<u>**Lecture 6**</u>

Lecture 6: What Makes a Quality Image

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In this Lecture

- Learn how to evaluate an image to determine if it is a quality image
- Know the 5 biologic densities
- Understand the silhouette sign
- Know the difference between density and opacity

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We are close. Very close. Oh so very close to actually looking at radiographs. So close I can taste it. In fact, in this lecture we will actually start looking at radiographs. Unfortunately we will only be evaluating them for **quality**. Think of it this way. When you download songs from Kaazaa or Morpheus at 96kbps it sounds crummy. Songs sound like they were recorded through two coffee cans with a string between them. You want to get the songs that were encoded at 320kbps. Same with radiographs. You will miss the diagnosis every time if the radiograph is crummy.

What makes a radiograph crummy you ask? That is a tough question to answer. An easier question to answer is "what makes a quality radiograph?" The answer is simple, a quality image faithfully reproduces an anatomic part so that it can be easily evaluated on the radiograph. The following lecture explains how we make that faithful reproduction and how we evaluate the radiograph to determine if it is a quality radiograph.

In this lecture you will be exposed to words like opacity, density, subject density, radiographic opacity, radiopacity, radiolucency, contrast, scale of contrast, latitude and a few others. All of these terms refer to how black, white, or gray a radiograph it. Expect confusion. Read the notes a few times. See if you can sort it out. I did my best. If you don't get it after a time or two. I recommend taking a break. Maybe cry a little in a fit of rage over why you need to learn this nonsense. Eat some Ben and Jerrys. Then read it again. If you don't get it by then. Don't hesitate to come see any of us in the radiology department. It is important and we know it is confusing. However, if you left this for the night before the test and you are having problems at midnight, well, you are on your own.

Opacity: 5 to live by

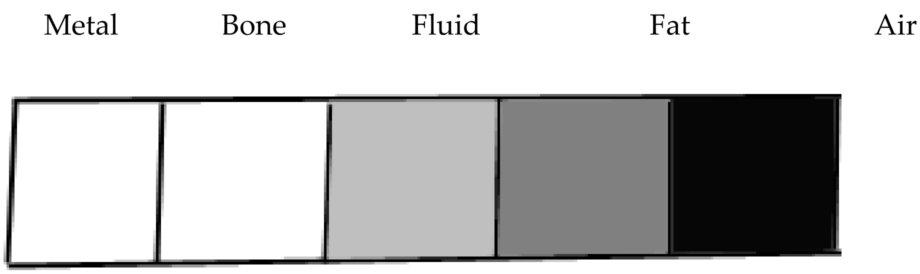
Remember the following paragraph regarding radiographic density. You <u>will</u> be asked about it senior year. Dr. Hathcock <u>will</u> point to something on a radiograph and ask you, "What opacity is it?"

In order to answer the question you have to know what opacity means. Opacity is a description of the radiographic appearance of an object. If refers to how many x-rays are allowed to pass through that object. Object that allow many x-rays to pass through are black on a radiograph. Objects that do not allow many x-rays to pass through are white. <u>Whiter areas on a radiograph are more opaque than black ones. Whiter areas are called radiopaque. Blacker areas are called radiolucent.</u>

Now, back to Dr. Hahcock's question. Don't let him throw you off. After reading these notes, you will understand that he is really asking you a multiple choice question. This is because there are only 5 radiographic opacities. These are:

1. Gas: organs such as lungs and a gas within the stomach have a gas opacity
2. Fat: falciform fat, perirenal fat
3. Fluid or Soft tissue: all soft tissues structures are of soft tissue opacity
4. Mineral: bone
5. Metal: fracture fixation devices, arrowheads, gun shot pellets, barium

The preceding list was ordered that way for a reason. The list is organized in order of radiographic opacity; from radiolucent to radiopaque; from less opaque to more opaque; from black to white.



As you can see, the ability to differentiate organs on a radiograph is based on their radiographic opacity. Radiographic opacity is based on the differential absorption of x-rays (remember the interaction lecture…I told you it was important) in various body structures. Specifically:

- <u>More radiation is absorbed by more dense objects</u> (bone). Therefore, fewer x-rays will expose the film. The film under these areas will be underexposed and the part will appear whiter on the radiograph. Bones are radiopaque.

- Conversely, less dense organs (lungs) will have less interaction. This will allow more x-rays to hit the film and the organ will appear black on the radiograph. Lungs are radiolucent.

5 radiographic opacities. Memorize those three words. That's it. No more, no less. Easy. Simple. However, a radiograph is composed of many shades of gray. How can that be if there are only five radiographic densities? Well, the appearance of an anatomic part as it appears on a radiograph is related to three factors:

1. <u>The density of the object.</u> The density determines the radiographic opacity. There are only 5. We just talked about this one.

2. <u>Thickness of the object:</u> Remember the Compton interaction business. Well, back then we said that there would be more Compton interactions with increased patient thickness. Here is why it is important. Since, more x-rays are absorbed by thicker parts, thicker parts will allow less x-rays through to expose the film and the anatomic part will appear more white on the radiograph. So, you see. A real thick piece of fat may appear almost as white as a very thin piece of heart.

   This concept of thickness can cause real problems when you consider that a radiograph is a two dimensional representation of a three dimensional structure. Therefore, all of the organs in a radiograph **summate** with one another to form the final radiograph. Therefore, when two objects overlap, the overlapping portions will have an apparent opacity equal to the sum of the density of the two objects alone. Focal areas of summation are often seen in the thorax where ribs are superimposed over larger vessels. These areas are often mistaken for small nodular lung lesions.

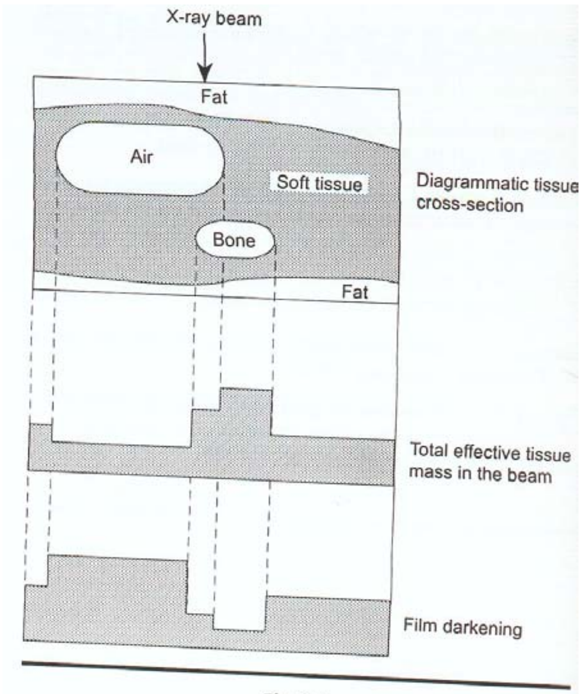


Fig. 6-1
RELATIONSHIP BETWEEN OBJECT MASS AND FILM DENSITY
Diagrammatically, the limiting effect of various tissues on the resulting number of photons that eventually reach the film can be shown. The x-ray beam interacts with a cross-section of tissue and the selective absorption of the primary photons is shown with the resulting film darkening at the bottom of the drawing. Note that the total effective tissue mass in the beam is dependent both of the thickness of the tissue and its composition.

3. <u>The objects surrounding it</u>: We can only see an object on a radiograph if it is surrounded by an object of a different opacity. Just like it would be tough to see a polar bear in a snow storm because they are both white, we cannot see the difference between two structures on a radiograph if they are the same density. We cannot, for example, differentiate a muscle from a tendon on a radiograph because they are both the same opacity. Now, paint the fur of the polar bear with green paint and you can easily see him. With regard to our analogy, we could put some barium around the tendons and we would be able to see them too. We can differentiate abdominal organs even though they are all soft tissue opacity because they are surrounded by intrabdominal fat.

There even a stupid name for this phenomenon…"**the silhouette sign."** Simply, if an object is in intimate contact with material of the same radiographic density, the object border will be obliterated. I say it is a stupid name because it seems to me that if something "silhouettes" with something else we should be able to see the borders better! One renegade radiologist even attempted to change the name to the more appropriate **"border effacement sign"** but it didn't stick.

Quick review: There are only 5 radiographic opacities on a radiograph. The opacity of an anatomic part on a radiograph depends on the density of that part (there are only 5 (that is the last time I promise)), the thickness of the part, and the organs and tissue surrounding the anatomic part. If that were all it would be easy and you wouldn't need the Ben and Jerrys. Unfortunately, there is more. Get out the ice cream for this one.

More on film opacity - Exposure

We said previously that **film opacity** refers to the blackness or whiteness on a radiograph. There are two <u>main</u> factors (there are a number of secondary factors) that affect the radiographic opacity of a body part on the film. These are:

1. **Subject density**: we just talked about this. See the preceding section

2. **Exposure:** Radiographic exposure describes how **overall** white or black a radiograph is. This is just like exposure on a photograph. If the photograph is too dark, it is overexposed. Everything in the photograph is black regardless of what it is. In an underexposed photograph everything is washed out and white regardless of what it is. The same goes for radiographs. In an overexposed radiograph everything is too black. Exposure is the number one determinant of film quality. Exposure is the number one determinant of film quality. Exposure is the number one determinant of film quality. Exposure is the number one determinant of film quality. Exposure is the number one determinant of film quality. Exposure is the number one determinant of film quality. Exposure is the number one determinant of film quality.

These days many settings on a camera are auto selected to give you a reasonable exposure every time. The factors your camera takes in to consideration and the settings it chooses to properly expose a photograph are the amount of light you have available to expose the picture, how wide you to open the shutter (f-stop), and how long to expose the film (time of exposure.) There are two similar (not identical) factors that control the exposure of a radiograph. These are: mAs and kVp.

1. **mAs: milliamperage seconds**
    - mA stands for milliamperage. S stands for seconds. MAS is the product of these two(mA x S = mAs)
        - mAs describes the amount of current applied to the cathode.
        - mAs determines the **number of electrons** that are boiled off of the cathode filament.
        - mAs represents the **number of x-ray photons** that are produced by the anode.
    - mAs is important because it is one of the settings you must give the x-ray machine before you expose a radiograph. Generally the mA and the seconds each get their own dial on an x-ray machine. However, the amount of radiation is a product of the two. You can get the same mAs by using different combinations of the two. For example:
        - 300mA x 1/30s = 10mAs
        - 100mA x 1/10s = 10mas

      So which do you chose? In general, with animals, the faster the better. Shorter exposure times minimize blurred images due to patient motion. Exposure times of 1/60sec or less are best.

    - mAs is important because it a big determinant of film exposure. The more x-rays you have to expose the fim, the blacker the film will be. A rule of thumb states that doubling the mAs will double the film exposure.

3. **kVp: kilovoltage potential**.
    - kVp describes the electrical potential across the x-ray tube when x-rays are produced.
    - kVp affects both the energy of the x-ray beam and the number of x-rays produced. <u>The energy of the x-rays determines if they can penetrate an anatomic part.</u>
    - Increasing kVp will increase the penetrability of the x-ray beam and therefore increase the exposure of the film since it increases the number of x-rays, which have sufficient energy to penetrate the subject.
    - Increasing kVp will also increase the exposure because more x-rays are produced.
    - kVp is also a major determinant of contrast. We'll talk more about contrast to next section.

You can think of kVp with the following analogy. Let's say you are in Tora Bora searching caves looking for Osama Bin Laden. In this analogy, the number of weapons you fire in your mAs. The size and power of the weapon is the kVp. The resulting destruction to the cave is film exposure.

- If you shoot one million dinky bullets at the cave nothing will happened. The bullets will simply bounce off the outside of the cave. Likewise, if you try to expose a radiograph with wimpy little x-rays (i.e. a low kVp beam) the x-rays will not penetrate the patient and there will be no film blackening. It doesn't matter how many bullets you have (high mAs) you still won't destroy the cave (get a black image).

- If you use a single bunker buster bomb you destroy the whole cave in one shot. Likewise, if you use a high KVP beam all of the x-rays go through the patient and the film would be overexposed.

- However, what happens if you just wanted to bust up the cave only a little bit. Maybe break down a wall and have some bullets go through and hopefully hit something but you still wanted to leave the cave infrastructure relatively intact so you could search the cave for bodies. Well, you would have to use a weapon of intermediate destructive power. Likewise, in a radiography we don't want and all or none phenomenon. We don't want a radiograph that is totally black or totally white. We want a radiograph of many shades of gray.

In order to get a radiograph with many shades of gray we must use an appropriate kVp and mAs for a give n anatomic part. The radiographic term for “shades of gray” is **image contrast.** We will com back to the concept of contrast in the next section. For now just know that kVp is a primary determinant of image contrast.

Relating kVp, mAs, and film opacity: There are a few rules of thumb that relate these terms nicely:

1. Doubling the mAs will double the film blackness.
2. Halving the mAs with halve film blackness
3. Increasing the kVp by 20% will double film blackness
4. Decreasing kVp by 15-20% will halve film blackness

Contrast

Contrast is the opacity difference between adjacent areas on radiograph. Here comes the confusing part. The **scale of contrast** refers to the number of density gradations between the lightest radiograph shadow and the darkest radiographic shadow. This is where it gets confusing.

- An image with a lot of contrast is said to have a short scale of contrast. A high contrast image only has a few shades of gray between the lightest and darkest areas of the radiograph. High mAs and low kVp exposure factors are one method of achieving a short scale of contrast. A short scale of contrast is oftentimes preferable for bone examinations.

- An image with a little contrast is said to have a long scale of contrast. A low contrast image has many shades of gray between the lightest and darkest areas of the radiograph. Low mAs and high kVp exposure factors are one method of achieving a long scale of contrast. Radiographs with a long scale of contrast oftentimes preferable for abdominal examinations. Long scale is also referred to as latitude.

Short Scale of contrast	Long Scale of contrast
High contrast image	Low Contrast Image
A lot of blacks and whites few gray	Many Shades of Gray

CONTRAST **LATTITUDE**

There are a number of factors that affect radiographic contrast. These are:

1. Subject contrast: we have no control over this factor. Previously we discussed the fact that thickness and physical composition of the subject affect the opacity of a radiograph.

2. Film contrast: different types of film results in radiographs with different scales of contrast for the same exposure factors. This is a little bit confusing but remember:
   a. long latitude film results in decreased contrast with many shades of gray
   b. short latitude film (a.k.a. contrast film) produces radiographs with more contrast and only a few shades of gray. Like Oxyclean, it will make your whiter and your brights brighter (well blacks, blacker.)

3. Development time: excessive development time and temperature will result in a loss of contrast. Likewise too little development will also decrease contrast. If the developer is old and has reduced activity it will also result in decreased contrast.
4. KvP: we said previously that and increased kVp will decrease contrast. Increased kVp will decrease contrast for two reasons"
   a. First, increasing kVp creates a radiographic beam with a variety of energies of x-ray photons. Therefore, these photons will be absorbed by different tissues in different amounts. This can be a tough concept so I will present it in two different ways
      i. Think of it in the converse. A very low kVp beam will have x-ray photons that will either go through the patient or they won't. It is an all or none phenomenon that produces black or white with no shades of gray.
      ii. Using an analogy, a high kVp beam is like shooting many bullets of different sizes shot out of different size guns into a brick wall. As far as bullet penetration, it is not an all or none phenomenon. There would be many different size holes in the wall. Some will bounce off, someone go right on through, and some get stuck in the wall.

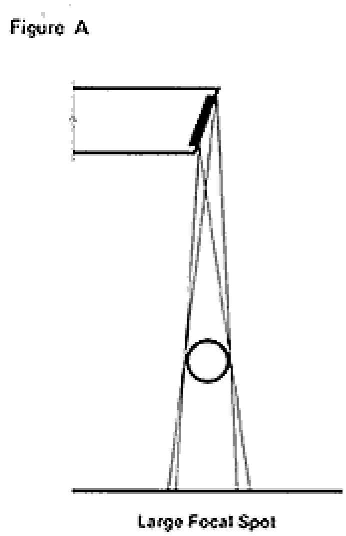
      If none of that make sense, don't worry about. Just remember increasing kVp decreases film contrast by a producing many shades of gray.

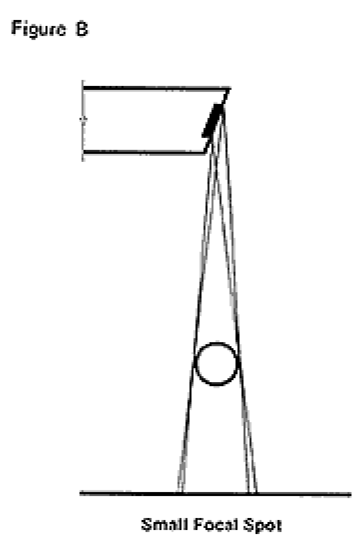
b. Second, increasing kVp increases the amount of scatter radiation formed. Previously we said that scatter is bad the cause into grades image quality. Scatter decreases image quality by decreasing contrast.

Detail

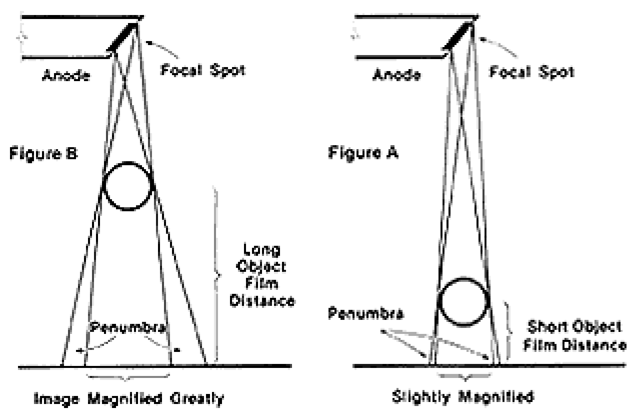
The final aspect of the image we must talk about is detail. Think about it, you can have a properly exposed radiograph (i.e. it is not too dark or too light) with an appropriate scale of contrast (i.e. there is an appropriate gray scale) but if it is blurry you couldn't diagnose a thing. When making a radiograph, attention must be made to ensure that there is optimal radiographic detail. There are a number of factors that affect detail. These are:

1. Focal Spot Size: In a previous lecture we talked about how a smaller focal spot was required to improve image detail. (Remember the flashlight analogy? The rotating anode?)





2. Location of the object relative to the film. This is known as the **object film distance**. Basically, the closer the object is to the film the better. Think of it this way…let's say that you shine a flashlight against the wall and put your hand in the light beam. If your hand is close to the wall, the edges of your hand are easy to discern. Conversely, if you put your hand somewhere between the light and the wall, the edges of the shadow of your hand will be blurry. You may also note that the size of the shadow of your hand gets bigger as your hand gets further form the wall. In radiography, this is important because objects that are farther from the film will be magnified to a greater degree than objects closer to the film.



3. Location of the film relative to the x-ray tube. This is known as the **focal film distance.** Basically, the closer the film is to the x-ray tube, the more magnification and loss of detail there is. Back to the flashlight…let's say that you put your hand 5 inches away from the wall and shine a flashlight on your hand. A you move the flashlight farther and farther away the image of your hand gets sharper and sharper. Conversely, as you move the flashlight closer and closer, the image of your hand becomes larger and blurrier. As far as radiography goes, focal film distance of less than thirty inches results in significant magnification. In general, the tube is places 40 inches from the film. In the figure below, penumbra represents the margin of the object. A large penumbra means it is blurry.

Figure C

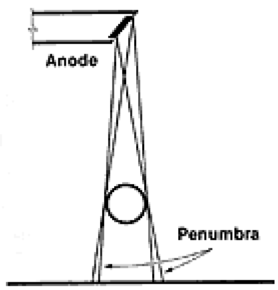
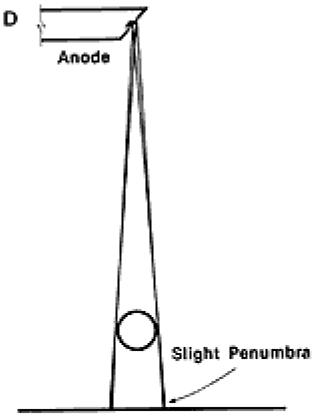


Figure D



4. **Motion unsharpness**: This one is a no brainer. If you move either the patient or the cassette there will be motion blur.

5. **Distortion:** Distortion results from the unequal magnification of different parts of the same object. I am out of analogies and who knows they maybe confusing you more than anything else at this point. So, look at the two pictures below to see how object placement and orientation relative to the x-ray beam can affect the appearance of the object in the final image.

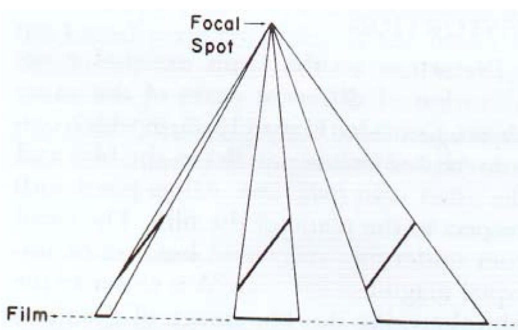


Figure 15–6 Distortion of the shape and size of the image of a tilted object depends on the position of the object in the x-ray beam

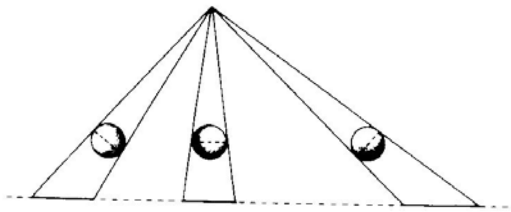


Figure 15–7 The size and shape of the image of a spherical object depends on the position of the object in relation to the central part of the x-ray beam

6. **Intensifying Screens**: We talked about this one before. Remember, faster screens have less detail. There is always a tradeoff between detail and screen speed.
7. **Scatter:** Our nemesis wields it's ugly head again. Scatter causes a loss of detail. Always collimate and use grids appropriately.
8. **Film:** Remember, some film can produce crisper images than others.