Dynamic Chiropractic

X-RAY / IMAGING / MRI

Check Your Physics

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I recently needed to brush up on my x-ray physics to teach a course to x-ray chiropractic radiographic technologists. Upon reviewing this topic with the course participants, I realized from their questions that many of their employers also needed to review their x-ray physics.

Let me give you an example of some of their comments:

• "We always use 200 mA and change the kVp even though we have 300 mA capabilities."

• "We are not allowed to tilt the x-ray tube."

• "We use a technique chart that I think he got from an x-ray salesperson."

• "We have a tube rating chart, but we are always going over the limit when we take lateral lumbars."

• "We don't really have a technique chart."

• "We only change the processor's chemistry once every couple of months."

If any of these questions/comments raise a question for you, read on. If not, jump to the end and just read the summary.

There are basically three factors we can control to obtain an x-ray: the mA, the kVp, and time. I'd like to discuss mA and time together. One ampere is equal to one coulomb/sec, where one coulomb is equal to a specific number of electrons. Amperage then refers to the number of electrons passing a fixed point in one second. The prefix "milli" means one one-thousandth, so milliampere refers to 1/1000 of an ampere.

The designation "s" stands for seconds. Therefore, mAs means the rate of flow of electrons for a preselected time. For example, 100 mA means that 100 x 1/1000 (or .1) of a coulomb will pass a given point in one second.

The mAs also mean mA x time (seconds). We can arrive at specific mAs value with various combinations of mA and s. For example, to get 100 mAs, we can use the following: 100 mA for one second; 200 mA for 1/2 second; or 300 mA for 1/3 of a second. The mAs control the number of electrons produced at the cathode, and subsequently the number of x-rays produced at the anode. The mAs control the quantitative character of the exposure factors.

The mAs have a direct and linear relationship to intensity. If we double the mAs, we will double the beam intensity, providing all other factors remain the same. The beam intensity directly affects the film density, therefore, mAs have a direct and linear effect on the film density. The film density relates to the total darkness or lightness of the film. The kVp or kilovoltage peak is the other factor we can control to obtain an x-ray. A volt is defined as a unit of electrical force needed to move one ampere through a resistance of one ohm.

Kilo means 1,000, so kilovoltage refers to a thousands volts. The "p" stands for peak, therefore, kVp means kilovoltage peak. Peak denotes the highest voltage attained in a given electrical alternating current. The kVp is the factor which controls the energy of the electrons as they move across the tube, or the speed of the electrons. The higher the kVp, the greater the energy/speed of the electrons and therefore the greater the impact of the electrons with the target or anode.

It follows that higher energy electrons produce higher energy x-rays. Scientifically speaking, high energy photons or x-rays mean short wavelength photons. The shorter the wavelength, the higher the energy, for the wavelength and the easier it becomes to pass through matter. This is referred to as penetration. The greater the kVp, the greater the penetration. By controlling the energy of the x-ray beam, kVp controls the quality of the beam.

Unfortunately, kVp is not as easy to work with clinically as far as controlling the beam intensity. While both mAs and kVp directly affect beam intensity, kVp has a direct and exponential relationship. If we wanted to double the intensity using kVp, we would not double the kVp but increase it by an amount determined by an equation in which beam intensity varies approximately according to the 2.3 power of kVp. You'll need a chart to figure it out, so it is much easier to use mAs to change the density since it has a linear relationship.

Now let's talk about film density and film contrast. First, let's discuss film density. For this discussion, we are going to define film density as blackness of the film. The blacker the film, the more density it has.

Both kVp and mAs have a direct affect on film density. The mAs have a linear relationship to film density; kVP has an exponential relationship. It is hard to predict accurately and easily how much change the kVp will affect the change in density. In general, approximately 5% change in kVp will affect the density; therefore this allows for a small margin of error. With mAs, the relationship is linear. There also generally needs to be a 20-30% change in mAs to be discernable on the radiograph. For example, if we take a radiograph and feel that the contrast is adequate, but the density is about half what it should be, then we can easily correct this by doubling the mAs.

If we define density as the blackness of the film, contrast is defined as the difference between the blackest part and the whitest part of the film. A film that is of high contrast is one in which parts of the film are either white or black, with very few shades in between. A low contrast film is one in which there is not that great a difference between the black parts and white parts and there are many shades of gray.

The difference between how black the black is and how white the white is, is termed contrast. The number of shades in between the blackest black and the whitest white is termed scale. If there are many shades between black and white, it is termed a long scale; if there are fewer shades between black and white, it is termed a short scale. Therefore, a high contrast film is one with a short scale, and a low contrast film is one with a long scale.

Film density is affected by both mAs and kVp, but film contrast is also affected, mainly by kVp. One could go as far as to say clinically that if we wish to affect the contrast, we should only be concerned with the kVp.

The higher the kVp, the lower the contrast, but the longer the scale of contrast. For example, PA chest views are taken at 110 kVp to demonstrate subtle differences between the soft tissues of the lungs. A thoracic view is taken at 80 kVp to shorten the scale of contrast and demonstrate the osseous structures. This is where the 16-20% rule comes into play.

Suppose we have taken a radiograph and wish to change the factors but maintain the same beam intensity. The 16-20% rule allows us to do that. This rule states that to maintain the same beam intensity, we can:

• increase the kVp by 20% and reduce the mAs by 1/2; or

• decrease the kVp by 16% and double the mAs.

With the first change in technique, increasing the kVp and decreasing the mAs, we will decrease the contrast and lengthen the scale of contrast; in the second, we will increase the contrast and shorten the scale of contrast while keeping the same film density.

That's enough physics for today. I hope this little review helps you take the quality of films you want. Just to summarize what we have been discussing:

mAs

• control the number of x-rays produced;
• mAs = mA x s (time);
• mAs have a direct and linear relationship to the x-ray beam intensity and hence film density.

kVp

• kVp means kilovoltage peak and controls the energy of the photons, hence the energy of the x-rays;
• kVp has a direct but exponential relationship to beam intensity and hence film density.

Density and Contrast

• film density is film blackness;
• mAs are used to control film density;
• film contrast is the relative difference between the black and white on the film;
• kVp is used to control film contrast;
• use the 16-20% rule to control the contrast.

References

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