50 things working correctly are required to produce a quality radiographic image

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1. Incoming Power - Electricity that most of us are familiar with and use daily for lighting, computers, refrigerators and other household appliances is 120 Volts alternating current (vac). Your large appliances such as range/oven, hot water heaters and air conditioners use 220V. The current which flows in the wires alternates its direction through the wires 60 times per second and is called 60hz. This voltage is generated and regulated at your local power company and transmitted over power lines in the millions of volts. The reason for using high voltage at the power company is because of the "loss" in the distribution lines over long distances. The voltage coming into our homes, schools and workplace is reduced to 220 vac by a transformer located on a utility pole nearby. Most hospitals, institutions and factories require 480 volts a/c to operate higher power consumption equipment. An x-ray generator "generally" operates on 220 volts a/c but not all of them, some use 120 volts a/c and others require 480 volts a/c.

2. Voltage regulation - When an x-ray exposure is made it is an "instantaneous surge" of current on the power line and due to the amount of power required to operate x-ray machines the power line voltage regulation is very important and must be adequate to maintain the generator calibration factors. It is critical that the wire size be sufficient to carry the rated amperage of the x-ray generator. X-ray generators also have transformers, which regulate and compensate for the incoming voltage.

3. X-ray generator calibration factors (kVp, mA, time) The front panel of an X-ray generator control has selections for the operator to make which adjust specific electronic selections (techniques) that produce an x-ray and deliver a "dose" of radiation. These selections that control image quality include: kvP, mA, and time.

4. kvP –

k = 1,000

v = Volts - This voltage also called "potential" is a rectified a/c waveform which approaches dc or direct current. Many newer generators now use high frequency rectified a/c which appears as a nearly pure dc waveform. Dc flows in one direction only while a/c alternates both positive and negative.

P = peak (the voltage is measured at the peak of the rectified a/c waveform) General radiography is performed in the ranges of 50 kvP to 120 kvP. The voltage determines the penetrating ability of the x-ray beam. The higher the voltage the greater the penetrating ability. The Federal Regulation 21CFR 1020.31(a)(4) states that the deviation between the value selected on the generator (by the operator) and the actual value measured must not exceed the manufacturers specifications.

5. mA - = milliamperes - This term describes the actual electric current flowing through the x-ray tube during an exposure. It is a DC current and flows in only one direction from cathode (-) to anode (+). X-ray tubes have a maximum "tube rating" for the amount of

current which can safely flow through the x-ray tube without damaging the tube. The Federal Regulation 21CFR 1020.31(a)(4) must be met and requires that the mA (tube current) is linear with respect to image dose mR (millirads) between adjacent mA selections. The allowance means that the adjacent mA stations do not differ by more than .10 times their sum.

6. s - = Time – Another calibration factor is time which is measured in seconds. X-ray exposures vary in length of exposure time due to the thickness of the subject being examined and the amount of detail needed in the image. A millisecond is 1000th of 1 second. Exposures may have a wide range of variation from a few milliseconds to several seconds. This exposure factor "time" is generally combined with the mA exposure factor and together they are called "mAs". The Federal Regulation 21CFR 1031.(a)(4) states that the maximum deviation between the value selected and the value measured must not exceed the manufacturers specifications.

7. X-ray tube - The x-ray "tube" is a specially manufactured "light bulb" or "glass enclosure" which is evacuated. Inside of the glass enclosure is an electric motor called the "rotor". This motor has metal bearings on each end of the armature shaft which rotates. On the end of the armature shaft is a 3" diameter wheel made of tungsten, one of the hardest metals on earth. This round wheel of tungsten is called the "rotating anode". A special smooth surface is machined into the tungsten wheel which creates a "face" (--:\ ) that is angled both toward the "filaments" in the tube and toward the "exit port" in the tube housing. Over time and usage the metal bearings on the armature shaft can become "noisy" and cause the "rotor" to not come up to speed as quickly as it should.

8. Filaments - – Inside the glass enclosure of the x-ray tube, a short distance away from the tungsten anode "face", are the tube filaments. The filaments are a fine tungsten wire coil which "burns" brightly when filament current begins to flow in the filament circuit during the "prep" stage of making an x-ray exposure. Approximately 5 amps of filament current will flow through the filament wire causing it to heat up from a warm red to white hot color and begin "boiling electrons" out of the tungsten wire. This "electron cloud" becomes the ma current that flows from the filament to the face of the tungsten anode and through the high voltage cables and secondary transformer windings when the "primary" high voltage is applied.

9. Focal spot size - Most x-ray tubes are designed with two filaments called small and large (just like low beam and high beam on your car). Focal spot size is "created" on the tungsten anode when the electron "cloud" impinges on the tungsten target face. Focal spot size can change over time from the target material being bombarded with electrons. It is ideal to create x-rays from a "point source" because any increase in source size will result in blurring of the final image. This blurring has its main effect on edges and small objects. The effect of this blurring depends on the geometry of the object and worsens as the distance between the object and the image receptor (film or digital) gets increased. The x-ray tube focal spot can be measured geometrically with a specially designed test object. It can also be measured with a special camera for that purpose. There is no government regulation, which specifies focal spot size requirements other than mammography. Average focal spot sizes are (.3mm x .3mm) to (.7mm x .7mm) small focal spot and (1.0mm x 1.0mm) to (2.0mm x 2.0mm) large focal spot. Mammography focal spot sizes range from (.1mm x .1mm) to (.3mm x .3mm). Mammography uses lower energy x-rays for the area of interest and also uses molybdenum target material and molybdenum filters.

10. Rotor – Prior to making an exposure the rotor button on the x-ray control panel is pressed (prep) which causes the motor to run inside of the x-ray tube and spin the tungsten

anode. The reason for spinning the tungsten anode is to provide cooling of the tungsten metal during the exposure by creating a constantly changing "face" for the "impinging electrons" to slam into. This constantly changing face is called the "focal spot" or "point source". This rotor circuit prevents the high voltage from being applied until the electric motor (rotor) which is turning the tungsten anode gets to a specified r.p.m. The r.p.m. for low speed is 3,000 and high speed is 10,000 r.p.m.'s.

11. Space Charge – This electronic circuit in the generator control generally "adds to" or "subtracts from" the filament current (electron cloud) depending on the kvP selected. Space Charge regulates the initial surge of "boiling electrons" at the instant the x-ray button is pressed.

12. X-ray energy – The x-ray button on the operator control panel is pressed causing an electrical contactor to close which allows 50,000(50kVp) to 120,000(120kVp) volts of electric potential to be applied between the filament (-) and the rotating anode (+). This high voltage causes the "boiling electrons" around the focused filament to be attracted to the rotating anode face with such force that the filament electrons actually knock other electrons in the tungsten "target" out of their quite peaceful and stable orbits. During this period of instability, "x-ray photons" of energy (Characteristic radiation) are generated. Other x-ray photons are created by "a change from the higher level of energy back to the lower level of energy" when the tungsten atom electrons return to their stable orbits (Bremmstralung radiation). Medical x-rays are in the energy spectrum above visible light beginning at 3 X 10`16 Hz and before gamma wave particles at 10`19 Hz. Medical x-rays are "ionizing radiation" and cause a chemical change to take place in human tissues due to their interactions with the cells. Low energy x-rays are undesirable because they increase radiation dose to the patient by absorption but do not contribute to the final image. Low energy x-rays are almost totally absorbed in the body. The number of low-energy x-rays is usually reduced by use of a layer of absorber (aluminum) called a "filter" which absorbs the low energy x-rays. "There is no harmless dose of ionizing radiation with respect to radiation mutagenesis and carcinogenesis" --- a conclusion supported in 1995 by a government – funded radiation committee. "[1]

13. Half-Value Layer - Also called "half-value thickness" and or "beam quality" is the amount of aluminum that will cause a specified "dose" of radiation energy to be cut in half. A diagnostic x-ray beam produces a range or spectrum of x-ray energies and the half-value layer provides important information about the energy characteristics of the x-ray beam. Basically, if the half-value layer for a given x-ray beam is low, then the x-ray beam contains more low energy and less penetrating radiation. This low energy "ionizing radiation" will be absorbed by the patient and does not contribute to the final image.

14. Filters - Adding aluminum "filtration" to the exit port of the x-ray tube by the manufacturer will cause the undesirable low-energy x-rays to be absorbed in the aluminum while allowing the desirable higher-energy x-rays to pass through the aluminum and the patient to the "image receptor" (film or digital detector assembly). On the other hand, if there is too much filtration in the beam, the energy becomes too high, and there is a loss of contrast in the x-ray image. Filtration can be physically added or taken out. Filtration can also increase in a x-ray tube. Over a period of time, particles of tungsten resulting from the bombardment of the anode settle on the tubes exit port. X-ray tube assemblies are required by Federal Regulation 21CFR 1020.30(m) to have a minimum half-value layer of .5 mmAl (millimeters of Aluminum) below 50kVp, 1.5 mmAl at 50-70kVp, and 2.5 mmAl above 70kVp in the exit port of the tube. X-ray tube half-value layers also are used to determine the amount of shielding in walls for protection from ionizing radiation to workers and the public within the x-ray department.9 A x-ray tube half value layer can be measured with a radiation dosimeter

and placing thin (.5 mm) sheets of aluminum in the beam which reduce the initial measured dose by one-half.

15. Dose – An amount of ionizing radiation measured in Sieverts Sv. An average adult male chest x-ray is…. ? Sv, abdomen / Sv……Background radiation from the sun, radon gas in the earth and all other sources is ……… In January 2007, The National Toxicology Program (NTP) released its 11th Report on Carcinogens, a biennial list of the latest cancer hazards. Ionizing radiation was included as a type of radiation that causes cell damage by depositing high energy in body tissue. Christopher Portier,PhD, associate director of the NTP says "The lesson with ionizing and ultraviolet radiation comes down to the dose. It's the amount and magnitude and frequency. Those are the things that will kill you".

16. Exit port – Also called "exit window" where the x-ray photons of energy exit the x-ray tube and enter the collimator.

17. Collimator - A collimator is a lead-lined mechanical device which is attached to the exit "port" or "exit window" of the x-ray tube. As described previously, the x-ray photons of energy "go everywhere" they are allowed to go after crashing into the tungsten target. The major photon "beam" direction created at the "point source" or "focal spot" on the tungsten target face is 90° with respect to the "rotor" shaft. The collimator contains four (4) lead blades adjusted by the operator with longitudinal and transverse knobs on the collimator. This is used to adjust the "field size" of the x-ray image. The rest of the collimator is lined with lead to absorb all other "stray radiation". A light with a radiopaque mirror is built into the collimator, which indicates to the operator the "x-ray field" size. Federal Regulation CFR 1020.31(e)(2)(ii) states field size accuracy requirements for collimators light field to x-ray field congruency and center alignment, should be no greater than 2% of the source to image distance.

18. Lead - Symbol Pb, lead has the highest atomic number of all the stable elements and has the ability to absorb high energy x-ray photons.

19. Useful beam – This term is used to describe the beam of x-ray photons that are emitted from the collimator assembly during an exposure and produce the x-ray image.

20. Techniques - "Techniques" are settings used to make the image which include kVp, mA, time, distance and position or angles of the anatomical structure being examined.

21. Technique charts should be generated by the operator of a x-ray machine, which shows the settings of that machine which will produce the best image at the lowest possible dose for the size of patient anatomy being examined.

22. Anatomical Programming - New technology x-ray controls have lighted buttons which resemble little people on them. There is a button with a small size person, a button with an average size person, a button with a large size person and maybe a button that says lighter / darker. These buttons cause the ma and time to be set by a programmed function of the buttons without any knowledge required of what selection makes the best image. Generally, the highest ma that the tube will allow and the shortest time, which creates the "dose" needed for that size person, is programmed into the generator control. Normally the kvP still needs to be selected by the operator and depends on the thickness of the area being radiographed.

23. Source to Image distance – "SID" is the distance from the "focal spot" on the tungsten anode to the "image receptor". The SID is selected by the operator for each exposure

determined by the anatomy that requires examination. Standard SID's are set at 40" (102cm) and 72" (182cm) for common radiographic techniques. The Federal Regulation 21CFR 1020.31 (e) (1) states that the indicated source to image distance must be within 2% of the actual source to image distance when the equipment indicates that the beam is perpendicular to the plane of the image receptor. SID affects "blurring" of images due to geometry. This can be demonstrated by using a flashlight and a small object. Place a small object about 6" away from a wall and shine the flashlight on the object. The closer the flashlight is to the object, the more blurred the image shadow projected on the wall will be. This is because the light has a "point source" or "focal spot" which is the bulb filament and projects light from the entire area of the bulb. The area of "unsharpness" on the wall is called the "penumbra".

24. Image receptor - An "image receptor" can be a film cassette placed under the patient on top of the table. It can also be a film cassette placed under the patient under the table in a "reciprocating bucky". It can also be a digital detector assembly, which is also under or behind the patient.

25. Subject size - The size of the patient or the anatomy being examined also plays into the ability to make a quality radiograph. The x-ray photons travel through the anatomy interacting with matter causing other interactions, which scatter the original source photons and cause further blurring of the image. To help correct this scattering, a type of "polarized lens" called a "grid" is used to allow only the photons which are traveling in a straight line, after passing through the patient, to create the image on the film or image receptor.

26. Grid – If you understand how polarized sunglasses work, this is the way a grid works with x-ray photons. A grid is made of thin strips of aluminum which are laminated together and form a large plate which is normally the size of the image receptor being used. The aluminum absorbs the "stray x-ray photons" that are not traveling parallel from source to image. These "stray or unparalleled photons" will cause blurring of the image. Using the grid means that more radiation is required to produce the image details. The grid is placed behind the patient and in front of the film or CR imaging plate.

27. Reciprocating bucky- The grid is mounted in a "reciprocating bucky" which is a device that moves the grid side to side during an exposure. The grid must be moved during the exposure or the thin strips of aluminum in the grid will show up in the image called "grid lines".

28. Operator - The operator of an x-ray machine has the responsibility to ensure that the images are acquired with radiation exposure to the patient "as low as reasonably achievable". Some states require that x-ray operators are "registered radiological technologists" RT(R). North Carolina requires that operators take a minimum number of hours of training from an approved training school.

29. Positioning - Positions are unlimited, due to the multitude of possible exams of parts of anatomy. Lead aprons are hopefully placed on critical areas of anatomy which are not to be receiving exposure.

30. Movement - Moving during an exposure will cause blurring of the image and may cause a "retake" which is additional radiation dose to the patient. Of course even though you can "hold your breath", you can not stop your heart from beating or the blood from rushing through your veins.

31. Automatic Exposure Control Ion Chambers – Some x-ray machines have an electronic device which detects a specified amount of radiation that has reached the "image receptor"

and terminates the exposure at that time. This can have an effect of reducing patient exposure due to improper operator techniques.

32. Image receptor - Image receptors are devices in which the image is created. The predominate image receptor in the general practitioner, podiatrist and chiropractors office is an x-ray cassette and x-ray film. Digital image receptors have been created in the past fifteen years, which eliminate the film and cassette and also the film processor. Most digital or "filmless" systems are being used in hospitals, specialty radiology clinics and dental offices.

33. Cassette / Screens* - the x-ray film is placed inside a x-ray cassette in the darkroom. This keeps the film from being exposed to "white light" in the x-ray room where the patient is. The cassette is placed behind or below the patients anatomy to be examined. The x-ray tube produces the "primary beam" which goes through the patient, through the table, through the automatic exposure control ion chamber, through the grid, the bucky, the cassette and strikes the "screens" and film inside the cassette. Today, "screens" are manufactured with phosphor crystals embedded called "rare earth" and the phosphor crystal emits green light when it is struck by a x-ray photon. The phosphor crystals produce individual microscopic "points of light". These points of light "draw" a "latent image" on the x-ray film by causing the silver halide crystals in the film, which are struck by the phosphor light to be "activated" or "switched on". The size of the "points of light" in the screens phosphor in combination with the size of the silver halide crystals in the film emulsion determine a "systems" (film/screen combination) "speed".

34. X-ray film* - There are probably as many different types of x-ray film as there are types of cars on the road. They all have some basic similarities that they begin with a "film substrate" or "base" which is a clear or blue tinted polyethylene terephthalate sheet. These sheets are cut into standard sizes. Medical x-ray films standard sizes are 14" X 17", 11" X 14", 10" X 12"and 8" X 10". Some are in metric sizes and measured in centimeters. The films base is coated with a microscopic "emulsion" of silver halide crystals (1,000,000 per sq. inch) which are designed to be sensitive to either "green" (550nm wavelength) or "blue" (560nm wavelength) light. 14

35. Film Speed - The physical size of the silver halide crystals in the "emulsion" determine the films "speed". The smaller the crystals in the emulsion the lower the speed number. Speed is represented by a numbering system in medical films from 50 to 800. A "green" sensitive x-ray film is used with "green" phosphor light emitting "screens".

36. Darkroom – The darkroom is a "light tight" area for handling photographic films.

37. Safelighting – A "safelight" is a light fixture with a filtering lens in front. The lenses which are used allow light to pass that will not affect the film emulsion but allow the operator to see what they are doing in the darkroom. A number of different lenses are used depending on the type of film being processed in that department.

38. Base Fog – The term "base fog" is used to describe unwanted light exposure to the film emulsion. This "unsafe" light can come from safelight lenses which fade and age with time. The light bulb in the safelight may be too high a wattage for the conditions being used, or is too close to the work surface. Also, light "leaks" can cause "base fog" which is white light coming around the door from the outside or equipment in the darkroom that may produce unwanted light. X-ray film stored improperly or improperly handled or exposed by stray radiation can also cause this. Optimum base-fog density values are .15 to .20D.

39. Film/screen combination Speed* - As mentioned under film, film is manufactured with

different physical sizes of the silver halide crystals. The larger the size of crystal the faster the film speed. As you can imagine, when one point of light from the screen phosphor activates a large halide crystal, the area of darkening per point of light becomes larger, consequently making the image in a shorter period of time. Slow speed films have more crystals per square inch and are called "detail" or "fine" and produce the highest degree of resolution possible. Screens are produced similarly with larger or smaller size phosphor crystals which emit light when struck by an x-ray photon. The screens with the most phosphor crystals per square inch are called "extremity" or "detail" screens. Detail screens in combination with medium speed film produce a relative system speed of 100. The highest degree of resolution is used for extremity studies. General x-ray studies use "regular" or "medium" speed film and "regular" or "medium" cassettes which produce speeds in the 400 to 800 range. X-ray departments don't use different speeds of film, they select one speed to use in the department and then select different speeds of cassettes. Generally only two speeds of cassettes are needed, a regular speed for all general x-ray exams and detail speed for extremities.

40. Manual dip tanks* - An x-ray film can be processed by simply dipping it in a properly heated developer solution for an amount of time in the dark where it is not exposed to any light. After the appropriate amount of time the film is transferred to the fixer tank and dipped again for an appropriate amount of time. The film is finally moved to the "wash" tank and rinsed for a time and "hung up to dry". This procedure produced what was called a "wet film" and still does for some low volume clinics or professional photographers today.

41. Automatic film processor* - Most busy offices left the manual dip tanks long ago for the convenience of a device which processes the films in a series of events "mechanically" and reduces manual labor of processing film. This mechanized process should be thought of rather than "automatic" because the term "automatic" makes operators believe the film processor requires no attention. There needs to be a considerable amount of attention paid to assure that the processor functions in the way the manufacturer intended, as well as maintain the activity of the chemistry at the intended levels.

42. Developer* - When a x-ray film is inserted into the automatic film processor, the first solution tank is the developer tank. The film travels through the developer "rack" or rollers first. The reason for the rollers is to cause the film to stay in the developer solution bath for a specific amount of time. The developer solution is heated to a specific temperature depending on the manufacturer's specifications due to the length of time the film is in the developer solution. The developer reacts with the film emulsion and causes the silver halide crystals, which have been "activated" during the exposure, to change into "black metallic silver".

43. Fixer* - When the film leaves the developer tank it is directed through the fixer tank where all of the silver halide crystals which were not "activated" by any light are washed off of the film substrate leaving the clear base of the film in between the "black silver halide dots".

44. Silver Recovery- The process of "fixing" causes silver particles to remain in the fixer bath. A great many small clinics do not reclaim the silver from fixer solution because it is an additional expense to them. The silver particles therefore end up in their drain pipes and waste water and can create a larger expense later on.

45. Chemistry Mixers – A new automatic film processor comes with storage or holding tanks for the developer and fixer (chemistry) to be mixed in and stored ready for replenishment. The holding tanks are marked in liters and/or gallons. A "mix" of chemistry

comes undiluted in two parts as described above. When the two parts are mixed together, water is added until the "mix" volume is 5 gallons. Automatic chemistry mixers are available which automatically add water to the concentrated parts until the correct specific gravity is obtained. This is the most accurate and mistake proof method of mixing the chemistry for automatic film processing. Unfortunately, many small clinics can not afford an automatic chemistry mixer and must rely on the operator to manually mix the chemicals.

46. Replenishment rates* - When the films go through these developer and fixer baths they carry the chemicals with them from one tank to the next. A pair of "squeegee" rollers are placed in the rear of each rack to attempt to save the chemicals that adhere to the film however, more chemicals must be added to "replenish" some chemistry after each film. A "replenishment switch" is activated as the film is inserted into the entrance rollers of the developer rack. This switch runs a pump and allows adjustment of the replenishment rates, which are based upon "usage". There are maximum and minimum working ranges. Less than 50 ft^2 of film/day = ~ 60 cc / film. More than 150 ft^2 of film/day = ~ 32 cc / film. A good technician can adjust, over time, the minimum amount of chemistry replenishment needed to produce quality films consistently without wasting chemicals.

47. Wash water* - When the film leaves the fixer bath it is directed through the water bath where clean water is constantly running through and down the drain. The water washes off all of the chemicals used in the developing and fixing process. The wash water tank is a good place for algae or "bioslime" to form if the tank is not drained daily after use.

48. Dryer* - After the wash, the film is directed through the dryer where heat and blowing air are directed across the film to dry it for reading by the physician.

49. Digitizers – The medical imaging industry is quickly becoming "filmless". The idea is to replace traditional film radiography to improve work flow and to enhance productivity. For example, hospital technicians can simply position a patient, take an image and check it in a matter of seconds to determine immediately whether the image is valid or requires a retake.

50. Digital detectors– Digital detectors are replacing the film screen systems. The only difference between a CR digital system and a film/screen system is the detector or "image receptor". Computer software has replaced the film/screen combination and film processor. Some large hospitals are completely "filmless". The United Kingdom has already begun a $10.6 billion National Programme for IT initiative in their Department of Health to convert all 178 of its "acute trusts" (radiology sites) to digital imaging by 2007. So digital is here to stay and will eventually replace all film/screen imaging for medical x-rays. There are as many types of digital systems as there are types of cars on the road. Presently, in 2007, two technologies dominate the market, CR (Computed Radiography) and DR (Digital Radiography).

51. CR - Computed Radiography was the first generation of digital system and still uses a type of phosphor screen as in film technology, however this screen has the ability to "store" an image temporarily. The screen is inside a type of cassette like a film cassette and placed behind the patient in the table bucky just like a film. The screen in the cassette gets charged from the the x-ray photons striking the screen phosphor. However, instead of having millions of silver halide crystals per square inch like on film, the digital detector has 10,000 "points" per square inch (called "voxels". The points charge up to different values depending on the amount of photon energy that struck the phosphor area. Now, the points used for "drawing" the image are larger but have levels of gray instead of black and white (like the silver halide crystals switching to black metallic silver). The cassette is placed in an electronic "reader" which evaluates the amount of stored energy in each energy point

and converts these energy levels to pixel data. Since the points mounted in the cassette have some empty space in between them, the manufacturer uses computer software to make up the information in the empty spaces so that images can be made larger, zoomed in on, change contrast and brightness. Any questions?

52. DR – Digital Radiography acquires the image similarly to CR but in a fixed detector assembly instead of one that has to be transported to a reader. New systems are being created every month which do it better and faster.

53. Software – Digital imaging is highly dependent on computer software. Let's go back to the x-ray film, which has microscopic grains of silver halide crystals in the film emulsion. The image on the film is "drawn" by making microscopic "dots" on the film (activated silver halide crystals converted to black metallic silver in the developer). In a digital system, the detector assembly consists of different technologies, most at present using a "charged coupled device" CCD which is a miniature electronic storage medium which is small, but not microscopic. The CCD receives it's "light" from a phosphor screen just like an x-ray film does.15 A typical detector assembly which has to cover a standard size of 14" X 17" both laterally and transverse directions may have 1000 X 1000 detector elements. Let's call these detector elements "dexels". So for a 17" area there would be 58.8 dexels per inch or 3460 per sq. in. (This area is changing rapidly so what is written now will be out of date by the time the project is completed.) Each dexel however is allowed to change in shades of gray (clear to black) possibly 264 or even 1024 levels of gray for each dexel. The level of gray of each dexel is determined by the amount of photon energy received during the x-ray exposure of the image (and the software or computer memory, storage and speed capabilities). The dexels are arranged in an assembly to provide the most compact area possible, however there are lots of microscopic "space" between the individual dexels. To demonstrate this, take a magnifying glass and hold it up to your computer monitor. See the "pixels" (picture elements) in your computer monitor. With a good enough magnifier you may be able to count the number of pixels per inch. A high resolution monitor will have 1200 pixels by 1000. In medical imaging 2000 x 1600 would be considered 3.2 megapixels. There are monitors with 5 megapixels available today. Remember, this value of pixels has to cover the entire viewing area. So the larger the monitor screen, the lower the resolution, unless you add more pixel data with more computer software and faster speed computations. Remember X-ray films are 14" X 17" with over 10 million silver halide crystals per square inch.

54. Post Processing images - The blank spaces between the dexels in a digital detector has to be "interpreted" by the computer software. That means they "make it up" or "create image data that isn't there". The spaces of missing information are "interpolated" by the computer software algorithm. Digital imaging allows a physician or radiologic technologist to "enhance" the images by what is called "windowing" or "leveling" which is the ability to adjust the contrast, brightness and gray scale of the image for what they believe is good quality to the "trained eye".

55. ROI – Digital images can be "zoomed" in on a particular region of interest (ROI). Each manufacturer of digital systems creates their own proprietary software which performs these functions in lots of different ways, as a matter of fact due to copyright laws one manufacturer can't make their software the same as another or they get sued. The software alone makes up 80% of the cost of a digital system.12

56. POI – (Pixels Of Interest) Digital x-ray imagers

56. PACS –(Picture Archiving and Communication System) – Once you have a digital image you can do all sorts of stuff with it. And they are. Images are archived or stored,

compressed, decompressed, written to removable media like tapes, CD's, laser printers, monitors. Medical imaging use an industry recognized acronym PACS. Images are created in the x-ray room, stored on the computer, manipulated into a patient file, a LAN (local area network) is distributed throughout the imaging department where all of the radiologists and attending physicians can pull patient images up on their view stations and read them. For referral consultations, images can be "e-mailed" to other physicians anywhere in the world. And they do that too. If you are familiar with the internet, it has something called a "bandwidth" which affects image compression and decompression, but all these things are being made better as we speak.

57. Viewboxes – Of course films must be "read" or interpreted by the physician also. The x-ray film is placed on a lighted viewbox and the light from behind the x-ray film shines through the spaces where the unexposed silver halide crystals have been removed by the fixer solution. The light shines directly into the doctors eyeballs. The doctor may even pick up a magnifying glass to see something really small in the film image. Doctors viewing digital images don't have to use a magnifying glass any longer, they just hit a "zoom" button on the dash board and the picture gets larger. We already discussed how the picture gets larger, didn't we? (Right, computer software)

58. Viewing Monitors – Viewing monitors are used in digital imaging and are being made bigger and better every year. The thing to keep in mind here with digital is that when an image leaves the hospital, by CD or by the web, images are being viewed by another physician who may not have the latest and greatest monitor like the hospital does.

59. Doctor's eyes - One of the final elements in the imaging chain is the doctor's eyes and eye glasses.

60. Doctor's brain - The final element in the imaging chain is the doctor's brain which includes experience, training and personal idiosyncrasies.