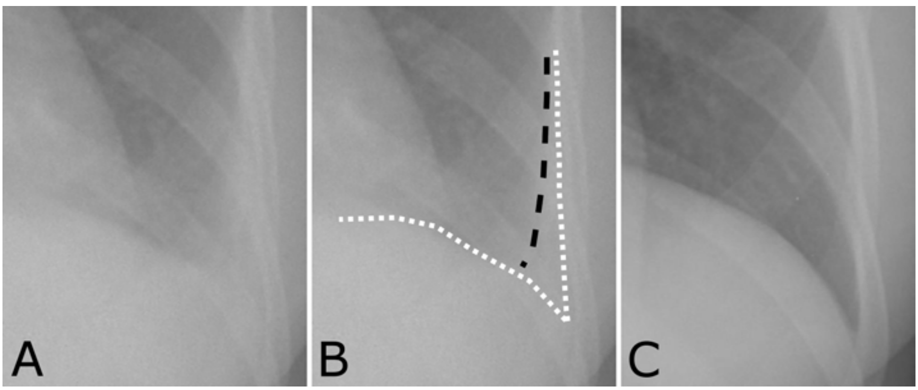

Figure 3.21 – Pleural effusion. A. Unmarked film. B. Marked film to show the blunting of the costophrenic angle from the effusion (black dashes). The normal location of the costophrenic angles is outlined with white dots. C. The same patient after the effusion had

The “classic” sign of a pleural effusion that is often discussed (and, to be sure, often seen) is blunting of the costophrenic angle. An example of this is shown in Figure 3.21. Since most pleural effusions are free-flowing, the fluid in the pleural space will go to the most dependent portion of the pleural space (because of gravity). In the upright patient the most dependent portion is the costophrenic angles (the point where the diaphragm comes in contact with the ribs, seen both laterally and posteriorly). The normal costophrenic angles have a sharp air-soft tissue interface that becomes blurred and widened in the presence of pleural fluid. In the supine patient this sign is also helpful, though less so than in the upright patient because often the costophrenic angle is no longer the most dependent portion of the lung. When there is a question about whether an effusion is present or not, or if there is a question about whether or not it is free-flowing, a decubitus view can be obtained. A decubitus view is a frontal film obtained with the patient lying on one side. The side with the questioned effusion should be the down side. (The view is named for the side that is *down*, so a left lateral decubitus view means the left side is down). Figure 3.22 shows a pleural effusion on a decubitus view.

A final complication that is worth discussing here is that of excess bleeding following the placement or manipulation of some hardware device. In some cases, abnormal bleeding into the pleural space will occur, and the finding will be that of a new pleural effusion. Many other times, though, bleeding occurs elsewhere, either extrapleural or within the mediastinum. It is always important to compare films with new life support to the prior films. Figure 3.23 shows a case where a central line was placed and a large mediastinal hematoma formed. Had the film not been compared to its prior, it is possible that the large hematoma would have been missed. After the patient was evaluated it was determined that the new central line had perforated through the SVC, resulting in the hematoma.

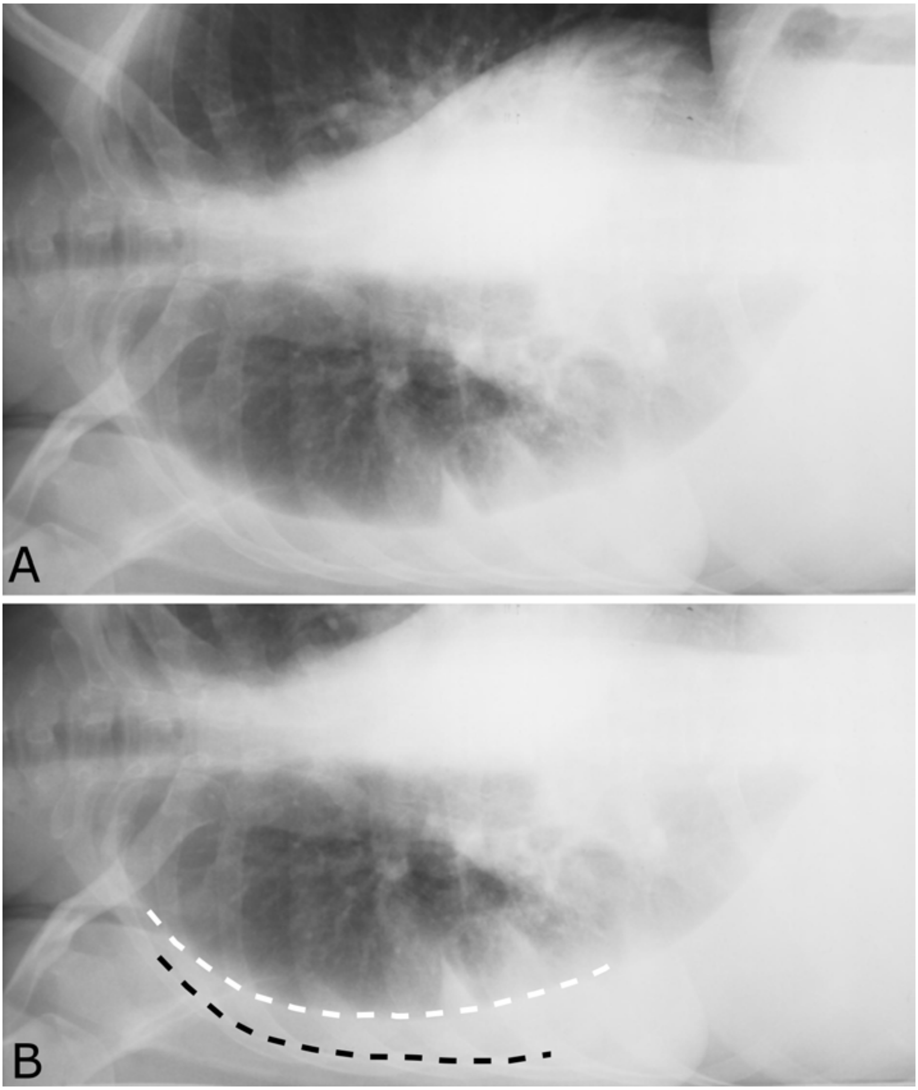

Figure 3.22 – Right lateral decubitus view of a pleural effusion. A. Unmarked film. B. Marked film to show the layering pleural effusion, which has displaced the lateral margin of the lung (white dashes) from the chest wall (black dashes). The pleural effusion represents all of the white fluid seen between these boundaries.

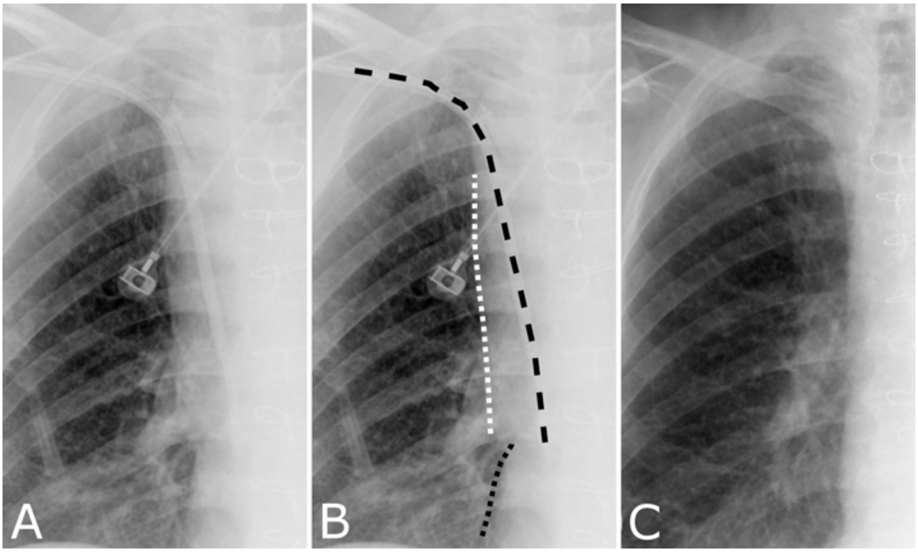

Figure 3.23 – Hematoma following line placement. A. Unmarked film. B. Marked film shows the central line (black dashes) and the hematoma (white dots). The border of the right atrium is also marked (black dots). C. Same patient on the day before the line was placed. Had this film not been available (or looked at) the hematoma may have been mistaken for a large SVC, but clearly there has been a dramatic change between the two films.

Physiology of the Chest

Chapter IV

The chest film can give a lot of information about the vascular status of the patient. This subject can get quite involved and complicated, so I will try to simplify the process into a form that is easy to understand and implement.

I think of the vascular status of the patient as a series of progressive stages. In fact, of course, it is a continuum, and one stage gradually blends with the next, but thinking in terms of specific stages makes the evaluation much easier to do. Of course the first stage is normal. From there, with increasing vascular fluid, the patient moves into the stage of having a large circulating vascular volume. The next stage is engorgement of the pulmonary vasculature, then interstitial pulmonary edema and finally alveolar pulmonary edema. I will discuss each stage independently.

Increased Circulating Vascular Volume

The key to evaluating the circulating vascular volume is to look at the "vascular pedicle." The vascular pedicle is the width of the mediastinum measured from the aorta (officially at the origin of the left subclavian vein) to the SVC (as it crosses over the right mainstem bronchus). While some people quote actual numbers for vascular pedicle width measurements, the most useful assessment is to determine if there has been a change from one film to the next. An increase in the width of the vascular pedicle is a good sign that the circulating vascular volume is increased. Figure 4.1 shows a normal vascular pedicle and the method for measuring it. Figure 4.2 shows a patient with an enlarged vascular pedicle.

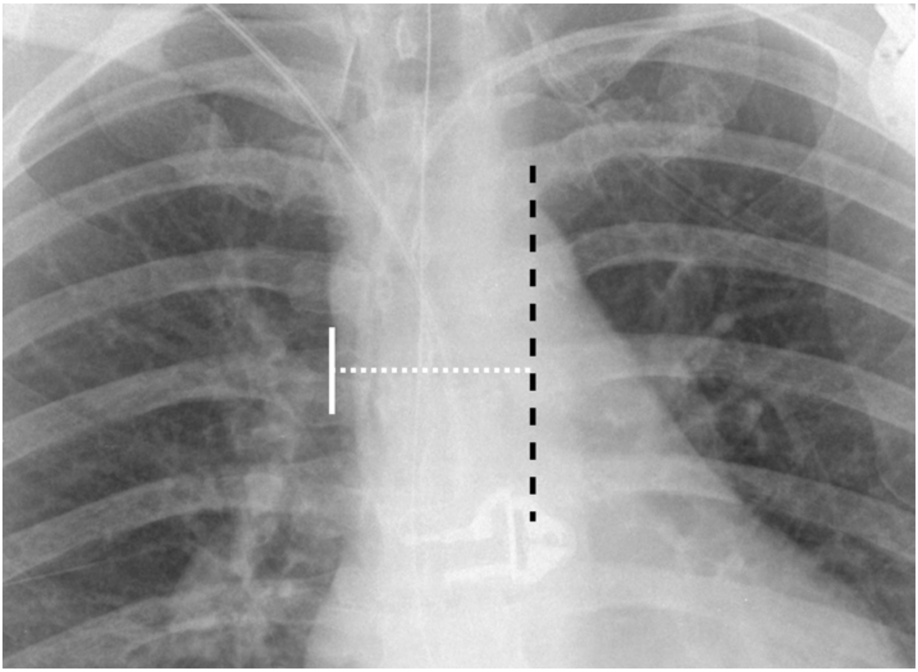

Figure 4.1 – Normal vascular pedicle. Lines show the proper way to evaluate the vascular pedicle (white dots), which is measured from the level of the take-off of the left subclavian artery from the aorta (black dashes) to the SVC as it crosses over the right mainstem bronchus (white line).

The vascular pedicle is not the only way to evaluate the circulating vascular volume, but is convenient and will get you well on your way to understanding it. Enlargement of the heart itself is commonly seen as a sign of increased circulating vascular volume. Another useful sign is enlargement of the azygous vein, which can be seen just above and to the right of the origin of the right mainstem bronchus. Again, relative changes in size are much more useful than absolute numbers.

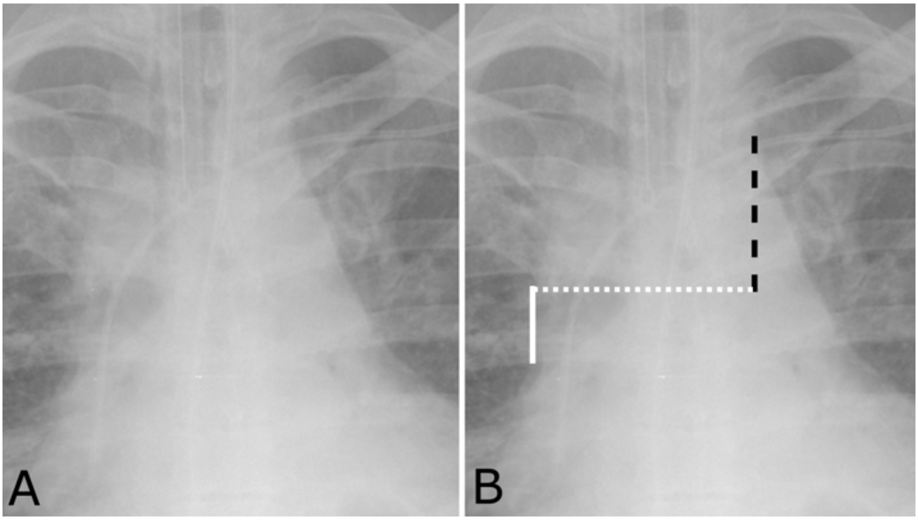

Figure 4.2 – Widened vascular pedicle. Note how much wider this vascular pedicle appears than the one of Figure 4.2. A. Unmarked image. B. Marked image using the same markers as the previous Figure.

Pulmonary Vascular Engorgement

The next step along this pathway is engorgement of the pulmonary vasculature. The easiest and most reliable way to evaluate for this finding is to look at the vessels themselves. Pulmonary arteries travel next to bronchi, and at any given distance from the hilum these two structures are about the same size in diameter. As the pulmonary vasculature becomes engorged, the pulmonary vessels increase in size, and this increase is most readily evident when a pulmonary artery is seen to be larger than its adjacent bronchus. Figure 4.3 shows an example of a patient with pulmonary vascular engorgement that be detected using this method.

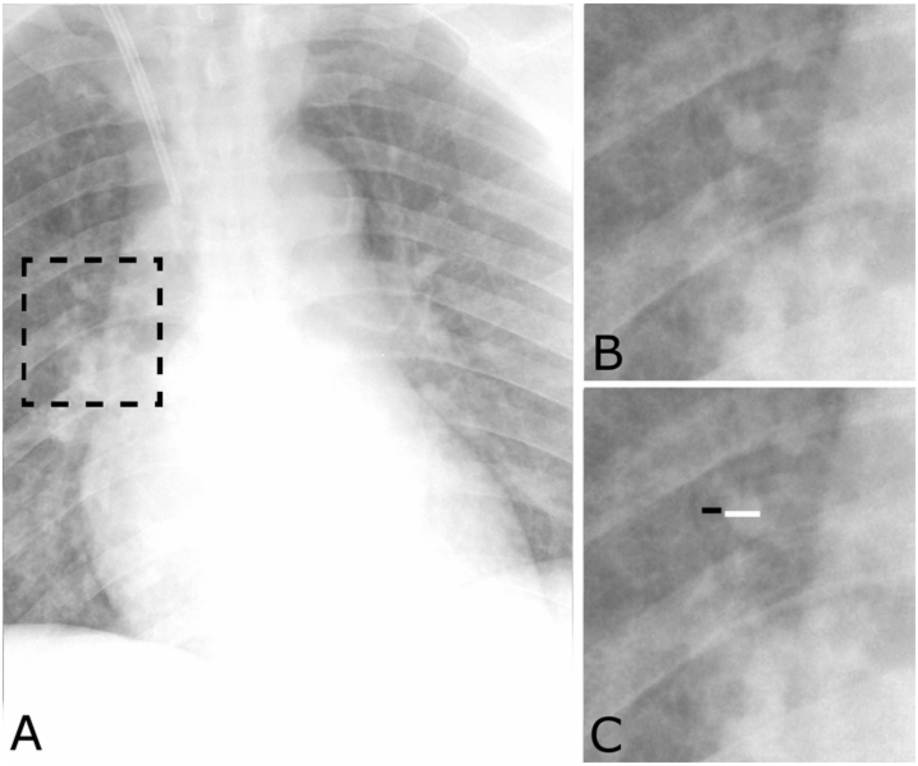

Figure 4.3 – Pulmonary vascular engorgement. A. Frontal radiograph shows widening of the vascular pedicle (indicating a large circulating vascular volume) but close evaluation of the region within the rectangle (exploded into views B, unmarked, and C, marked), shows a pulmonary artery (white line measures diameter) that is much larger than its adjacent bronchus (black line measures diameter).

Interstitial Pulmonary Edema

The next stage along the continuum is the development of interstitial pulmonary edema. At this stage, fluid moves into the pulmonary interstitium which results in several apparent abnormalities. First, the pulmonary vessels become somewhat blurred because there is a less sharp interface between the vessels and the surrounding air-filled lung. Also, the fluid in the interstitium may be seen as a pattern of increased lines throughout the lungs. In addition, bronchi seen end-on may appear to have a thickened wall because of the increased interstitial fluid (bronchial cuffing). Figure 4.4 shows a patient with interstitial pulmonary edema.

Alveolar Pulmonary Edema

The final stage is flooding of the alveoli with edema fluid. At this point, an airspace pattern appears because the alveoli no longer contain air but now contain fluid. In general, the bronchi and bronchioles remain filled with air, resulting in "air bronchograms" (discussed in the next chapter). The classic teaching is that alveolar pulmonary edema tends to be perihilar in distribution, though in reality this is not always the case. Figure 4.5 shows a patient with alveolar pulmonary edema.

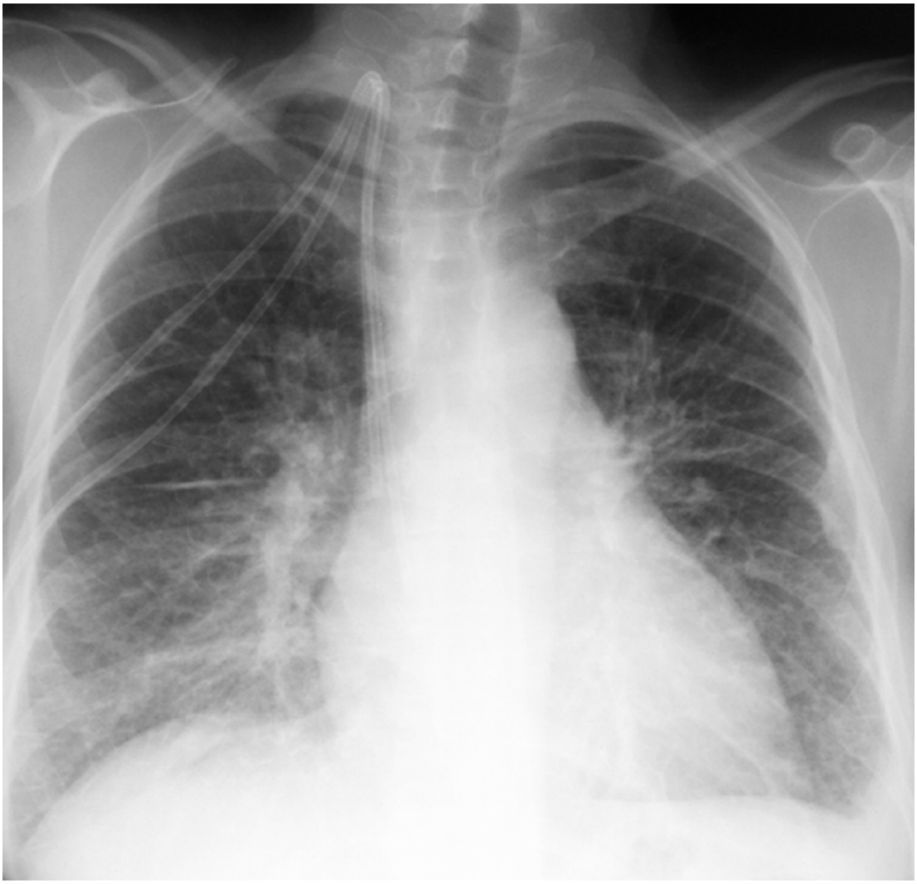

Figure 4.4 – Intersitial pulmonary edema. In this patient, innumerable excess linear shadows are seen throughout the lungs. These represent fluid in the inter- and intra-lobular septa throughout the lung. In addition, the vessels seem less distinct than in a normal chest radiograph.

Figure 4.5 – Alveolar pulmonary edema. In this patient, fluid has flooded the alveolar spaces resulting in the perihilar opacities seen here. Notice also that all of the other findings from the preliminary stages (large vascular volume, pulmonary vascular engorgement and interstitial pulmonary edema are all still visible on this film as well).

Relating to Pulmonary Capillary Wedge Pressure

As a rough approximation of reality, I use the "rule of sixes" to help me remember the pulmonary capillary wedge pressures (PCWP) that correspond to the stages seen on the chest radiographs.

Radiographic Findings	*PCWP, mmHg*
Normal	6 - 12
Large Vascular Volume / Pulmonary Vascular Engorgement	12 - 18
Interstitial Pulmonary Edema	18 - 24
Alveolar Pulmonary Edema	> 24

Acute Myocardial Infarction

One of the exceptions to some of the rules described above is the patient who is in heart failure because of an acute myocardial infarction. In the immediate post-infarction time period, there may not have been enough time for some of the changes described above to occur. Specifically, it is not uncommon to have a patient in pulmonary edema (whether it be interstitial or alveolar) with a completely normal appearing heart and vascular pedicle. Generally the clinical scenario will make the correct diagnosis clear, but at times it possible to mistake a person who is acutely short of breath with interstitial edema from an MI as someone with an interstitial pneumonia (see the next chapter). Figure 4.6 shows an example of a patient with an acute MI and pulmonary edema despite the normal size of the heart and vascular pedicle.

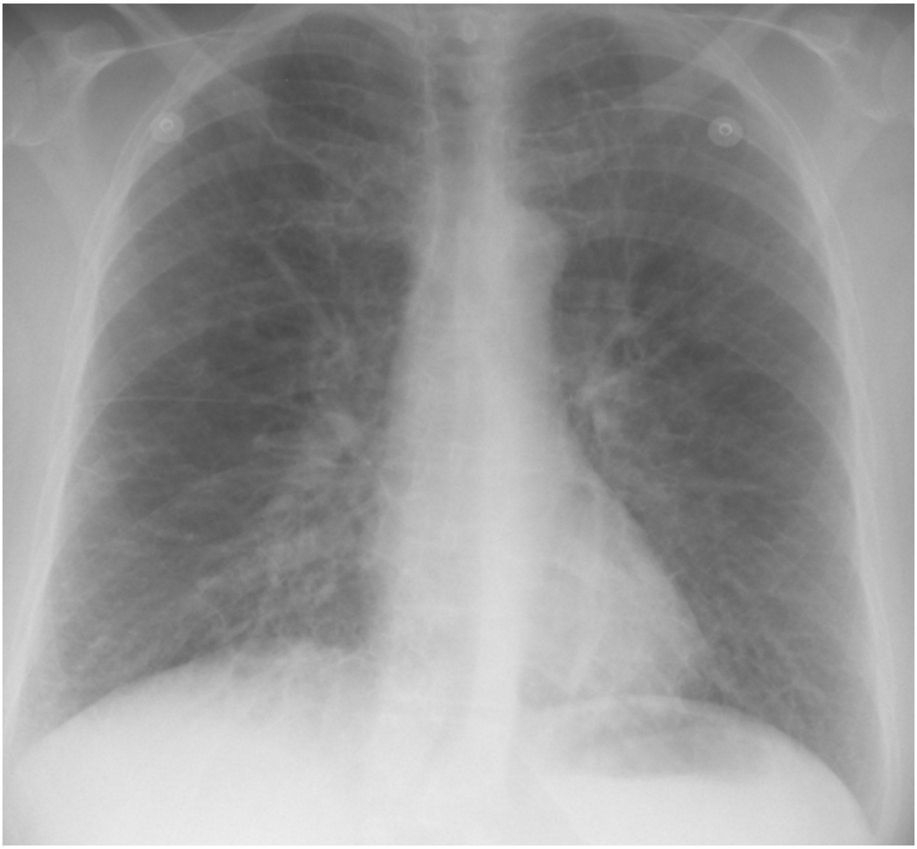

Figure 4.6 – Pulmonary edema following an acute myocardial infarction. All of the signs of interstitial pulmonary edema are present, except that the heart and vascular pedicle appear normal. This results because there has not yet been time for these structures to adapt to the sudden change in hemodynamics.

Neurogenic Edema

Another cause of pulmonary edema in the face of a normal heart size is that of neurogenic edema. This phenomenon occurs in patients with increased intracranial pressure from any of a number of causes. The exact mechanism is likely a combination of both hydrostatic and permeability factors. A patient with neurogenic edema is shown in Figure 4.7.

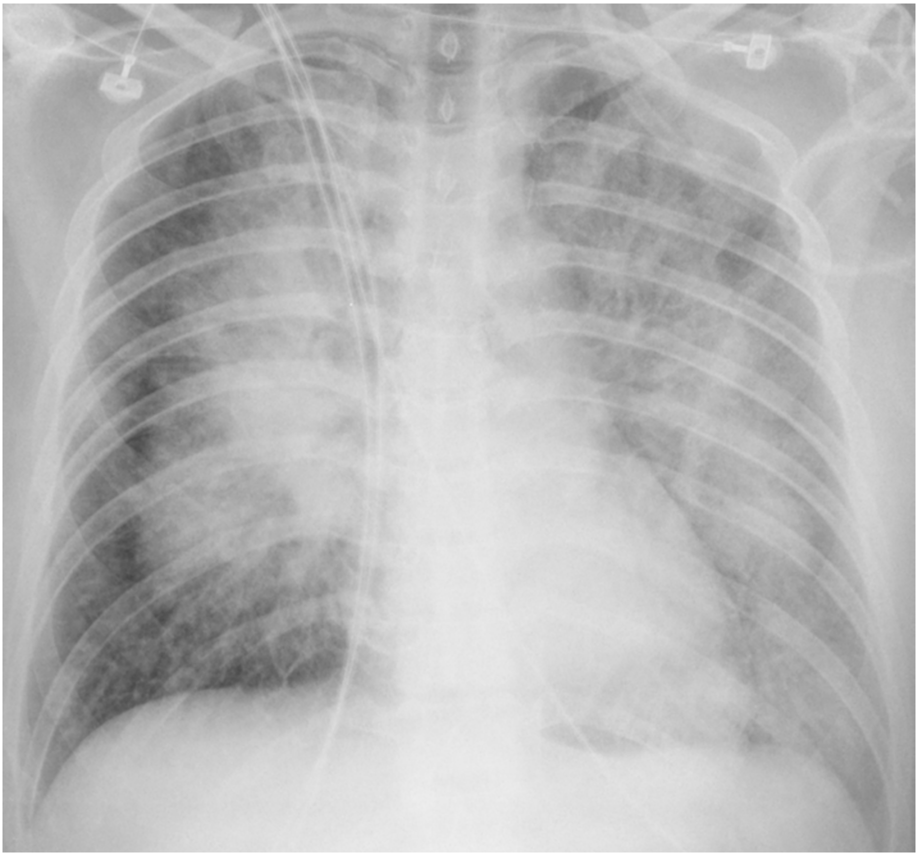

Figure 4.7 – Neurogenic edema. The pattern of edema here is that of alveolar pulmonary edema, but, similar to the patient with the acute MI, the heart and vascular pedicle are normal in size. This patient had a ruptured cerebral aneurysm and quite a bit of cerebral edema causing increased intracranial pressure.

Injury Edema

Not all pulmonary edema is caused by increased hydrostatic pressures. Sometimes pulmonary edema is caused by an increased leakiness of the capillaries. This situation occurs in patients with ARDS, and the edema pattern seen on the chest film is termed "injury edema." Injury edema appears much different from hydrostatic edema described above. Generally the heart and vascular pedicle are not enlarged. In addition, the distribution of the edema is much more peripheral, rather than central as is classically described for hydrostatic edema. Patients with injury edema are usually quite ill, so it is also very common to have other superimposed abnormalities, such as pneumonia. Figure 4.8 shows an example of injury edema in a patient with ARDS.

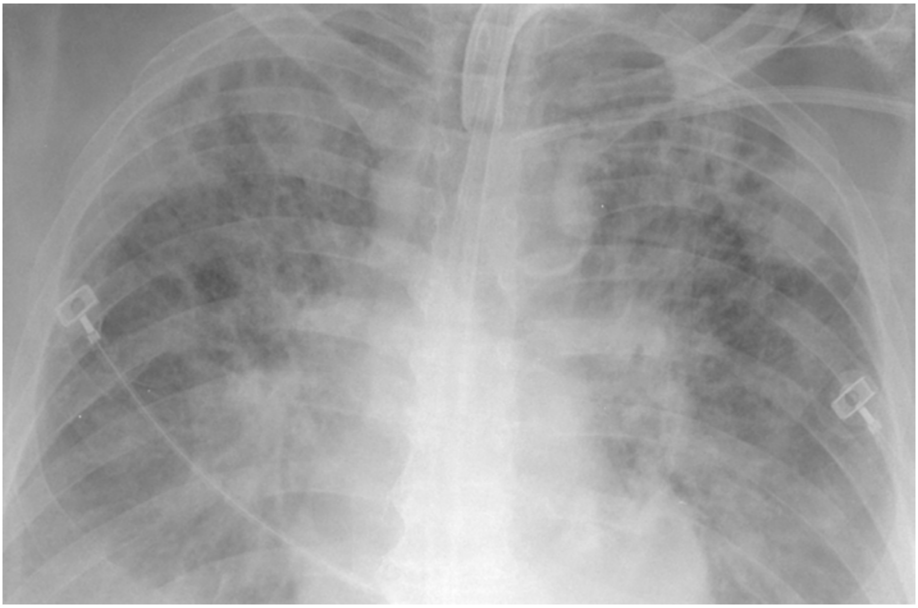

Figure 4.8 – Injury edema. This patient has ARDS and the edema pattern has resulted from increased permeability of the pulmonary capillaries rather than hydrostatic forces. The pattern tends to be more peripheral than edema from heart failure. In addition, the heart and vascular pedicle are normal in size.

Parenchymal Patterns

Chapter V

One of the most important concepts to understand when it comes to interpreting chest films is that of categorizing the pattern seen in the lung fields. There are many different patterns of opacification that can be seen. Most can be classified into one of three groups: (1) alveolar flooding, (2) atelectasis and (3) interstitial. Once you have correctly identified the pattern on the chest film, you are well on your way to coming up with a correct differential diagnosis.

Alveolar Flooding

The lung fields on a normal chest radiograph show a predominantly black background (composed of both air-filled alveoli and air-filled airways) with many branching and tapering white lines (blood vessels). In many disease processes, however, the alveoli fill with fluid. In this case, the appearance of the film changes to one of a generally white background (composed of fluid-filled alveoli and blood vessels) with many branching and tapering black lines (the airways, which are not flooded). These branching black lines are often called "air bronchograms," and they serve as an excellent indication that the underlying pathological process is one of alveolar flooding. The white appearance to the chest is not one of a pure white (as might be seen with a large effusion or lobar atelectasis) but rather an inhomogeneous, fluffy appearance that has been described as cotton- or cloud-like. Figure 5.1 shows an example of alveolar flooding with air bronchograms.

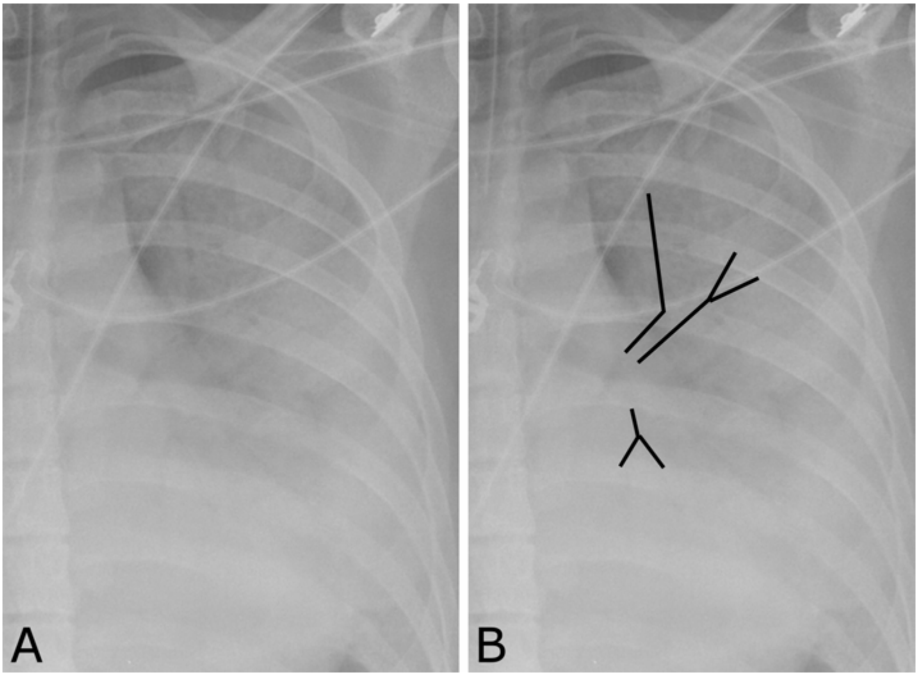

Figure 5.1 – Alveolar flooding with air bronchograms. A. Unmarked imaged shows a generally white background, but close inspection reveals that it is not a pure white, but rather a somewhat "cloud-like" appearance. In addition, black branching structures (air bronchograms) are seen throughout the pattern. B. Marked image to indicate the air bronchograms (black lines).

When faced with the pattern of alveolar flooding you can easily remember this simple differential diagnosis: water, pus, blood, cells. Specifically, one of these four entities is responsible for the flooding of the alveoli. In the case of "water," it is pulmonary edema causing the alveolar flooding, for "pus" it is a pneumonia that is the cause, "blood" reminds you that alveolar hemorrhage can have the same appearance, and "cells" refers to the fact that some tumors (especially bronchoalveolar cell carcinoma and lymphoma) may grow within the alveolar spaces and give this pattern on the chest film. To determine which of those four categories is causing the pattern in any particular patient requires looking at the distribution, time course and clinical situation of the particular patient.

Atelectasis

The term atelectasis means incomplete expansion of the lungs. To make the diagnosis of atelectasis requires evidence of volume loss. Signs of volume loss include:

1. Displacement of fissure
2. Elevation of a hemidiaphragm
3. Shift of the mediastinum
4. Crowding of the vasculature
5. Splaying of the vasculature

The first three on the list indicate direct signs of volume loss. A normal structure is shifted in location because of volume loss and this shift is directly visible. In the case of crowding of the vasculature, what is seen is the fact that there is less air between the normal vessels, and they thus appear to be crowded together. Probably the most difficult concept to understand is that of splaying of the vasculature, which is the exact opposite of crowding. That is, there is more air between vessels. Splaying is actually a sign of hyperinflation of a part of the lung, but generally when this occurs it is the result of volume loss elsewhere in the lung.

A common cause of atelectasis is pneumonia. The term *lobar pneumonia* is used to describe a pneumonia that predominantly occurs in the alveolar space. Lobar pneumonias cause the pattern of alveolar flooding. Other pneumonias, especially gram negative, nosocomial infections, are centered in the distal bronchiole and manifest themselves on the film as volume loss in the lung distal to the site of infection. This type of pneumonia is called *bronchopneumonia*. Figure 5.2 shows a typical bronchopneumonia with atelectasis.

Figure 5.2 – Atelectasis of the right upper lobe from bronchopneumonia. The volume loss is evident because of the increased opacity (partially from vascular crowding) as well as the elevation of the minor fissure.

Other common causes of atelectasis include mucus plugging and endobronchial tumors. When there is atelectasis of an entire lobe of the lung, the appearance is often striking and characteristic. With collapse of the right upper lobe, the minor fissure shifts superiorly and medially. Figure 5.3 shows a typical example of right upper lobe collapse (atelectasis).

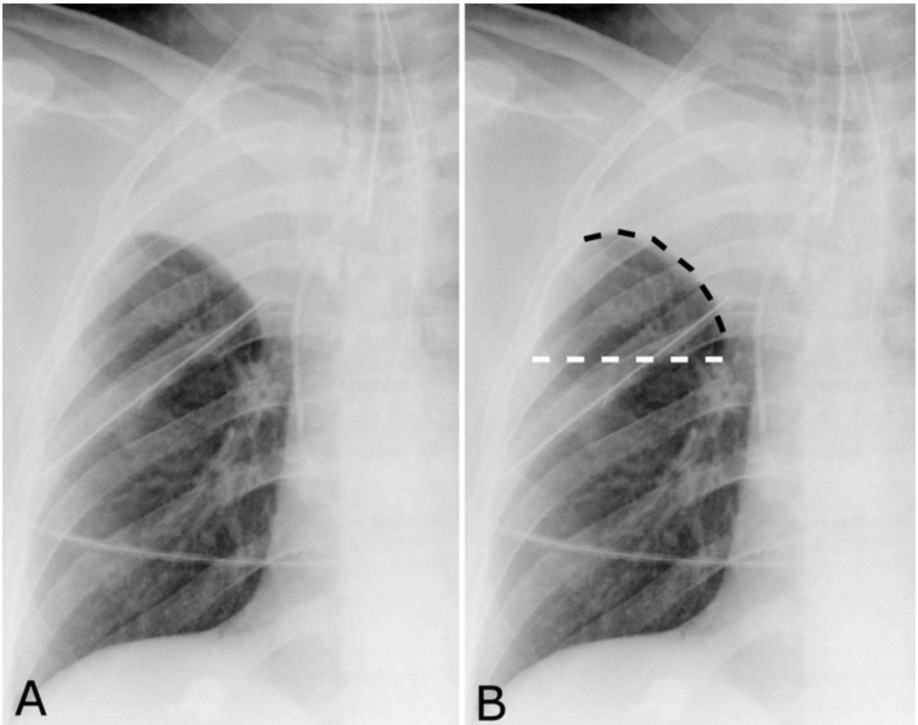

Figure 5.3 – Right upper lobe atelectasis. A. Unmarked film. B. Marked film to show the superior displacement of the minor fissure (black dashes). The normal location of the minor fissure is shown with white dashes.

With collapse of the right middle lobe, the minor fissure moves inferiorly. Often the major fissure will shift anteriorly. Right middle lobe atelectasis is better seen on the lateral film. A typical case is shown in Figure 5.4.

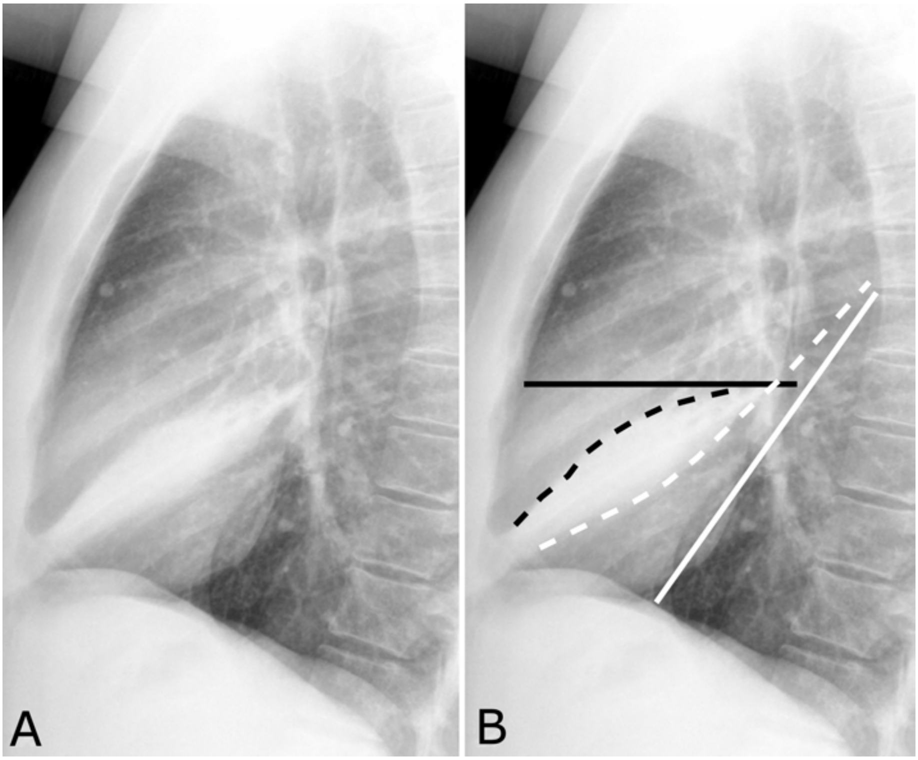

Figure 5.4 – Right middle lobe atelectasis. A. Unmarked film. B. Marked film to show the inferiorly displaced minor fissure (black dashes) and the anteriorly displaced major fissure (white dashes). The normal locations of the fissures are shown with the black

The situation in the left lung is different because of the lack of a minor fissure. The left upper lobe typically collapses anteriorly, with anterior displacement of the major fissure. On the frontal film the collapsed lobe will often appear as an increased density lateral to the hilum. It is also very typical for the hyperinflated lower lobe to appear between the aortic knob and the collapsed lobe. The lung shows up as an unusually lucent (black) crescent which has been term the "luftsichel" sign (which is German for air crescent). Figure 5.5 shows a typical case of left upper lobe collapse.

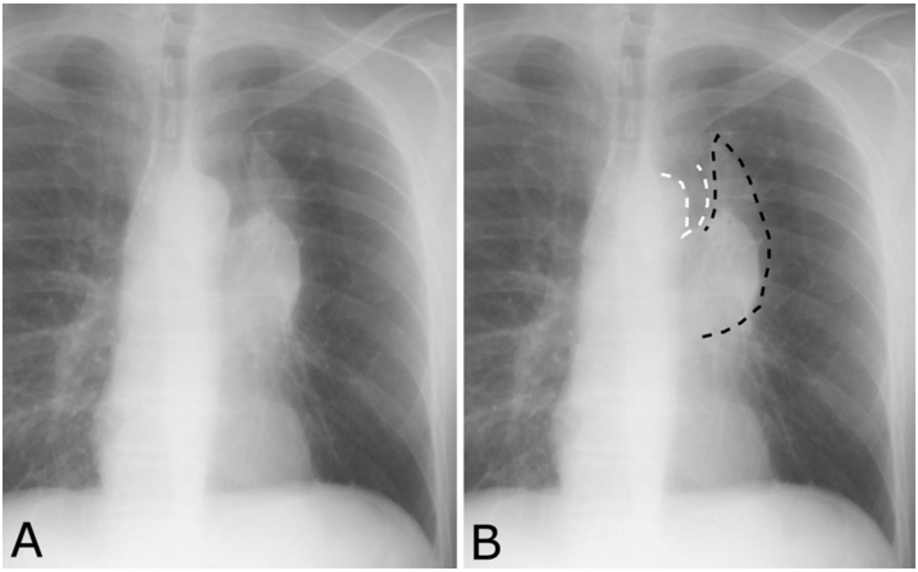

Figure 5.5 – Left upper lobe collapse. A. Unmarked film. B. Marked film to show the collapsed left upper lobe (black dashes). The luftsichel is the prominent air seen between the collapsed lung and the aorta (white dashes).

Collapse of the lower lobes occurs in the same way regardless of the side. With lower lobe collapse the major fissure shifts inferiorly and posteriorly. On the frontal film, the major fissure is normally not visible, but in lower lobe collapse it can rotate into view as moves inferiorly. Figure 5.6 shows an example of lower lobe collapse.

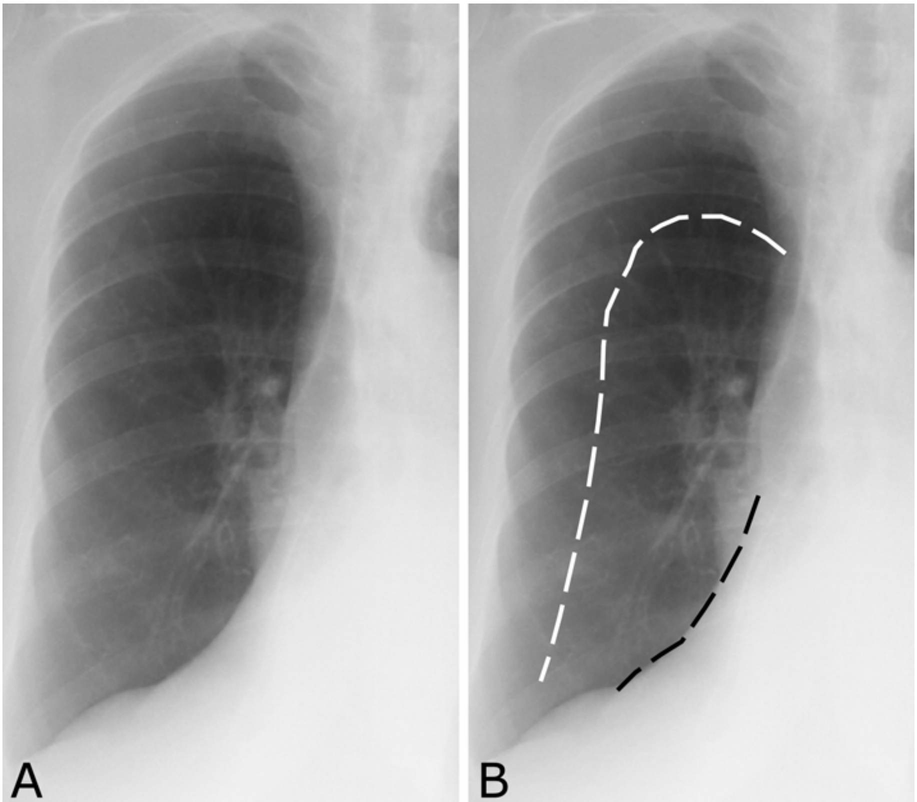

Figure 5.6 – Right lower lobe atelectasis. A. Unmarked film. B. Marked film to show the displaced major fissure (black dashes) this has appeared on the frontal film. The white dashes indicate the approximate location of the major fissure on the frontal film (though it is not seen in the normal case because of its obliquity).

In the extreme case there may collapse of an entire lung. In the case of total lung atelectasis the findings can be quite striking with essentially no air visible on the affected side. Generally there will be shift of the mediastinum towards the atelectasis. Figure 5.7 shows and example of total atelectasis of one lung.

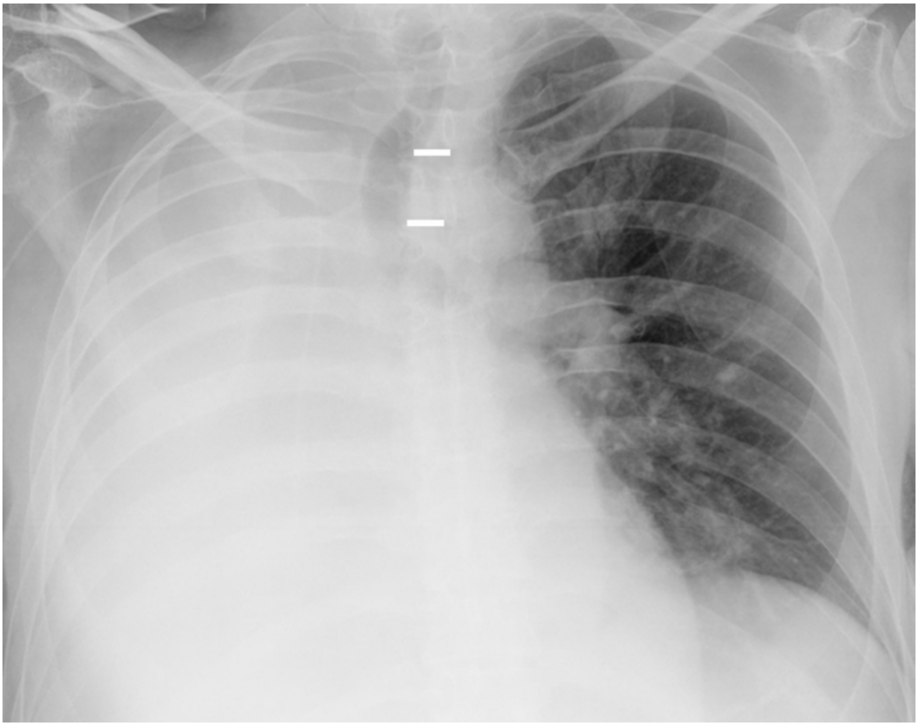

Figure 5.7 – Total atelectasis of the right lung. Notice the shift (white lines) of the trachea toward the affected side.

One common error I often see is confusion about the case of a "total whiteout" of one lung such as in the above case. Students often mistake the appearance for that of a massive pleural effusion. It is important to understand the difference, for although either diagnosis can cause one side of the thorax to be completely white, the two can readily be distinguished by observing the mediastinum. In total atelectasis of a lung, the mediastinum will shift *towards* the affected side. In the case of a massive pleural effusion, however, the mediastinum will be pushed *away from* the affected side by the large volume of fluid. Figure 5.8 compares the two scenarios.

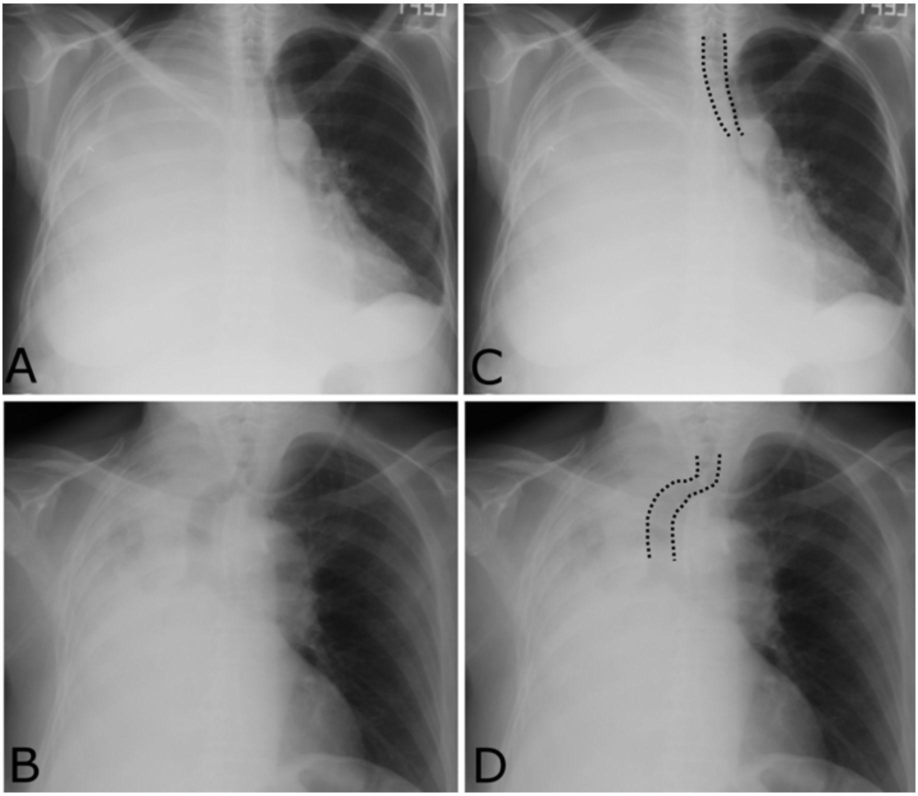

Figure 5.8 – Total whiteout of a hemithorax. A. Unmarked film of a massive pleural effusion. B. Unmarked film of total atelectasis of one lung. While both conditions cause the affected side to turn completely white, the mediastinum behaves differently in the two cases. C. Marked film shows that the trachea (black dots) is shifted *away from* the massive pleural effusion. D. Marked film shows that the trachea is shifted *towards* the total lung atelectasis.

Interstitial Pattern

The hallmark of the interstitial pattern is the presence of linear and irregular shadows. Unlike the patterns of alveolar flooding and atelectasis, the interstitial pattern is often subtle and may be difficult to distinguish from normal in some patients because the lines are mistaken for vessels. Look at the pattern of the lines and decide if you are simply looking at vessels or if there are too many lines and the pattern is too irregular to represent normal vessels only. Figure 5.9 shows a patient with a viral pneumonia presenting with an interstitial pattern.

The interstitial pattern includes many categories of diseases and there are several subsets of the interstitial pattern. A typical pattern, such as the one shown in the above case, is commonly seen in patients with "interstitial" pneumonias (classically viral pneumonias and mycoplasma pneumonia, but in patients with HIV pneumocystis pneumonia can present with this pattern too). In addition, as discussed in the previous chapter, patients with interstitial pulmonary edema can have this pattern. In these examples, the linear shadows represent prominence of the normal intra- and inter-lobular septa in the lungs. One classic indication of this type of interstitial pattern is the presence of "Kerley B" lines, as shown in Figure 5.10. While the interlobular septa can be seen throughout the lungs, near the periphery on the chest radiograph they are generally evenly-spaced and run perpendicular to the surface of the pleura, making them easy to identify. (Kerley also described 'A' and 'C' lines, which are the other linear shadows seen, but they all represent septal thickening and the 'B' lines are generally the most helpful).

Figure 5.9 – Interstitial pneumonia. Notice the excessive number of linear and irregular shadows throughout the film. In subtle cases it may difficult to distinguish the increased linear prominence from normal vessels.

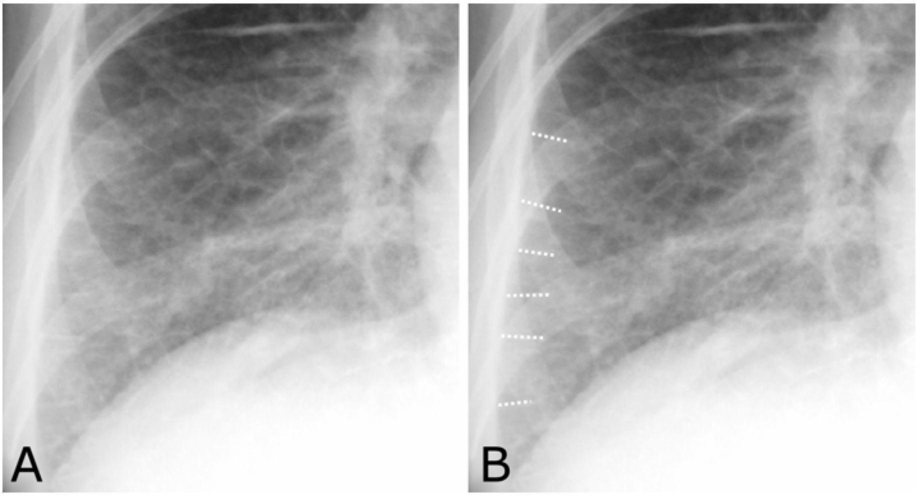

Figure 5.10 – Kerley B lines in a patient with interstitial pulmonary edema. A. Unmarked film. B. Marked film to highlight the Kerley B lines. Notice that they run perpendicular to the pleural surface and are relatively evenly spaced.

There are other causes of an interstitial pattern other than thickening of the septa. In patients with pulmonary fibrosis there are excessive linear shadows, but the underlying process of scarring and parenchymal distortion give a much different appearance. Figure 5.11 illustrates an interstitial pattern in a patient with pulmonary fibrosis from IPF (idiopathic pulmonary fibrosis).

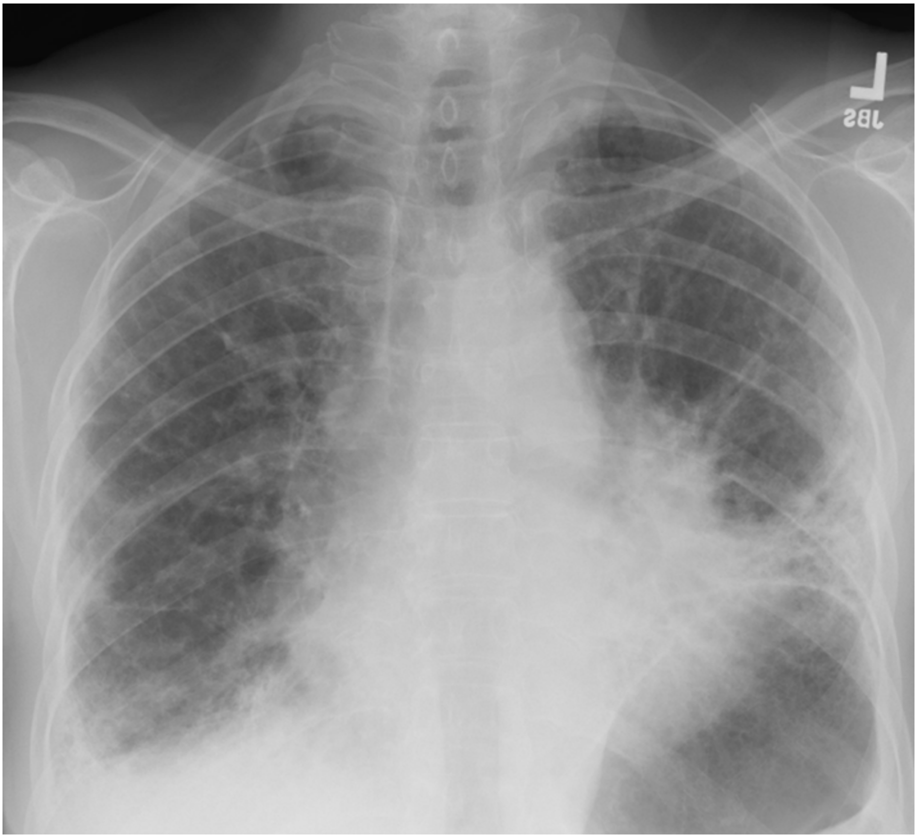

Figure 5.11 – Interstitial pattern in pulmonary fibrosis. Again a pattern of linear and irregular shadows is seen, but the lines do not represent thickening of normal septa. Instead they are more irregular and result from the underlying scarring and parenchymal distortion.

Another subset of the interstitial pattern is that seen with bronchiectasis. Bronchiectasis represents irreversible dilatation of the bronchi. Often there is associated thickening of the bronchial walls as well. In this scenario, the linear pattern seen represents the walls of the dilated airways that normally would not be seen. By identifying regular circles (airways seen end-on) and parallel lines (tram tracks, or airways seen from the side) the specific diagnosis of bronchiectasis can be made. Figure 5.12 shows an example of the interstitial pattern of bronchiectasis in a patient with cystic fibrosis.

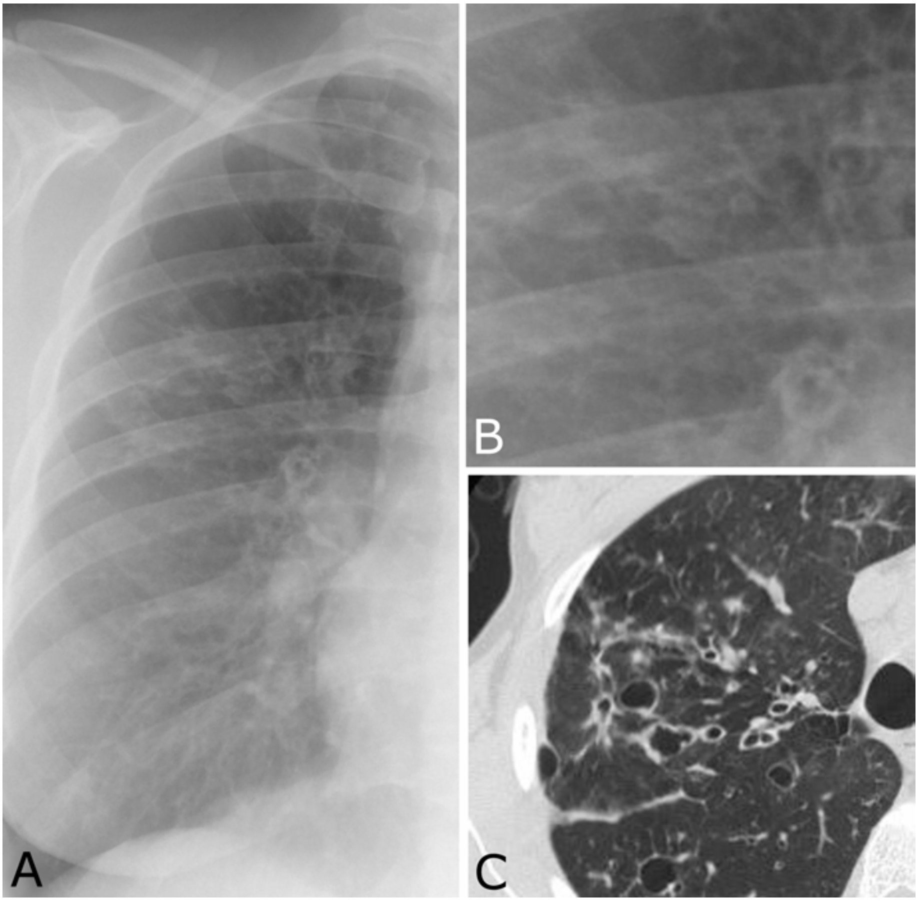

Figure 5.12 – Bronchiectasis. A. Frontal radiograph of a patient with cystic fibrosis, a common cause of bronchiectasis. Notice the linear (interstitial pattern). B. Magnified view to show that many of the lines are actually circles (end-on, dilated airways). C. Axial CT image shows many of these circles throughout the lung.

Nodules and Masses

Chapter VI

Because the chest is a very common site for both primary and metastatic malignancies, it is important to have an understanding of how to deal with abnormalities that may be tumors when they are seen on the chest film. The vast majority of nodules that are seen both on plain films and CT scanning are benign lesions, but it is always necessary to apply the proper workup to any nodule or mass that is identified. Figure 6.1 shows a typical solitary pulmonary nodule (SPN). It should be noted here that the only difference between a lung "nodule" and a lung "mass" is that of size. Traditionally, nodules are soft tissue lesions in the lung that are smaller than 3cm, while masses are lesions that are 3 cm or greater.

The most common scenario is the discovery of the solitary pulmonary nodule. All solitary pulmonary nodules need to be evaluated to determine whether it is likely that they represent a malignant tumor or not. Generally this process involves a series of progressively more-complicated steps. The first, and potentially most useful step, is the identification of prior films. If a nodule can be shown to be stable (unchanged in size) for a period of two or more years, then it is almost always benign and further evaluation is rarely warranted. Figure 6.2

shows an example where having a prior film of more than two years prior avoided the need for further workup.

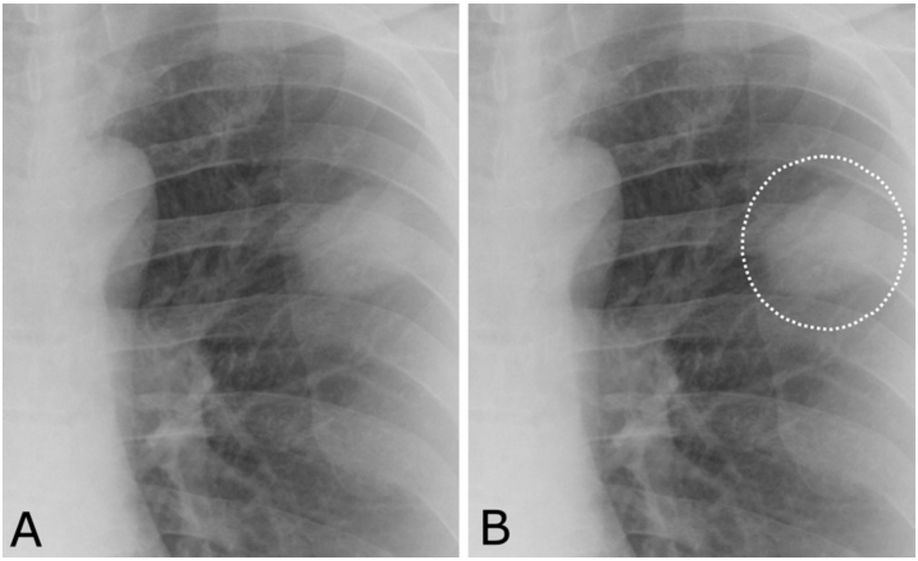

Figure 6.1 – Solitary pulmonary nodule. A. Unmarked film. B. Marked film to outline the nodule. Once the nodule has been identified it must undergo the appropriate workup.

In many cases, a pulmonary nodule will be identified on a patient's first chest film, or if there were any prior studies they occurred at other institutions and cannot be found or have since been destroyed. In these cases, the next step is to try to determine if the nodule displays one of the benign patterns of calcification. Nodules which have a central, homogenous, concentric (target) or "popcorn" pattern of calcification are almost always benign and rarely require any further workup (the first three patterns are seen in granulomata, the last in hamartomas). Malignancies may have calcifications, but they tend to be irregular or concentric. While these calcification patterns may be seen on a plain chest films, it common to need a chest CT to further evaluate whether or not a benign pattern of calcification is present. Figure 6.3 shows a nodule that was proven to have a benign pattern of calcification and thus need no further workup.

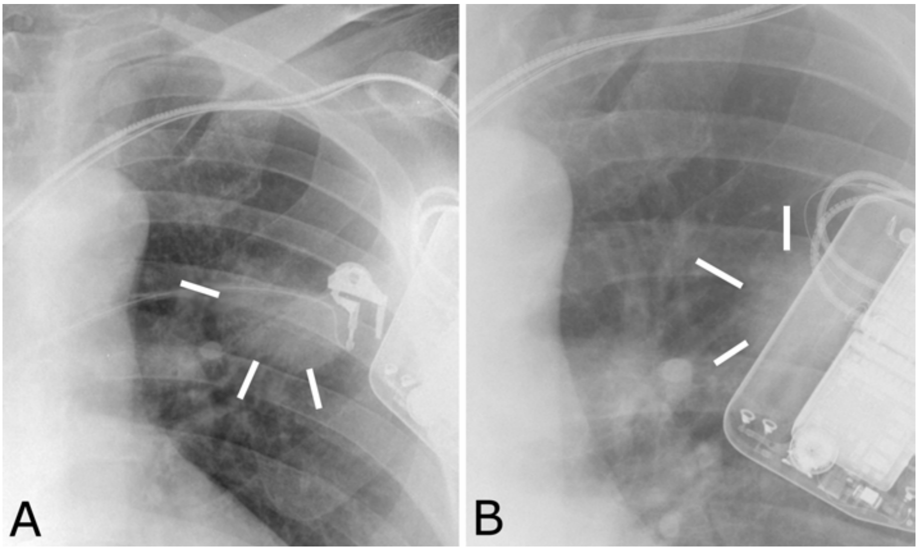

Figure 6.2 – Pulmonary nodule over time. This nodule was located just below the implanted control pack for the patient's transvenous cardiac pacer (a rather unfortunate place to have a nodule). A. Frontal chest radiograph where the nodule was identified. B. Prior study from over three years previous from another institution where the nodule had not been seen, but fortunately proved to be unchanged.

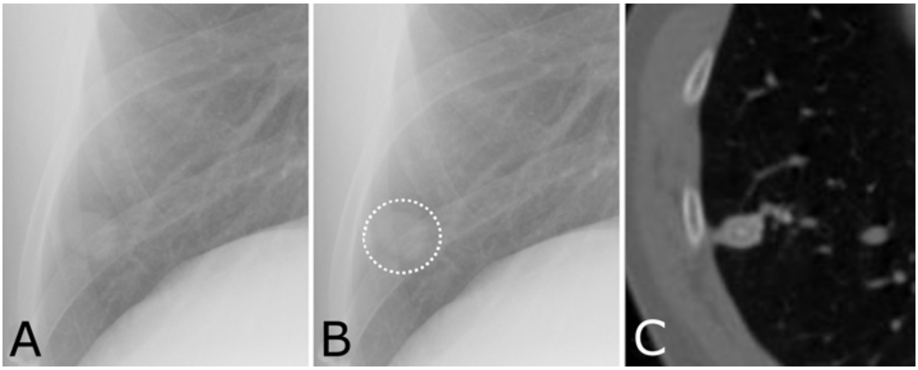

Figure 6.3 – Solitary pulmonary nodule with a benign pattern of calcification. A. Unmarked film. B. Marked film to show the solitary pulmonary nodule. It could not be determined from the film if the nodule was calcified or not. C. Axial CT image demonstrates a central calcification, indicating this nodule represents a benign granuloma and requires no further evaluation.

It turns out that there a lot of non-calcified pulmonary nodules out there and these all need some additional workup. For nodules that are roughly 7 mm or greater in diameter, the best next step is to perform a PET (positron emission tomography) study. PET is useful in many cancers because it can detect hypermetabolic tissue. A pulmonary nodule that is "hot" (hypermetabolic) on PET imaging then needs a biopsy. Nodules that are not hot on PET and those that are too small for PET imaging need serial CT imaging (usually at 6, 12 and 24 months). If the nodule grows on any of those CT scans, then biopsy is indicated. If no growth is detected over the two year period, then the lesion is assumed to be benign and no further workup is generally indicated. Figure 6.4 shows a nodule that was hypermetabolic on PET imaging.

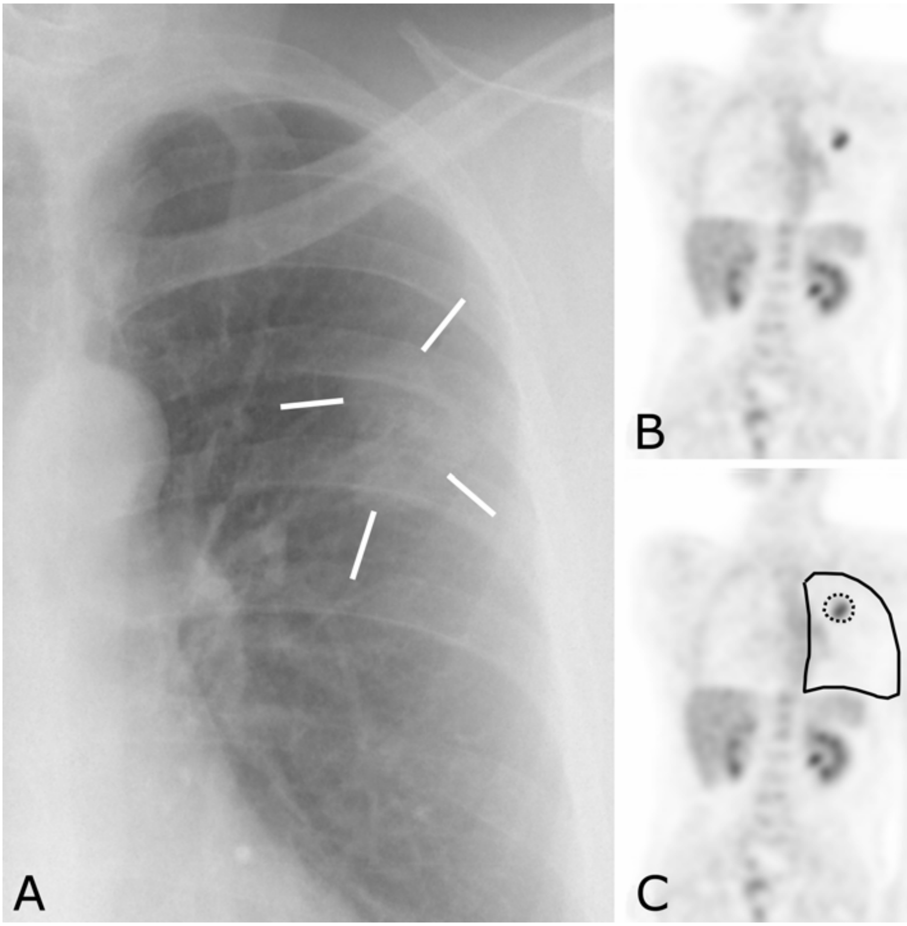

Figure 6.4 – Hypermetabolic solitary pulmonary nodule. A. Frontal radiograph shows a solitary pulmonary nodule (white lines). B. Unmarked coronal PET image of the thorax. C. Marked PET image shows the abnormality – a "hot" focus (black dots) in the lung. For clarity, the margins of the left lung are indicated with a black outline.

Primary lung cancers can have a wide range of appearances on chest films. The most common appearance is the solitary pulmonary nodule or the solid mass. Lung masses often have irregular or spiculated borders and they can occasionally be seen to erode through bone. Figure 6.5 shows a typical invasive lung cancer.

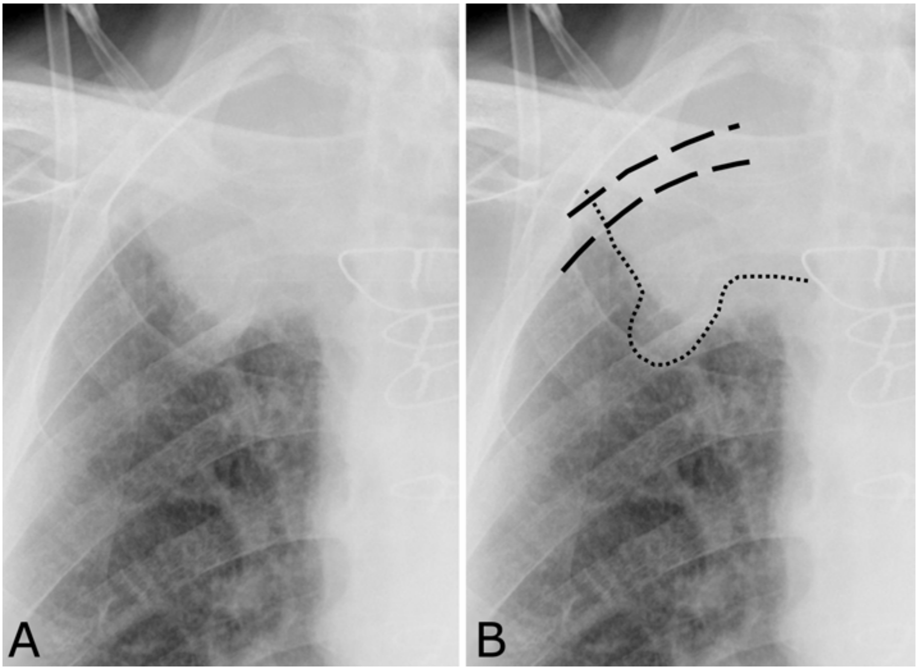

Figure 6.5 – Lung cancer. A. Unmarked film. B. Marked film outlines the irregular margins of the tumor (black dots). Careful inspection also reveals that the right third rib (black dashes) has been eroded by the tumor. A tumor in this location is called a

Lung cancers may also appear as cavitary masses. Curiously, it turns out that squamous cell carcinomas, both primary to the lung and metastatic from other locations, are the most common malignancies to cause cavitary masses in the lungs. Figure 6.6 shows a large cavitary primary squamous cell carcinoma of the lung. Identification of loculated air (and sometime fluid) indicates the presence of cavitation.

Figure 6.6 – Cavitary squamous cell carcinoma of the lung. This large cavitary tumor contains an air-fluid level in its center.

It also happens that sometimes it is not the tumor itself that is seen on the film as it is the effect of the tumor. Endobronchial tumors commonly obstruct the airway and may lead to either distal atelectasis or entrapment of pulmonary secretions and post-obstructive pneumonitis. In both cases the tumor itself may be rather small relative the visible effect it has on the film. Figure 6.7 shows an example of an endobronchial tumor obstruction the right upper lobe bronchus and leading to atelectasis of the right upper lobe.

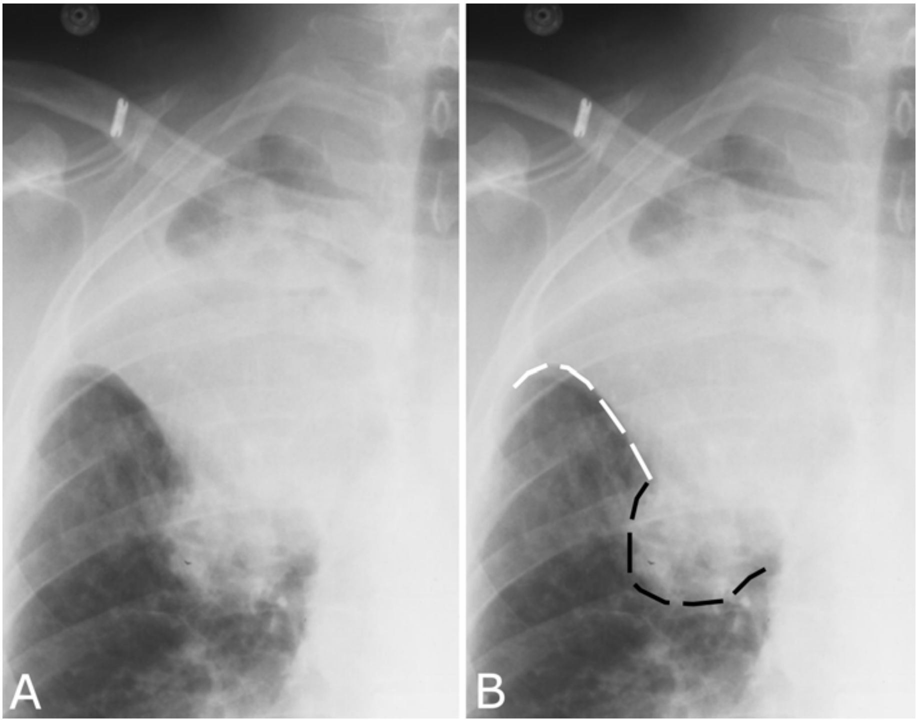

Figure 6.7 – Right upper lobe collapse from lung cancer. A. Unmarked film. B. Marked film. In this example, both the tumor itself (black dashes) and the effect of the tumor (the collapse of the right upper lobe) are visible. Notice the superior displacement of the minor fissure (white dashes). This combination of superior displacement of the minor fissure combined with a visible tumor mass has been termed the "S sign of Golden," named for the Radiologist who described this finding and felt that it gave the appearance of the letter 's' (albeit, backwards).

Masses in the chest are found not only in the lung but also in the mediastinum. Some Radiologists disagree about the proper way to divide the mediastinum into different compartments (usually anterior, middle and posterior). Often the discussion is rather academic, though, because the lesion is an unknown it is not always possible to decide exactly where it originated. While those differentials for "anterior mediastinal masses" and the others that all medical students seem to know are great, it is always important to consider that an unknown mass may have originated in an adjacent compartment, including the adjacent lung. Figure 6.8 shows a typical anterior mediastinal mass.

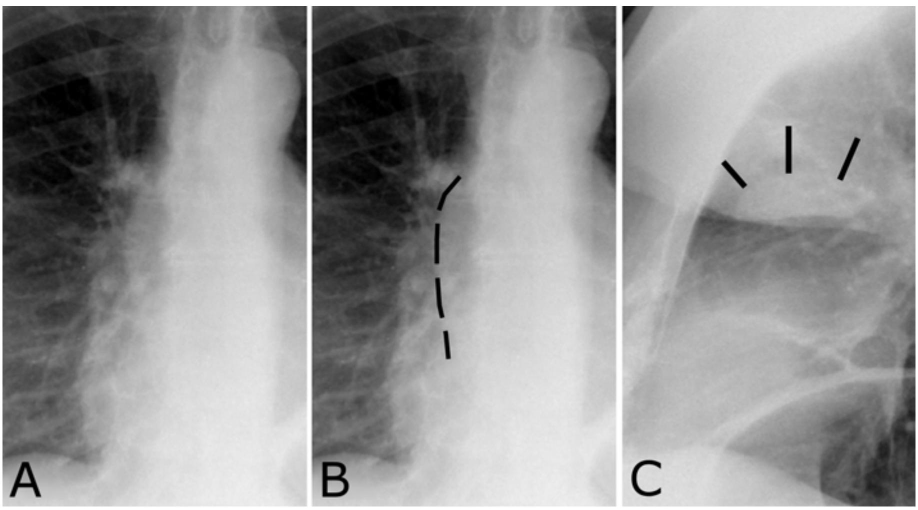

Figure 6.8 – Anterior mediastinal mass. A. Unmarked frontal film. B. Marked film to show the border of the mass (black dashes). C. Lateral radiograph to show that the mass (black lines) is centered in the anterior mediastinum, but you must always consider that it may have had a middle mediastinal origin or it may be a lung cancer invading the mediastinum.

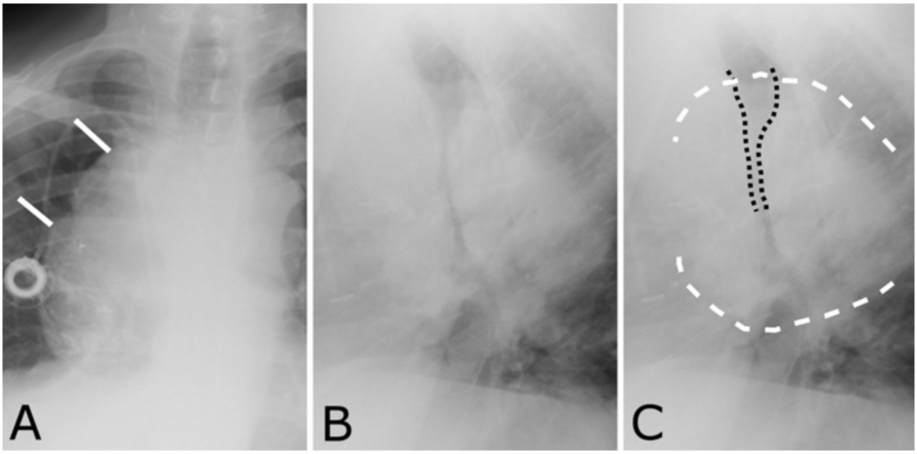

Figure 6.9 – Middle mediastinal mass. A. Frontal film shows a large mass (white lines) centered in the mediastinum. B. Unmarked lateral radiograph. C. Marked lateral radiograph shows the extensive mass centered in the middle mediastinum (white lines). Notice the marked compression of the airway (black dots).

For completeness sake, middle (Figure 6.9) and posterior (Figure 6.10) mediastinal masses are also shown. In almost all cases of a true mass the importance is identifying its presence. Once it is seen it will require further evaluation with CT scanning.

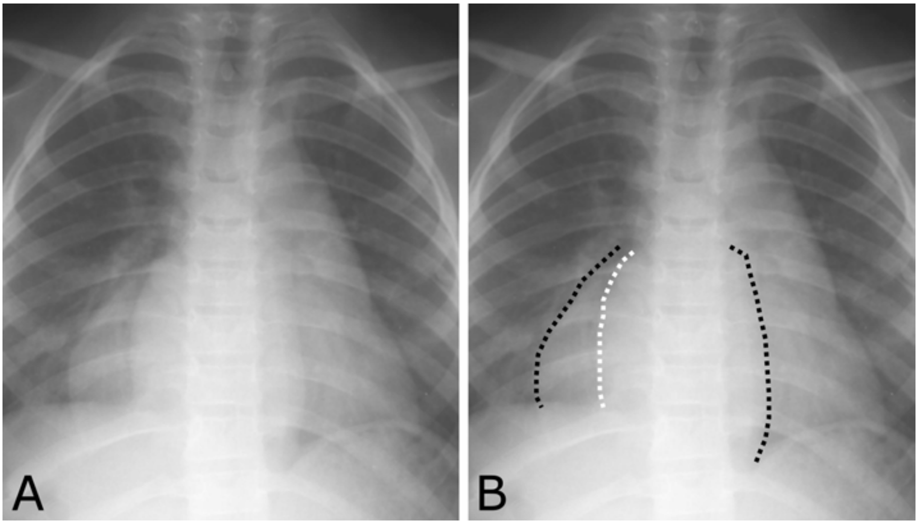

Figure 6.10 – Posterior mediastinal mass. A. Unmarked film. B. Marked film to show the mass (black dots). Because the mass is well behind the heart, it is surrounded by air and so its left border can still be seen "through" the heart. Notice also that the right heart border (white dots) can still be seen "through" the mass.

Don't-Miss Lesions

Chapter VII

Before I finish looking at any film, I always give a second look for some of the lesions that I commonly see people miss. While these should be found on the initial systematic evaluation of the film, it is so common for other people to miss them that I always think it is worth looking for them twice. I call these "don't-miss" lesions. The lesions I commonly see missed are:

1. Deviation of the trachea
2. Retrocardiac masses/densities
3. Lesions "below" the diaphragm
4. Lesions near the hilum
5. Adenopathy

Deviation of the trachea.

Because the trachea is so well seen, it can give good clues about what is going on in the neck or mediastinum. Enlargement of one side of the thyroid gland (whether from multinodular goiter, tumor, etc.) is common cause of deviation of the trachea. Unless you specifically look for this finding, though, it is easy to miss. Figure 7.1 shows a typical example of a deviated trachea.

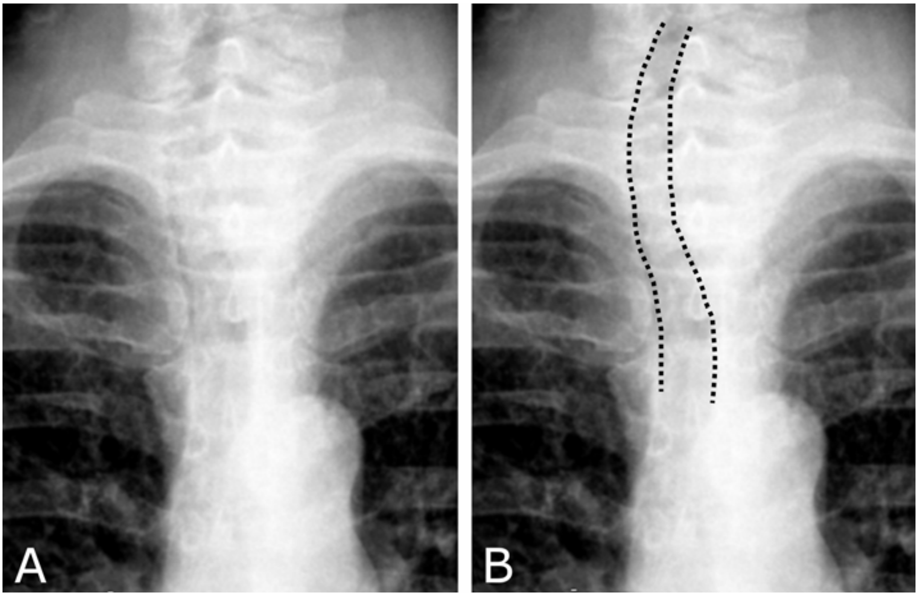

Figure 7.1 – Deviation of the trachea. A. Unmarked image. B. Marked image to show the prominent rightward deviation of the trachea in the neck. In this case, the left lobe of the thyroid was found to contain a large cancer.

Retrocardiac Masses/Densities

It must always be remembered when looking at a frontal film that is quite a lot of lung sitting behind the heart. On a good film this lung can still be well seen and evaluated. Nodules, masses and pneumonias (along with any other lung pathology) may be found hiding there. Since most films obtained on hospitalized patients are done portably without a lateral view, your only chance to see these findings is if you remember to look "through" the heart. Figure 7.2 shows a rather large nodule that might be easy to miss if you didn't specifically look there for it.

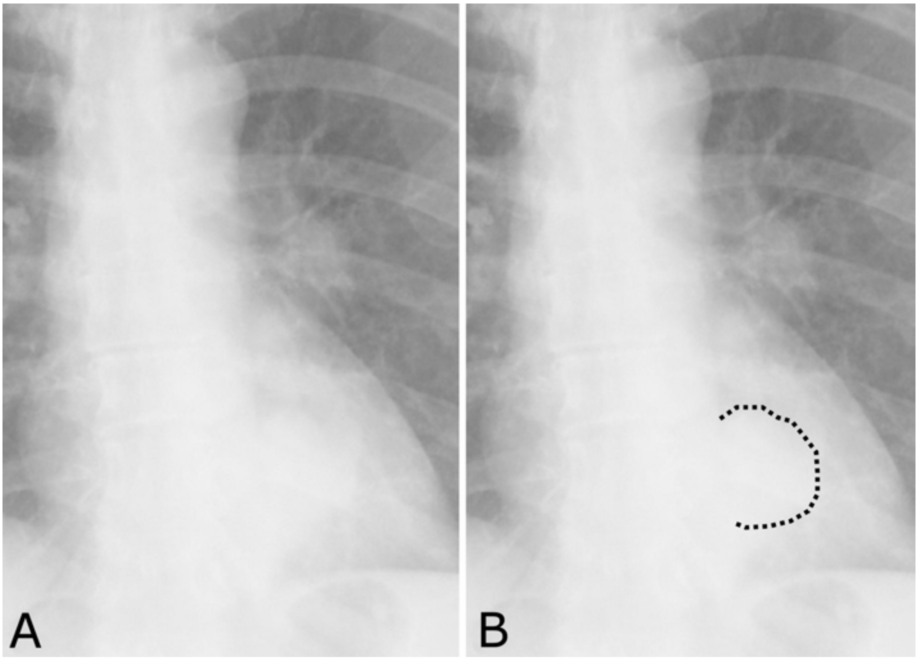

Figure 7.2 – Retrocardiac nodule. A. Unmarked film. B. Marked film outlines the borders of the large nodule (black dots) sitting in the lung that lies behind the heart.

Lesions "Below" the Diaphragm

The diaphragm has a three-dimensional shape that should be remembered whenever you are looking at a frontal film. The "diaphragm" that you see on the frontal film actually represents the highest point of the diaphragm and it is usually far anterior. Posteriorly the diaphragm drops far inferior (look back a normal lateral film, like Figure 1.2). All of that lung below (really posterior to) the highest part of the diaphragm can be seen "through" the diaphragm, similar to the lung behind the heart. Again, lesions here are easy to miss unless you make a specific effort to look for them. Figure 7.3 shows a lesion hiding "below" the diaphragm.

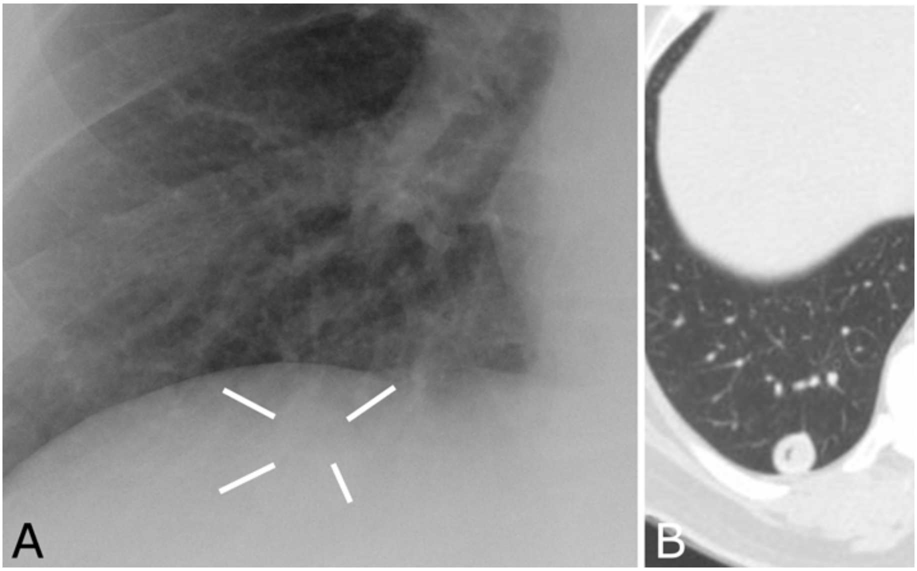

Figure 7.3 – Lung nodule "below" the diaphragm. A. Frontal radiograph shows that the lung nodule (white lines) projects below the highest part of the diaphragm. B. Axial CT image shows that the lesion is within the posterior inferior part of the lung.

Lesions Near the Hilum

The hilum is a busy place on the chest film, and it is easy to miss subtle lesions that occur here. Because I often see people miss these types of lesions, I always give the perihilar regions a second look. Figure 7.4 shows an example of a very large mass that was partially obscured by the hilum and easy to miss if you are not paying attention and specifically looking for it.

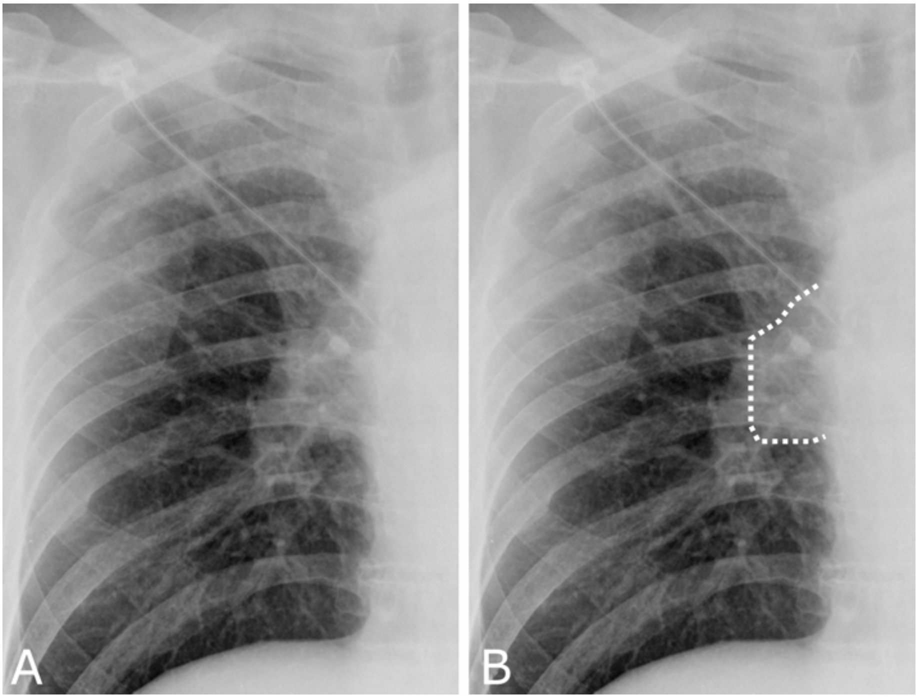

Figure 7.4 – Perihilar mass. A. Unmarked film. B. Marked film to outline the borders of the large mass (white dots). Because so many normal structures overlap within the hilum it is important to carefully look in that region for subtle (though maybe quite large) lesions.

Adenopathy

Hilar and mediastinal adenopathy is commonly seen with many diseases, both malignant and benign. Often, the presence of adenopathy will be the only abnormality in an otherwise normal chest film. Identifying adenopathy can have a significant effect on a patient's workup and management. Because the adenopathy is usually seen in either the hilum or mediastinum (where many other soft tissue densities live) it can easy to overlook. It always worth asking yourself about adenopathy just before you finish looking at the film. Figure 7.5 shows an example of a patient with hilar adenopathy from sarcoidosis.

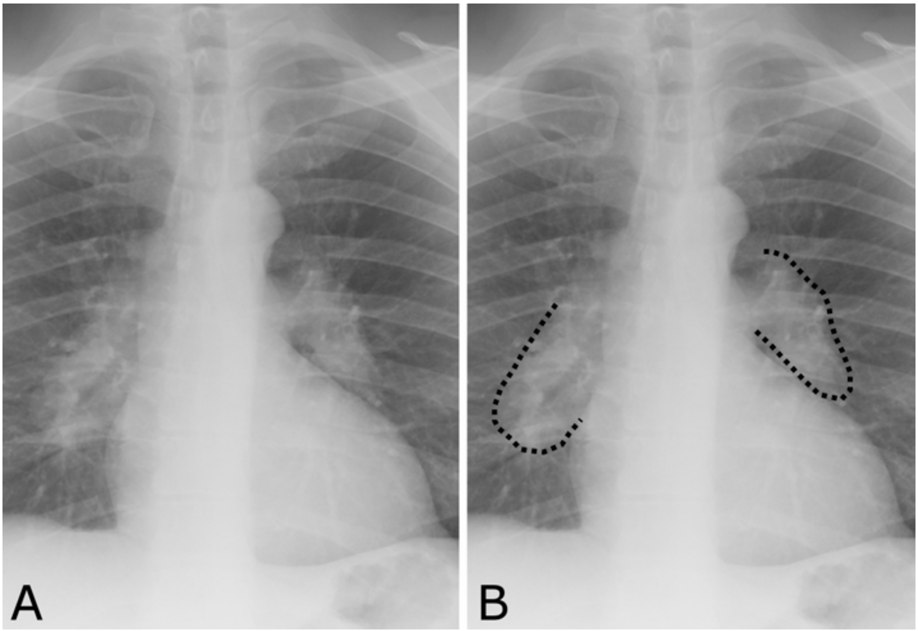

Figure 7.5 – Hilar adenopathy. A. Unmarked image. B. Marked image to outline the presence of bulky, bilateral hilar adenopathy. Occasionally even large lymph nodes like this are dismissed as pulmonary arteries.