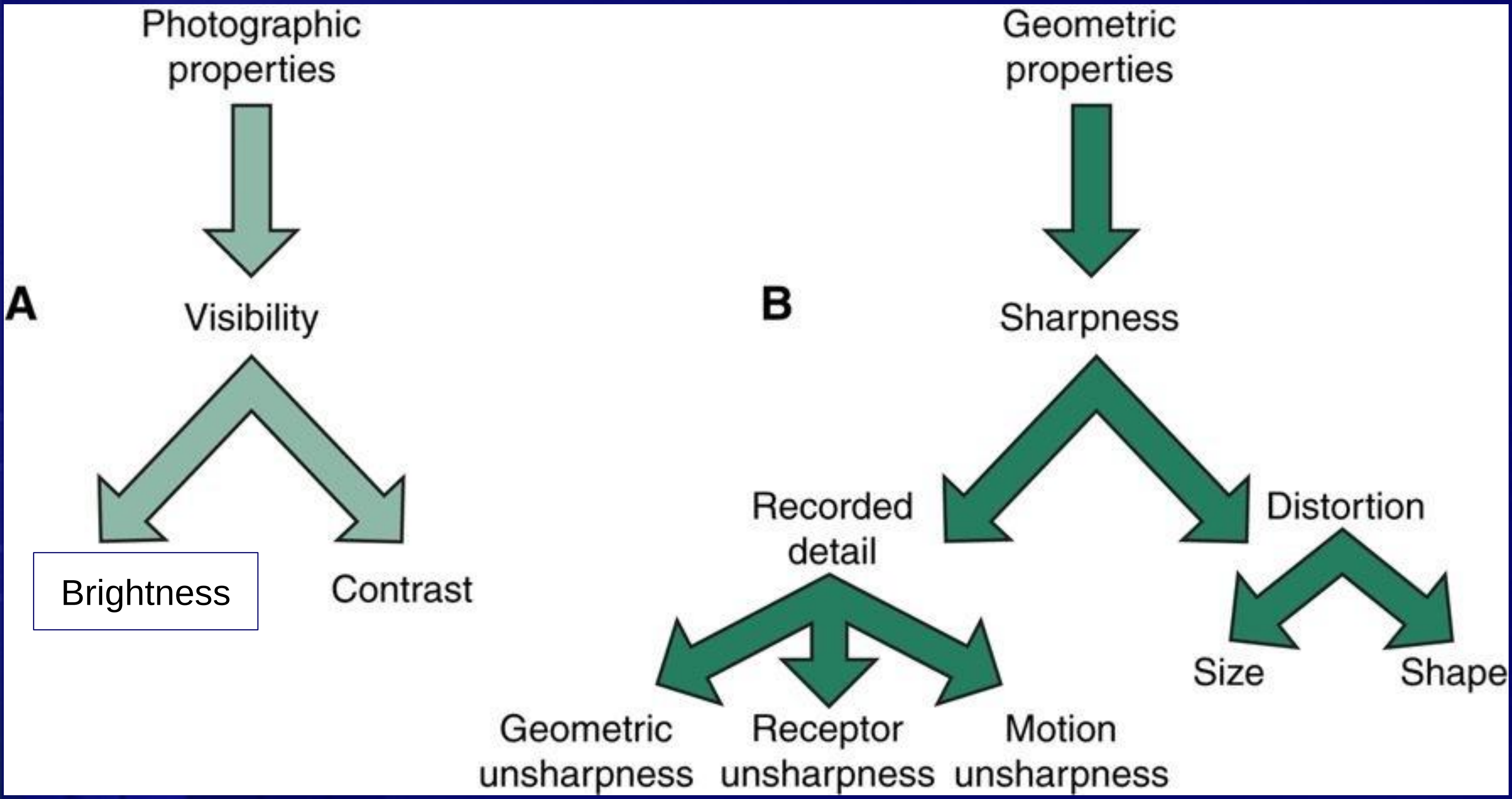
Geometric Unsharpness

By Prof. Jarek Stelmark

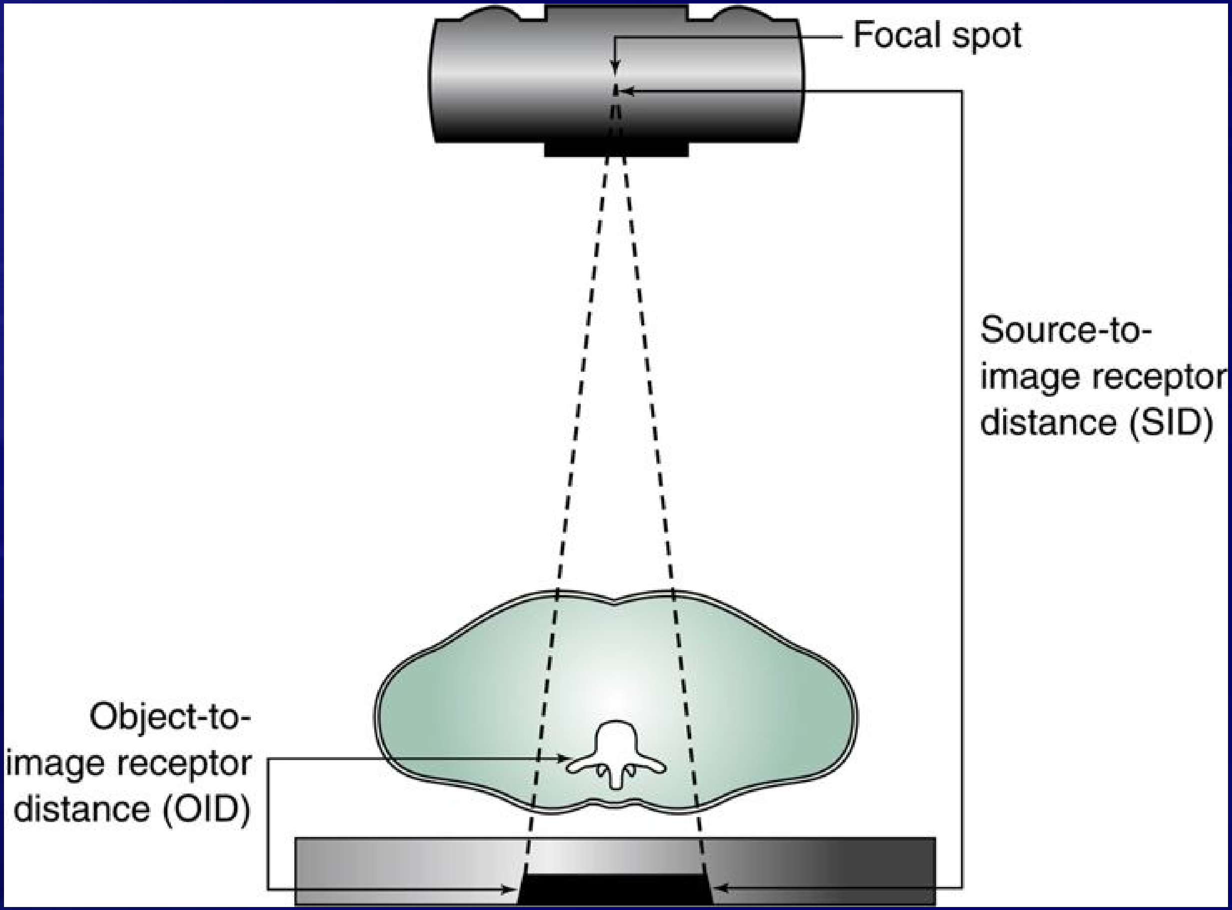
Geometric Properties (Sharpness)

The geometric properties of a film-screen image refer to the sharpness of structural lines recorded in the radiographic image. A radiographic image cannot be an exact reconstruction of the anatomic structure. Some information is always lost during the process of image formation. It is the radiographer's responsibility to minimize the amount of information lost by accurately manipulating the factors that affect the sharpness of the recorded image. Optimal geometric quality is achieved by maximizing the amount of recorded detail and minimizing the amount of image distortion

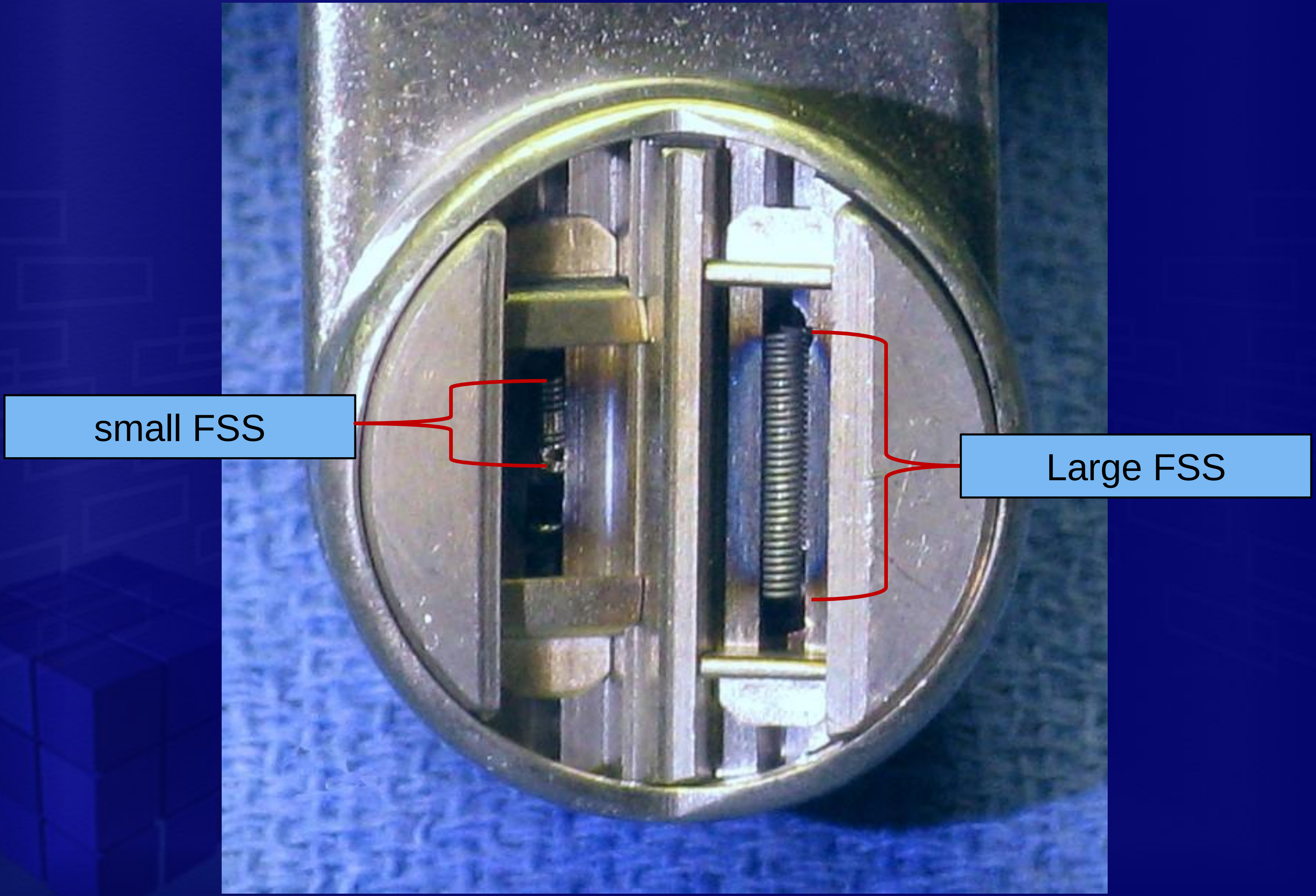

Photographic properties
A
Visibility
Brightness
Contrast
Geometric properties
B
Sharpness
Recorded detail
Distortion
Geometric unsharpness
Receptor unsharpness
Motion unsharpness
Size
Shape

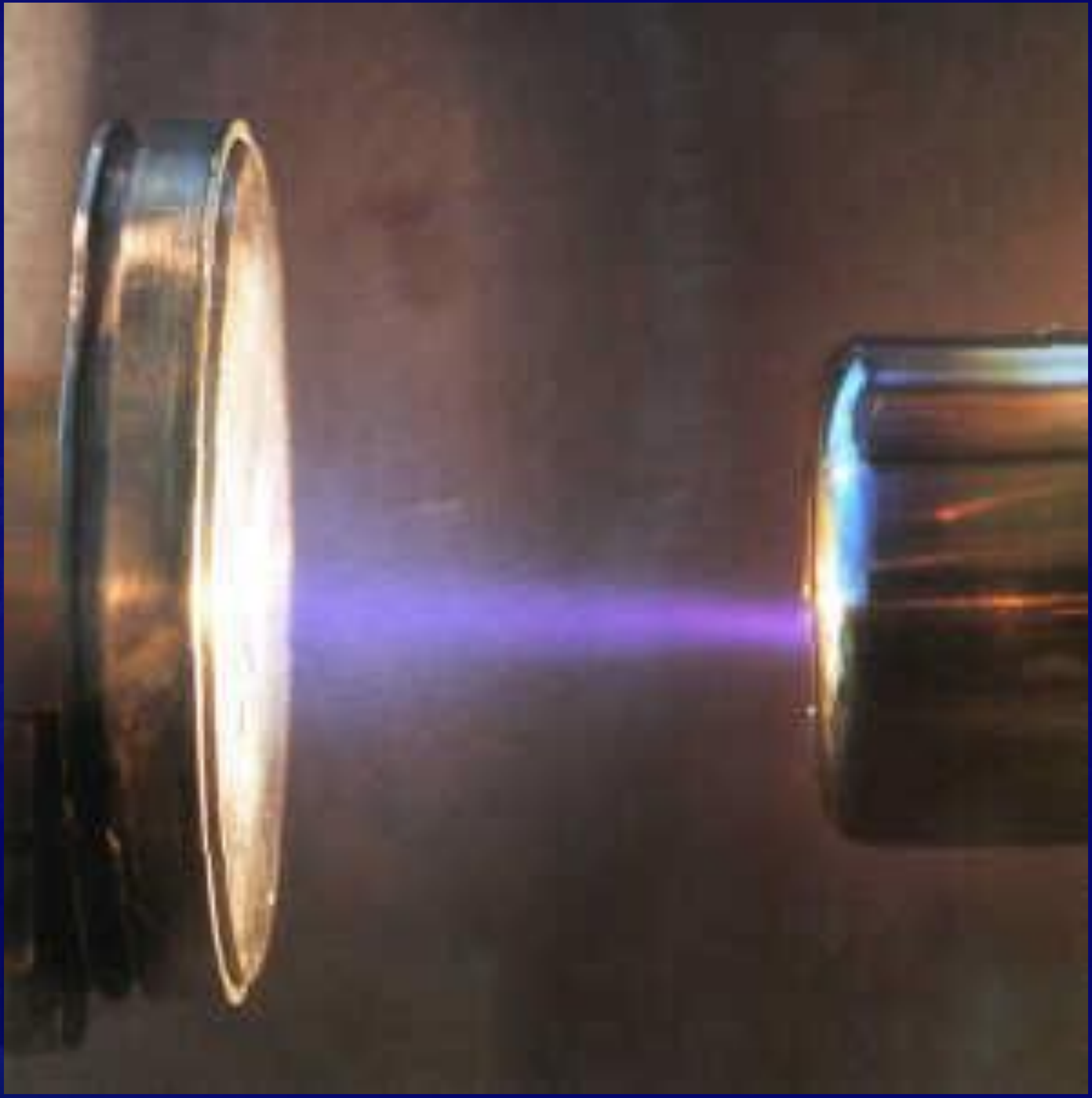
GEOMETRIC UNSHARPNESS

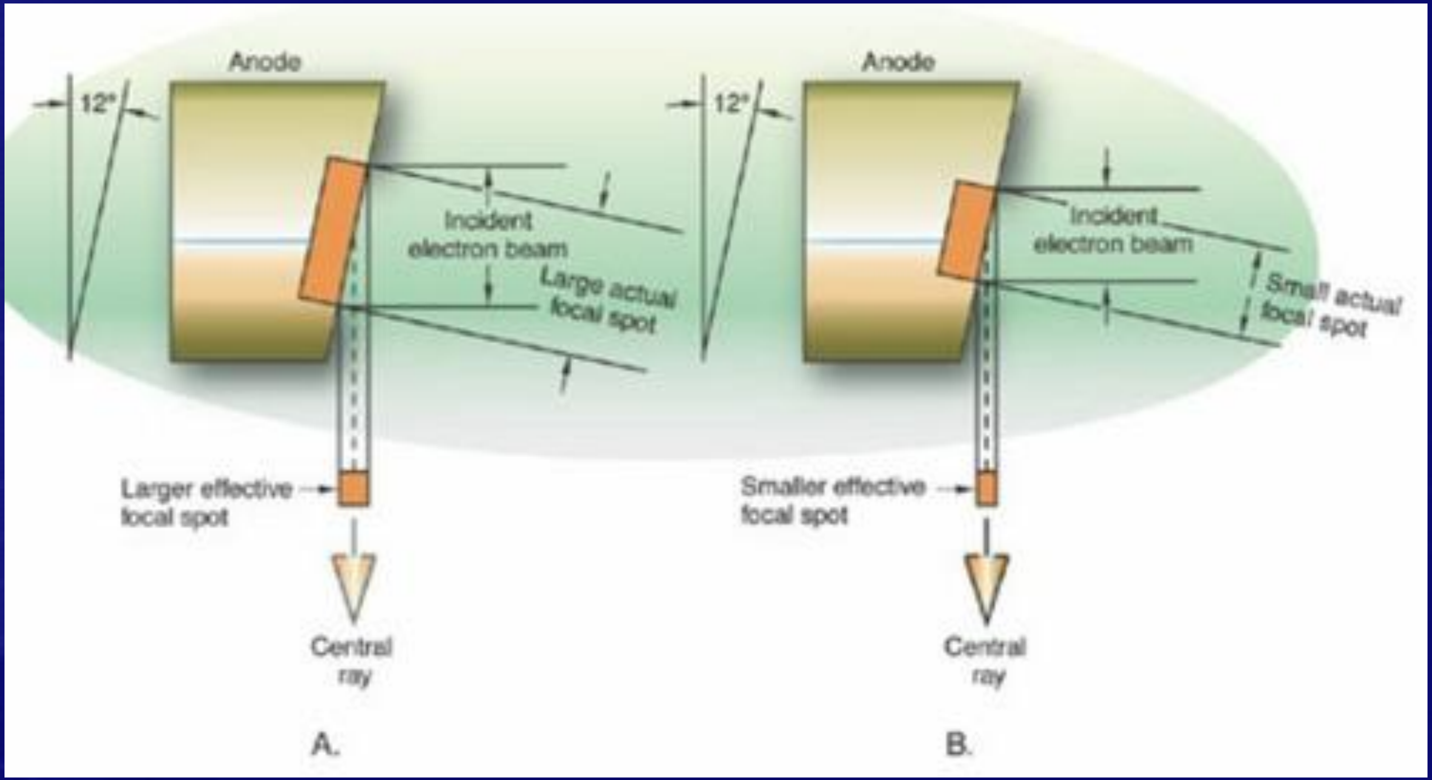
The amount of geometric unsharpness is a result of the relationship among the size of the focal spot, SID, and OID.



Focal spot size = Dimensions of the nominal focal spot in millimeters (mm)

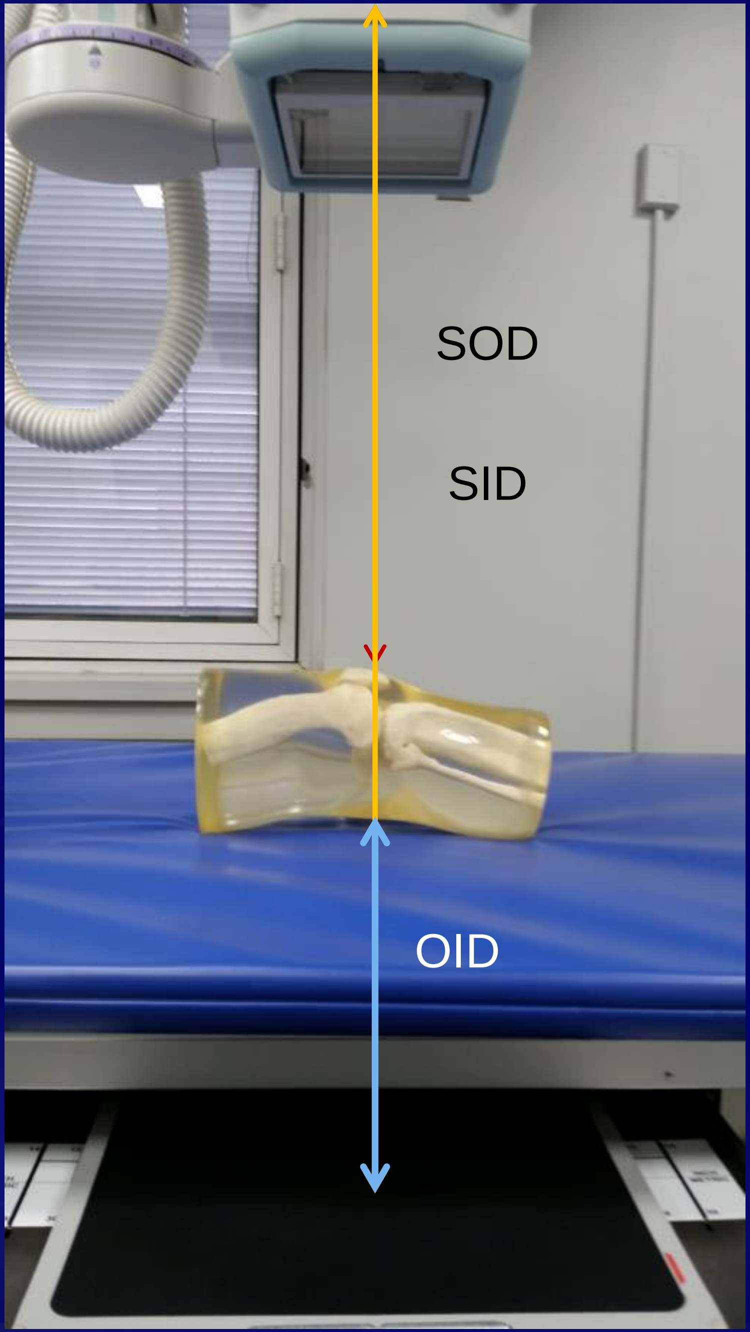






Anode
12°
Incident
electron beam
Large actual
focal spot
Larger effective
focal spot
Central
ray
A.
Anode
12°
Incident
electron beam
Small actual
focal spot
Smaller effective
focal spot
Central
ray
B.


OID	= The distance between the object (area of interest) and the image receptor
SOD	= The distance between the focal spot (source) and object (area of interest)
SOD	= SID−OID

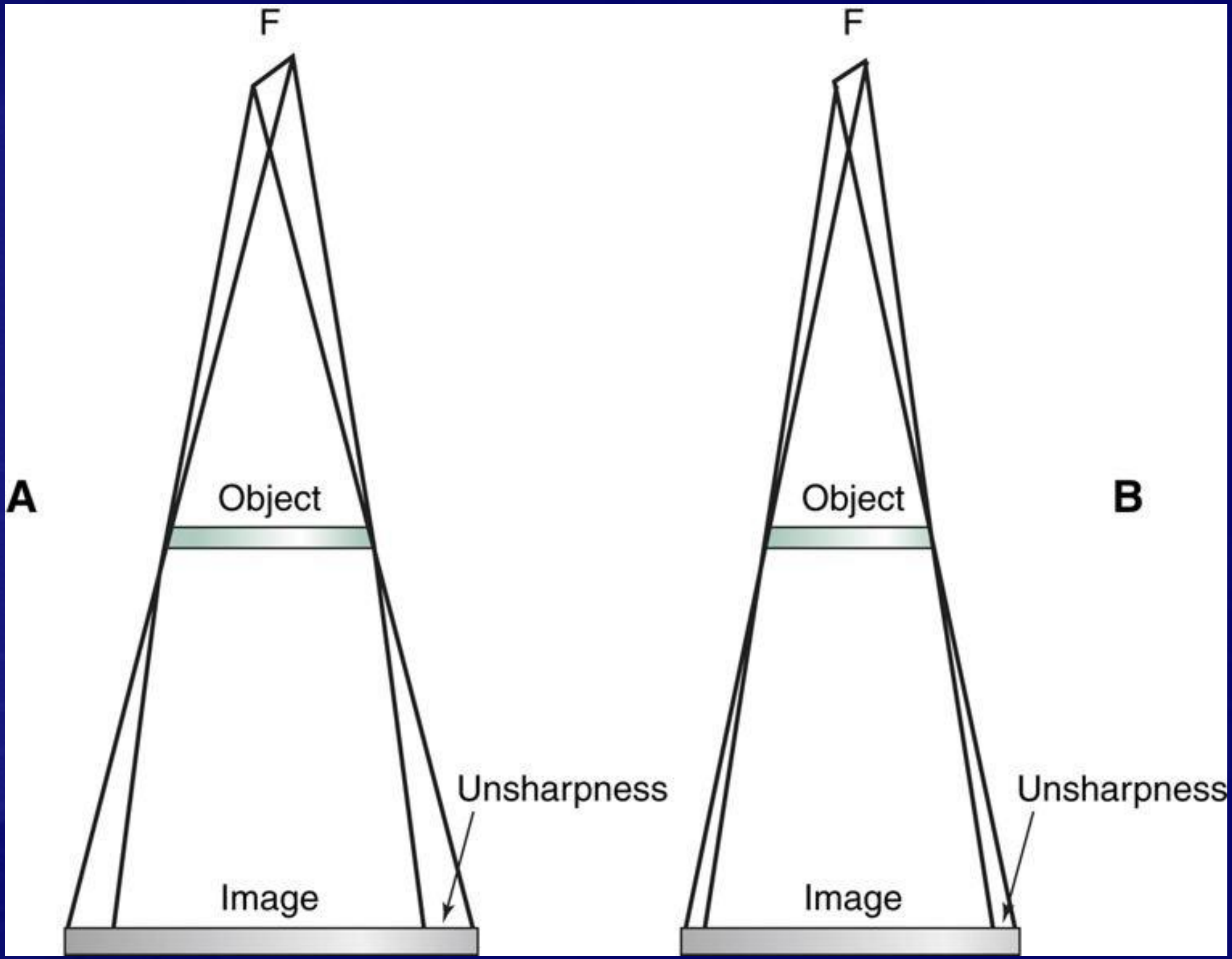

SOD
SID
OID

Focal Spot Size

The physical dimensions of the focal spot on the anode target in x-ray tubes used in standard radiographic applications usually range from 0.5 to 1.2 mm. Focal spot size is determined by the filament size. When the radiographer selects a particular focal spot size, he or she is actually selecting a filament size that will be energized during x-ray production.

The focal spot size affects recorded detail and can change as an x-ray tube ages.

The size of the focal spot stated by the manufacturer, or nominal focal spot size, can vary as much as 50%. A stated focal spot size of<0.8 mm can vary 50%, 0.8 mm to 1.5 mm focal spot size can vary 40%, and > 1.6 mm size can vary 30%.



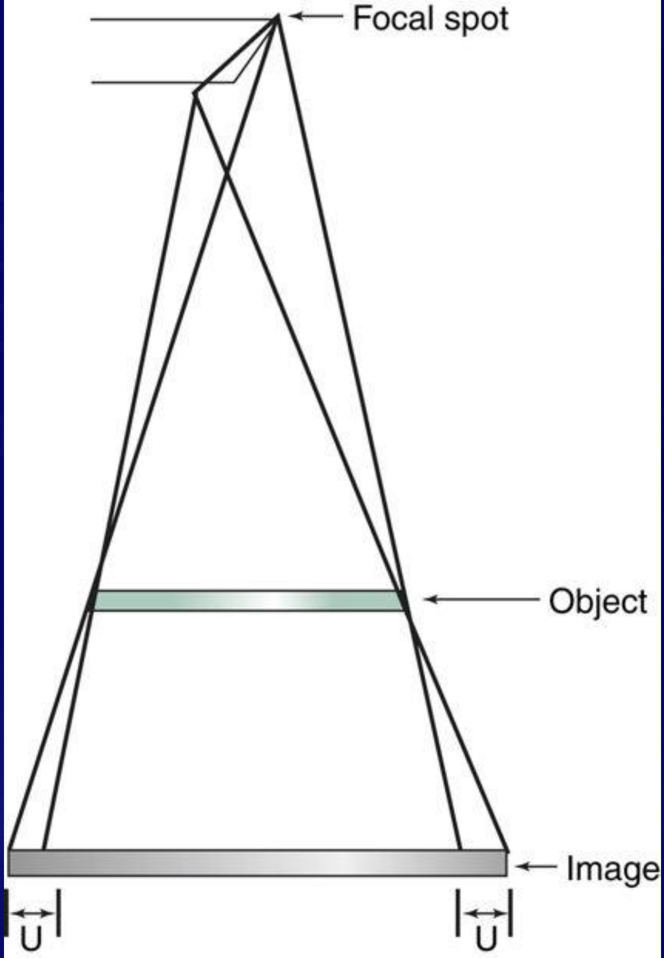
As focal spot size increases, unsharpness increases and recorded detail decreases; as focal spot size decreases, unsharpness decreases and recorded detail increases.

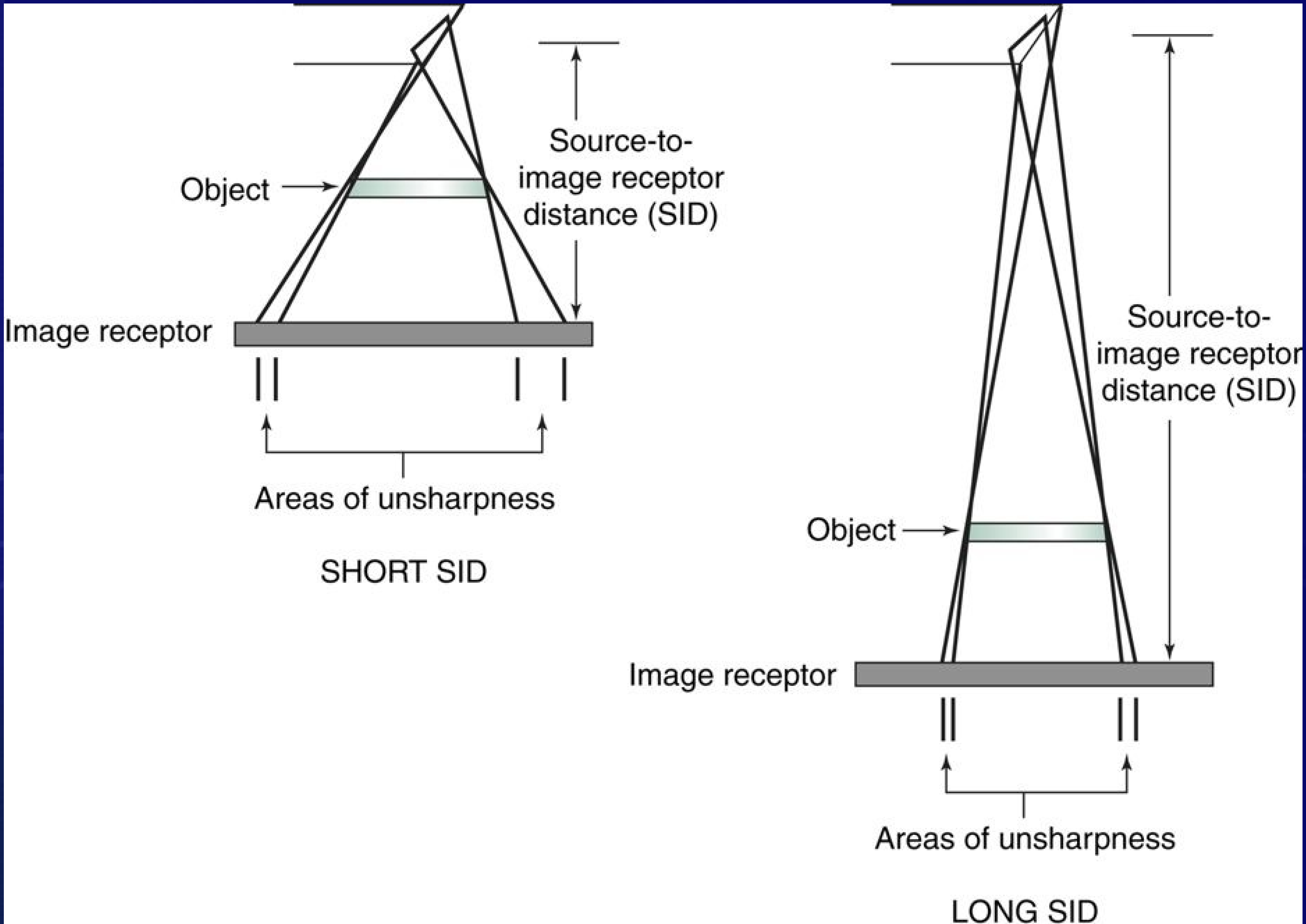
In general, the smallest focal spot size available should be used for every exposure. Unfortunately, exposure is limited with a small focal spot size. When a small focal spot is used, the heat created during the x-ray exposure is concentrated in a smaller area and could cause tube damage. The radiographer must weigh the importance of improved recorded detail for a particular examination or anatomic part against the amount of radiation exposure used.

Modern radiographic x-ray generators are equipped with safety circuits that prevent an exposure from being made if that exposure will exceed the tube loading capacity for the focal spot size selected. Repeated exposures made just under the limit over a long period can still jeopardize the life of the x-ray tube.

Distance

Distance plays an important role in radiographic imaging. Just as the intensity of the x-ray beam is altered when changing the distance between the source and object or the object and receptor, so is the amount of unsharpness recorded on the image. Because of the diverging properties of the x-ray beam, a geometric relationship exists among the source of x-rays, the object, and the image receptor.





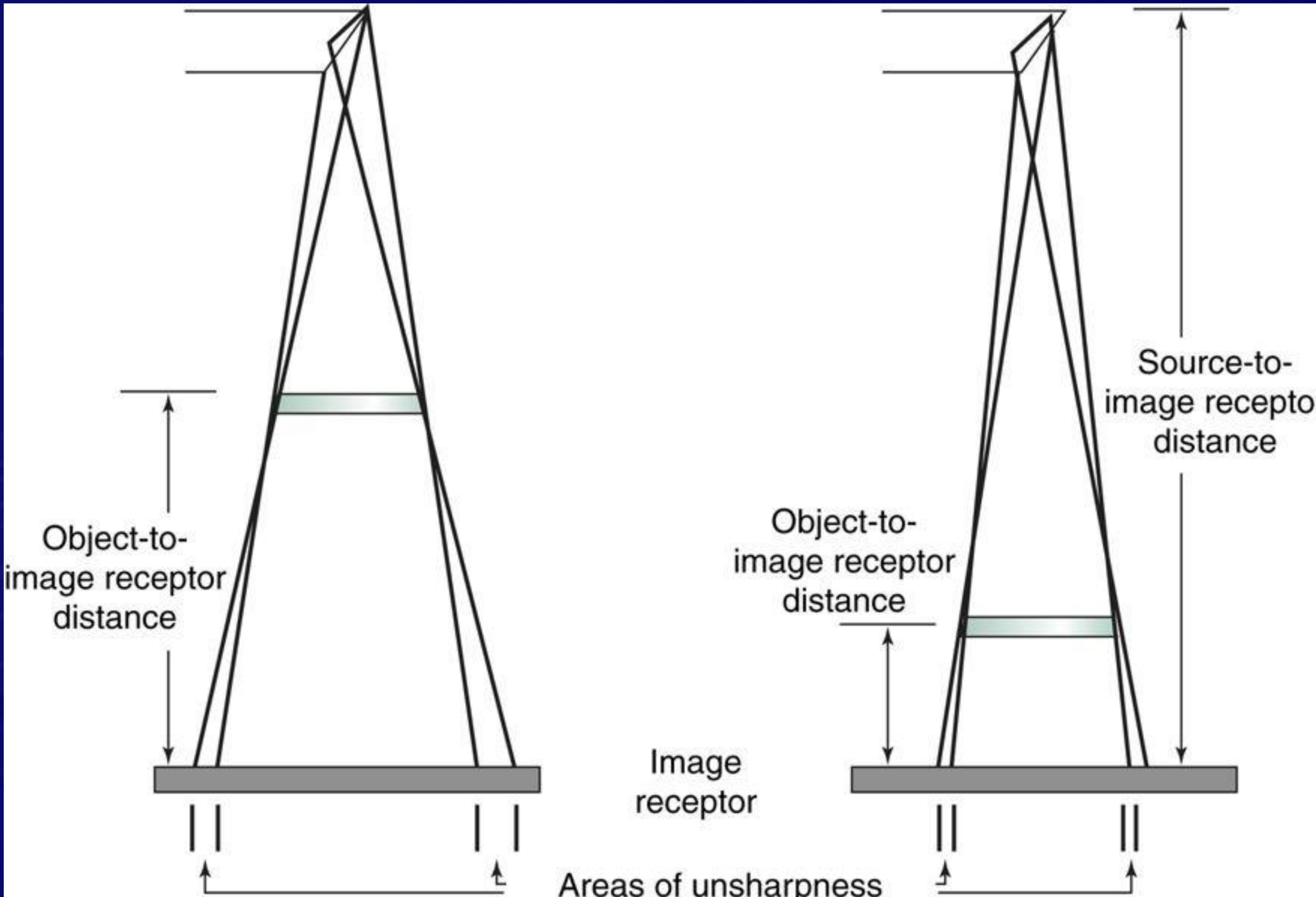
Source-to-
image receptor
distance (SID)
Object
Image receptor
Areas of unsharpness
SHORT SID
Source-to-
image receptor
distance (SID)
Object
Image receptor
Areas of unsharpness
LONG SID

Increasing the SID decreases the amount of unsharpness and increases the amount of recorded detail in the image, whereas decreasing the SID increases the amount of unsharpness and decreases the recorded detail.

The SID affects several aspects of radiographic quality, including radiographic density, magnification, and recorded detail. The SID indicator on the x-ray unit should be evaluated for accuracy. A simple tape measure can be used to verify that the distance indicator is correct.

SID indicators should be accurate within 2% of the SID

In addition to SID, the OID also affects the amount of unsharpness recorded on the image. Optimal recorded detail is achieved when the OID is zero. Unfortunately, this cannot realistically be achieved in radiographic imaging because there is always some distance created between the area of interest and the image receptor.


Object-to-
image receptor
distance
Source-to-
image receptor
distance
Object-to-
image receptor
distance
Image
receptor
Areas of unsharpness

Increasing the OID increases the amount of unsharpness and decreases the recorded detail, whereas decreasing the amount of OID decreases the amount of unsharpness and increases the recorded detail.

The distance between the area of interest and the image receptor has the greatest effect on the amount of geometric unsharpness recorded. When possible, the distance between the area of interest and the image receptor should be kept to a minimum. When a film-screen image receptor is used and placed in a radiographic table, some amount of increased OID will always occur. It is the radiographer's responsibility to position the area of interest as close to the image receptor as possible to minimize the amount of unsharpness recorded.

The distance between the area of interest and the image receptor has a greater effect on the amount of geometric unsharpness recorded than does focal spot size or SID.

$$Geometric\ Unsharpness = \frac{FSS\ x\ OID}{SOD}$$

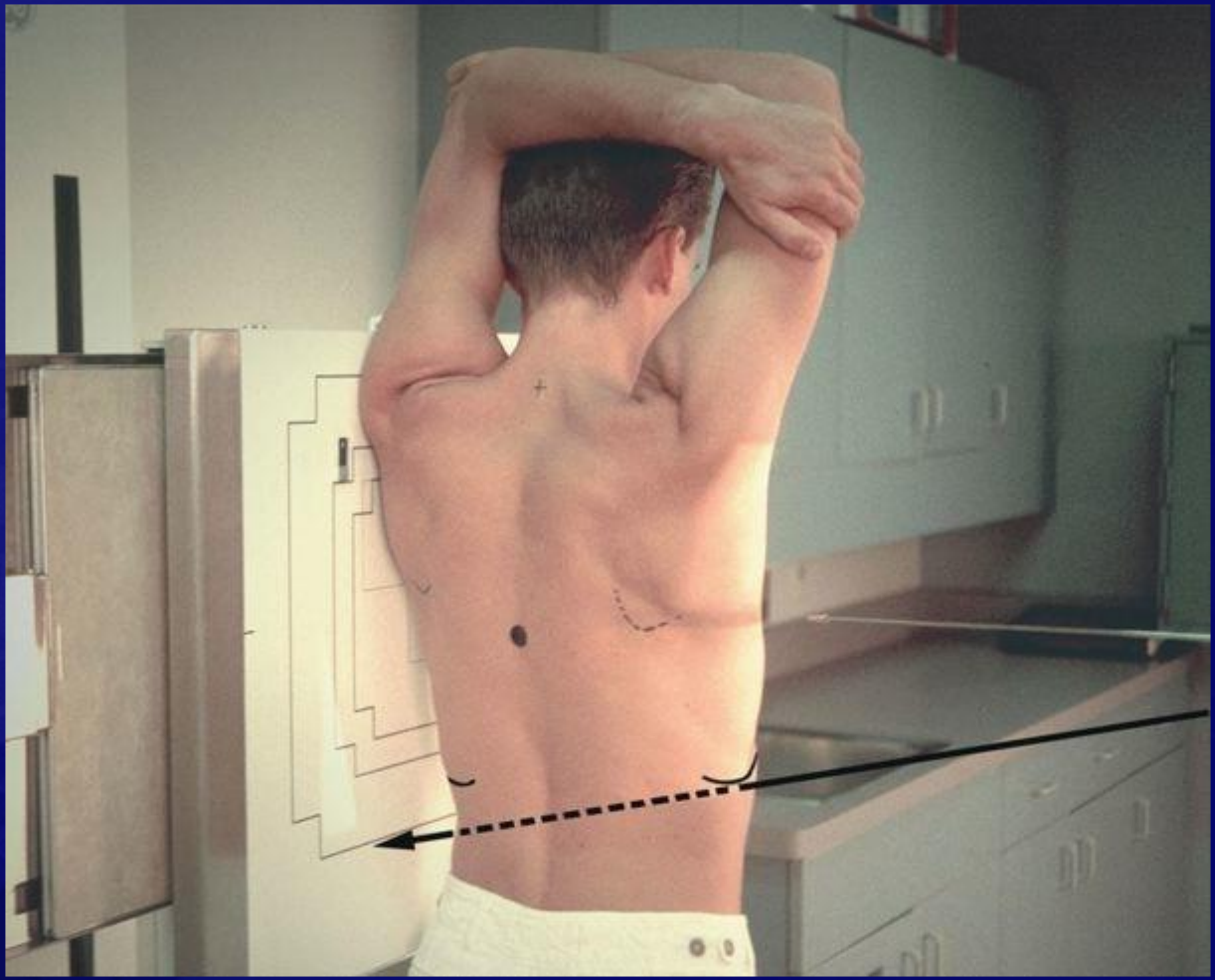
Source-to-object distance (SOD)

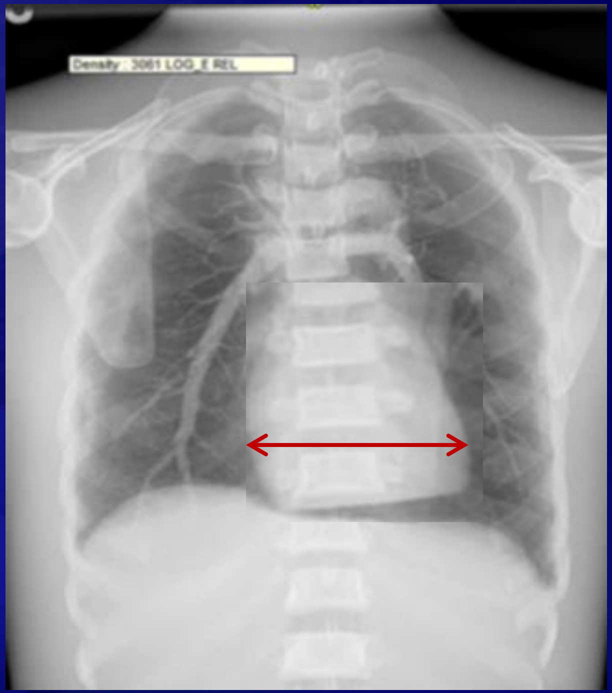
refers to the distance from the x-ray source (focal spot) to the object being radiographed. SOD can be expressed mathematically as follows:

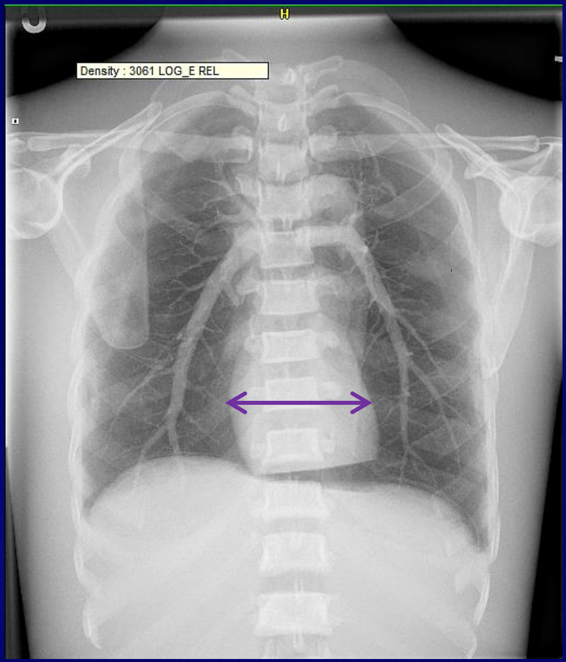
$$SOD = SID - OID$$

Minimizing Geometric Unsharpness

The radiographer should select the smallest focal spot size when maximal recorded detail is important; he or she should also consider the amount of heat load within the x-ray tube. In addition, the radiographer should select the standard SID when OID is minimal. When increased OID is unavoidable, SID should be increased slightly to compensate.




Density : 3061 LOG_E REL


H
Density : 3061 LOG_E REL

MOTION UNSHARPNESS

Motion of the tube, part, or image receptor causes a profound decrease in recorded detail. Motion must not just be decreased; it must be eliminated.

Unsharpness resulting from patient motion, known as blur, is the most detrimental factor to maximizing recorded detail.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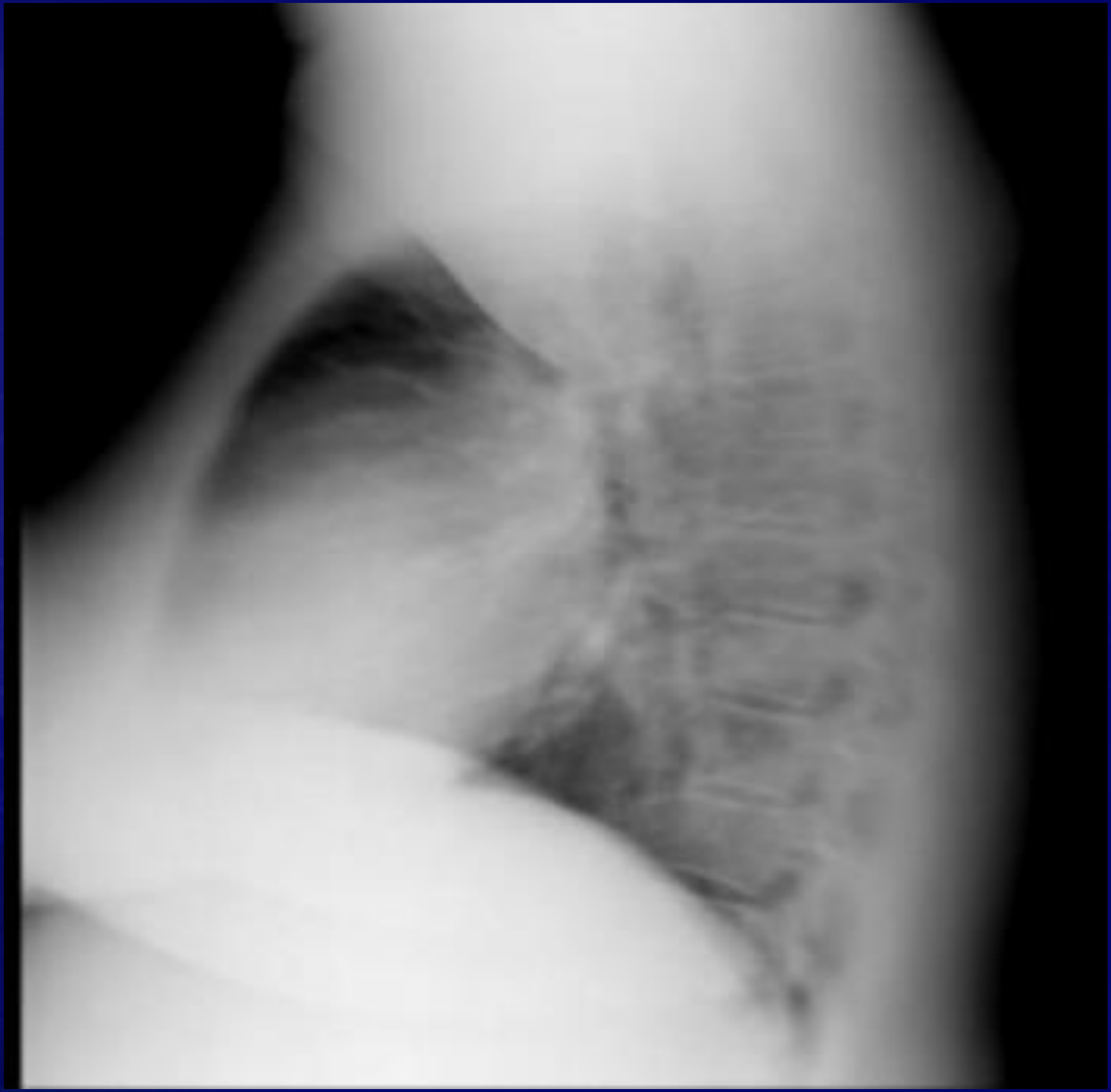
Downloaded from: www.xray2000.co.uk

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Unsharpness resulting from patient motion can be classified as:

1. Voluntary (within the patient's control)

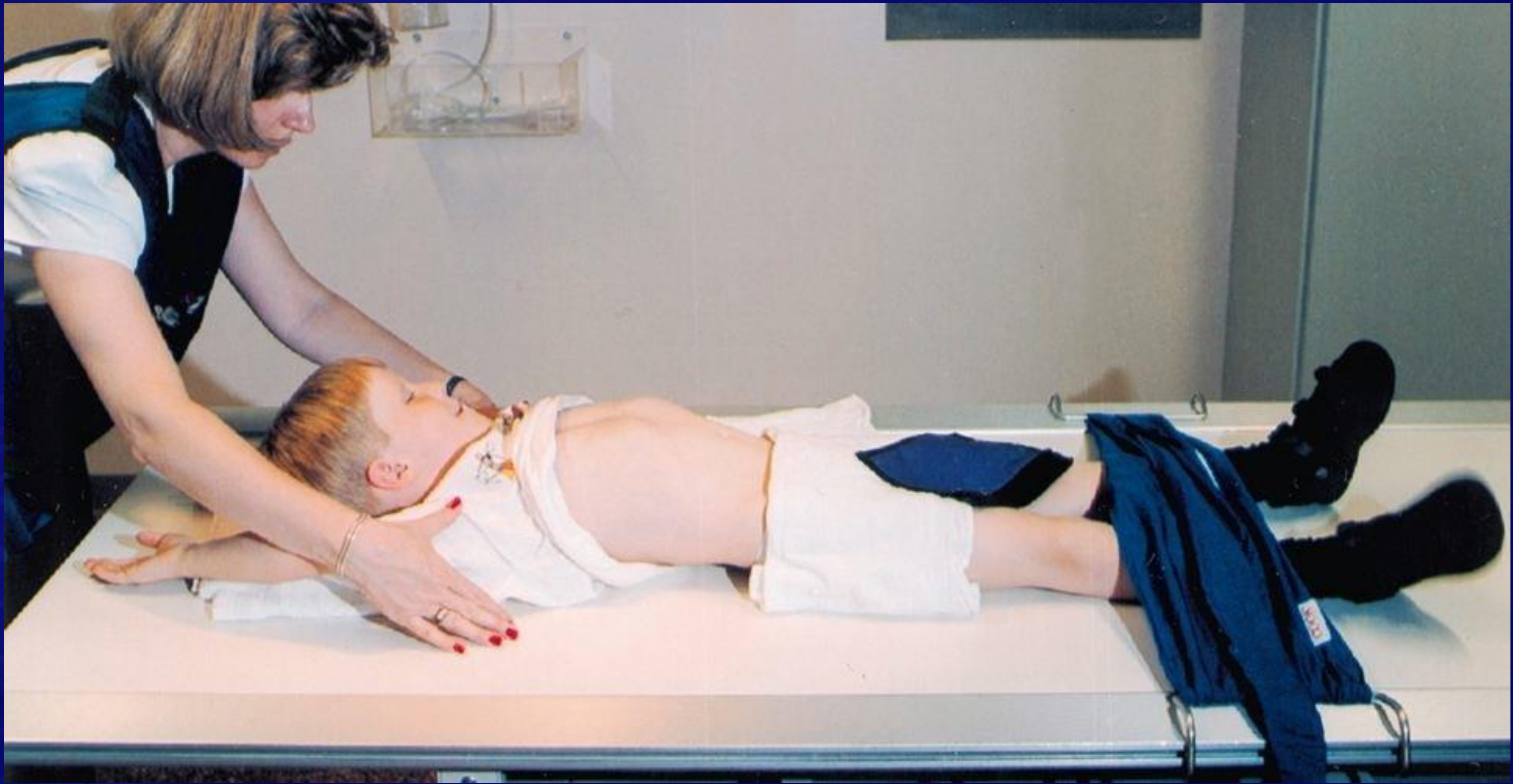
2. Involuntary (outside of patient's control, such as peristalsis)

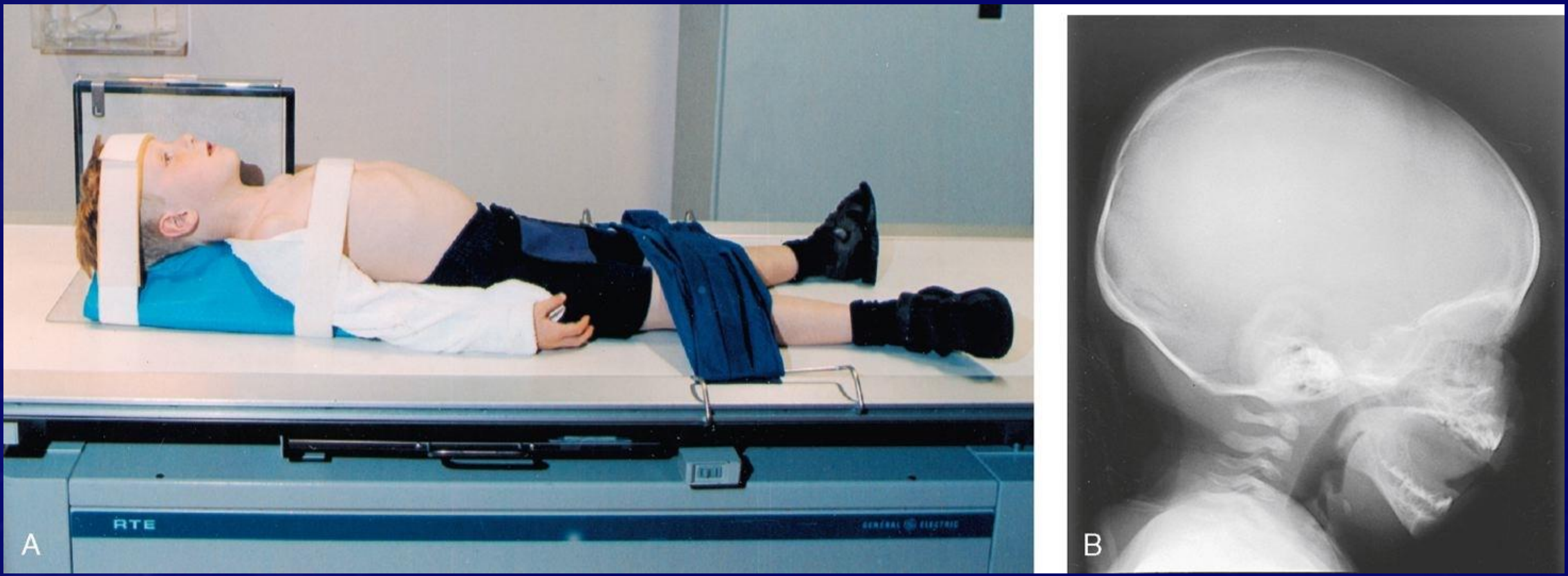
Most motion on radiographs results from the patient moving during the exposure. The radiographer can control patient motion to some degree. Patients who are least likely to cooperate, and therefore move, are pediatric patients, those with conditions such as Parkinson's disease that cause involuntary shaking, and those who are otherwise unwilling or unable to cooperate, such as intoxicated or traumatized patients.

If a patient needs to be physically held, it is generally recommended that the holder not be a person who routinely is exposed to x-rays. The holder should always wear lead shielding and, if female, be evaluated for the possibility of pregnancy before making the exposure.


A
B
R


RTE




RTE
A
B

Eliminating Motion

Patient motion has the most detrimental effect on recorded detail and can be controlled by the following:

1. Using short exposure times compensated for by higher mA (reciprocity)

2. Providing clear instructions for the patient to assist in immobilization

3.Using physical immobilization, such as sandbags, tape, or other devices, as deemed necessary

4. Using fast image receptors

5. Minimizing OID

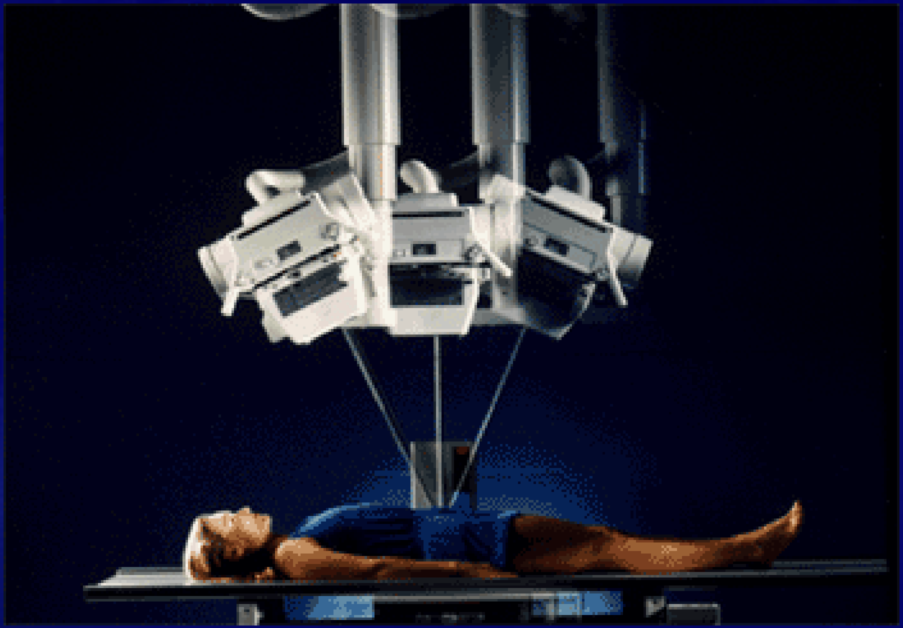
6. Maximizing SID

7. Utilizing 15% rule

Procedures where motion is desirable

- Tomography
- Pantomography
- Autotomography

Tomography: From the Greek word “tomos” section. The process for generating a tomogram, a two-dimensional image of a section through a three-dimensional object. Tomography achieves this result by simply moving an x-ray source in one direction as the x-ray film is moved in the opposite direction during the exposure to sharpen structures in the focal plane, while structures away from the focal plane appear blurred.

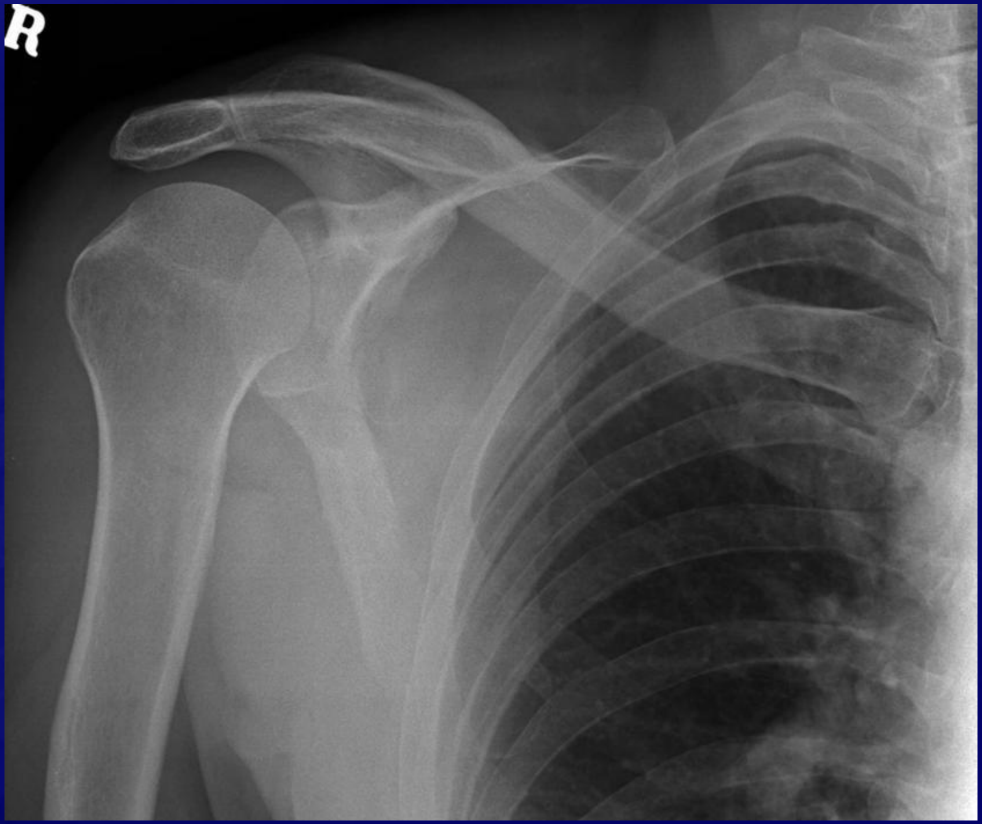


Tomography limitations

- Image blurr present

Pantomography

Autotomography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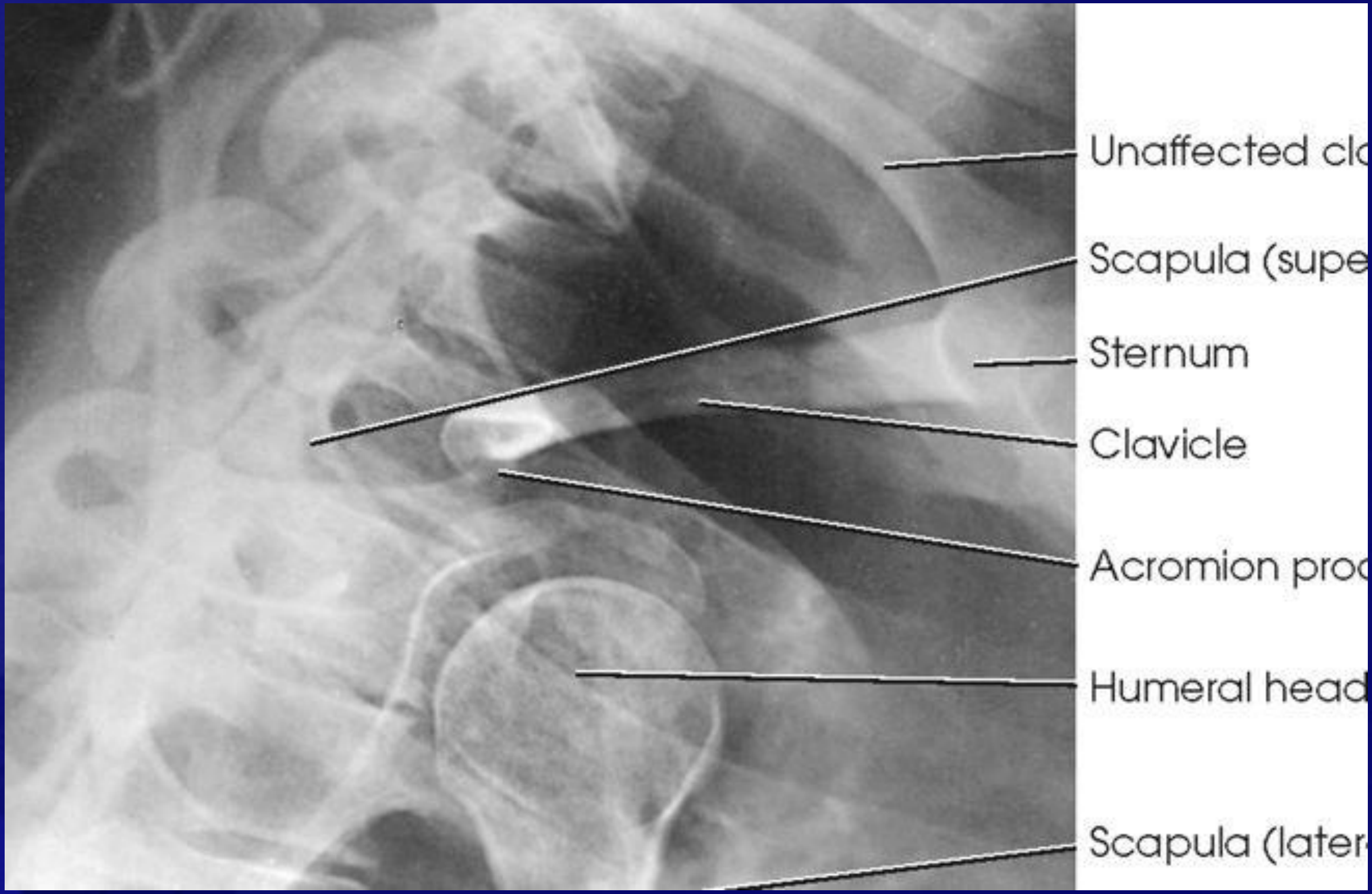
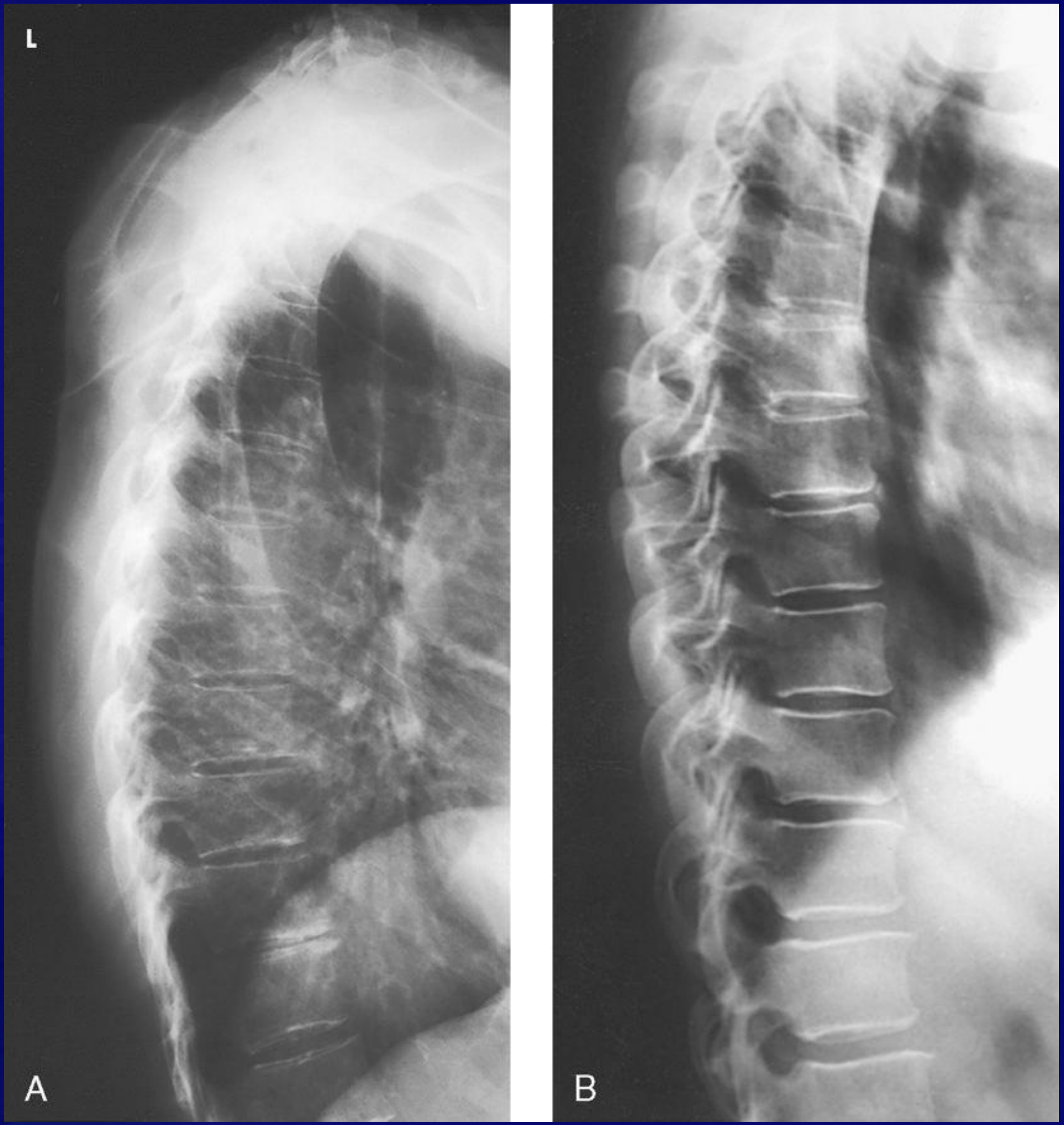

Unaffected cl
Scapula (supe
Sternum
Clavicle
Acromion proc
Humeral head
Scapula (later


L
A
B

Distortion

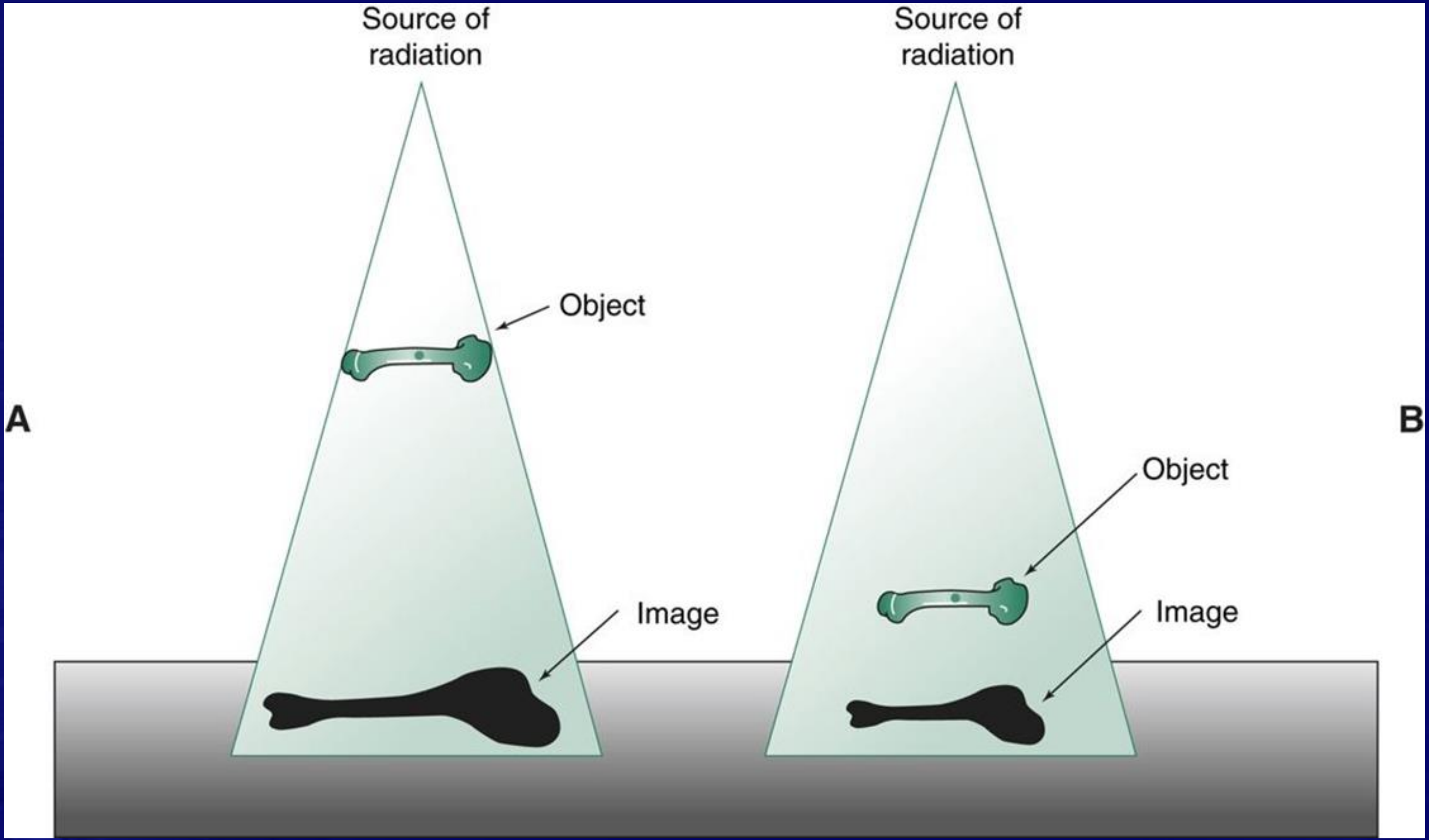
By Prof. Jarek Stelmark

Distortion

Distortion results from the radiographic misrepresentation of either the size (magnification) or shape of the anatomic part. When the image is distorted, recorded detail is also reduced.

SIZE DISTORTION (MAGNIFICATION)

The term size distortion/magnification refers to an increase in the object's image size compared with its true, or actual, size. Radiographic images of objects are always magnified in terms of the true object size. The distances used (SID and OID) play an important role in minimizing the amount of size distortion of the radiographic image.

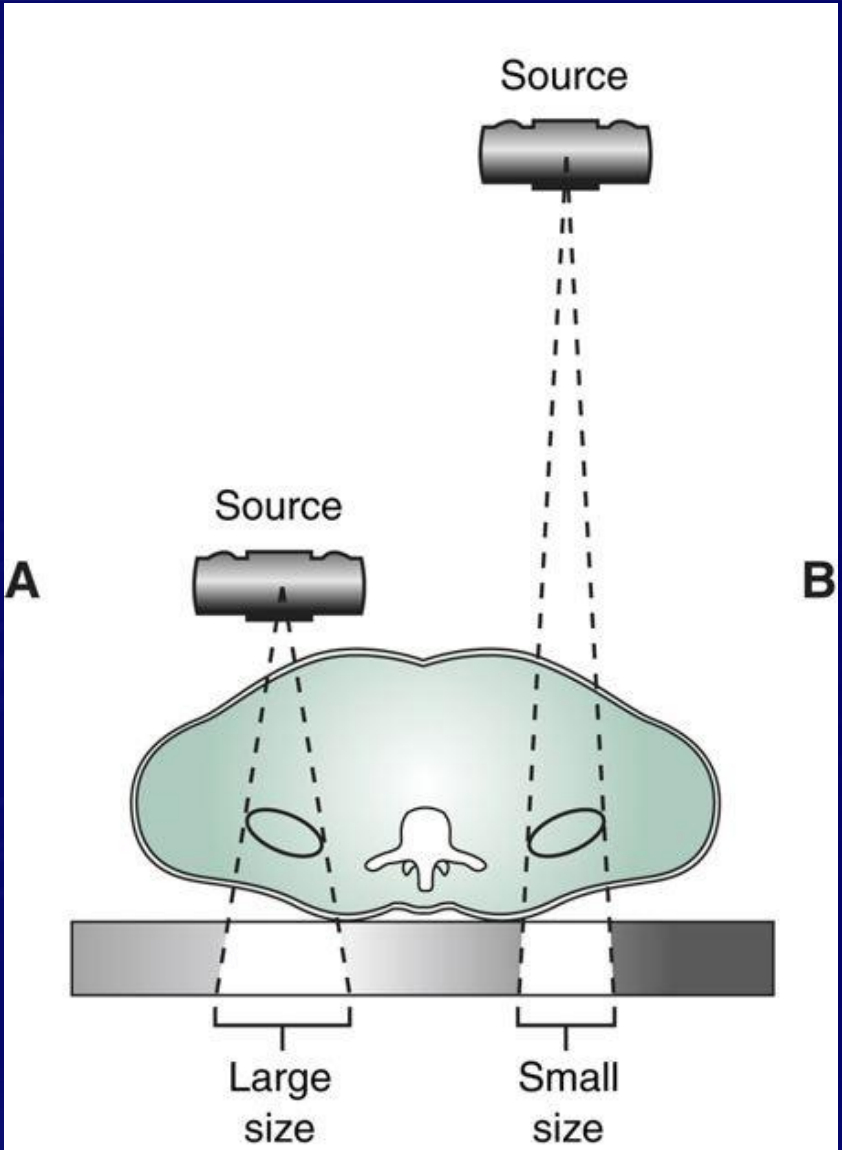


As OID increases, size distortion (magnification) increases; as OID decreases, size distortion (magnification) decreases.

Because radiographers produce radiographs of three-dimensional objects, some size distortion always occurs as a result of OID. Even if the object is in close contact with the image receptor, some part of the object will be farther away from the image receptor than other parts of the object. Those parts of the object that are farther away from the image receptor will be represented radiographically with more size distortion than parts of the object that are closer to the image receptor.

Source-to-Image Receptor Distance

SID also influences the total amount of size distortion represented on a radiograph. Although OID has the greatest effect on size distortion, SID is still an important factor for the radiographer to control in order to minimize size distortion. SID is inversely related to magnification.



As SID increases, size distortion (magnification) decreases; as SID decreases, size distortion (magnification) increases.

This is the reason that chest radiographs are obtained at a minimum SID of 72 inches (180 cm) rather than of 40 to 48 inches (100 to 122 cm), which is commonly used for most other examinations. A 72-inch (180 cm) SID results in less magnification of the heart and other structures within the thorax.

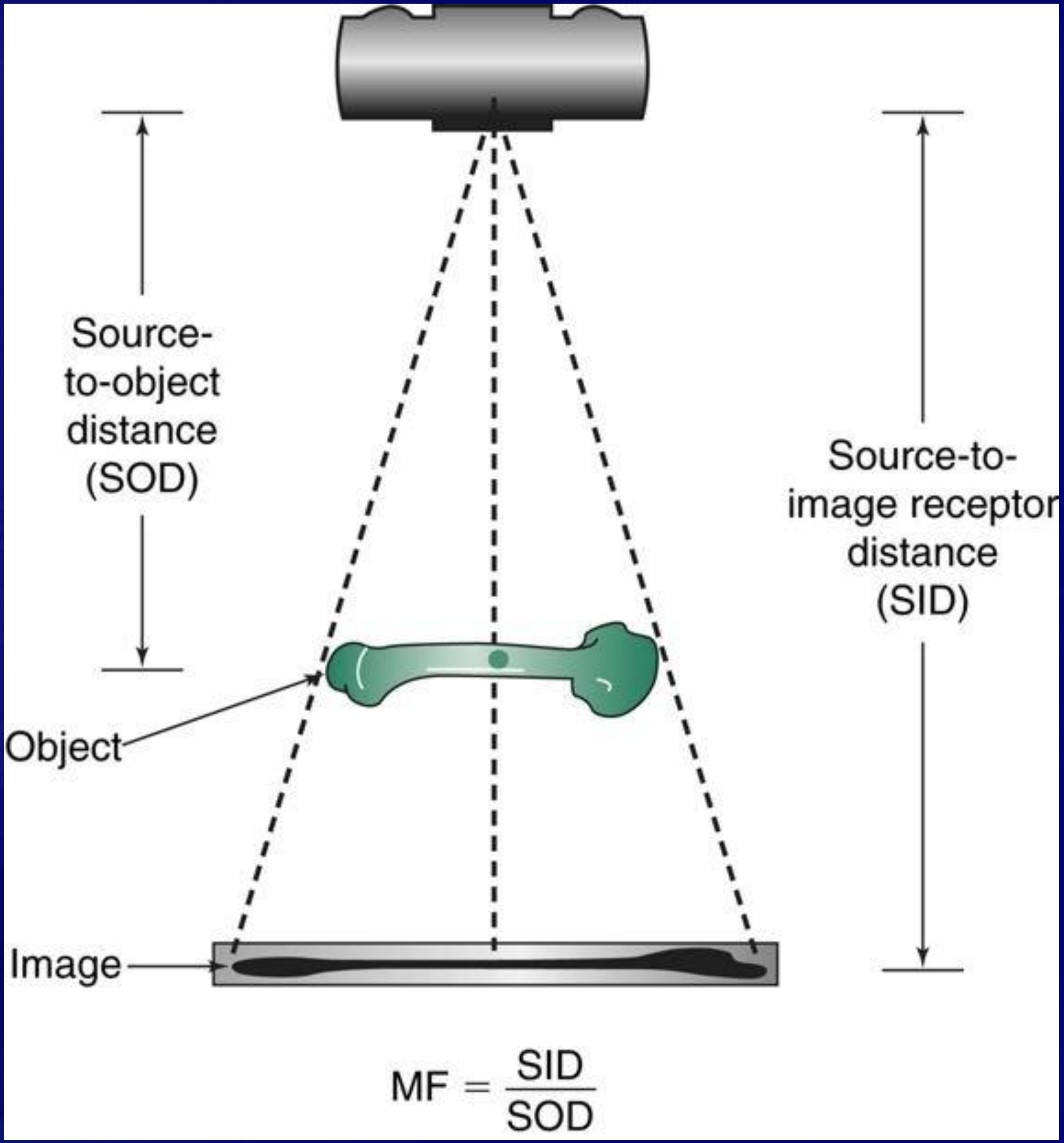
Minimum 40-inch (or 100-cm) SID

It has been a long-standing common practice to use 40 inches (rounded to 100 cm) as the standard SID for most skeletal radiographic examinations. However, in the interest of improving image resolution by decreasing magnification and distortion, it is becoming more common to increase the standard SID to 44 or 48 inches (112 or 122 cm). Additionally, it has been shown that increasing the SID from 40 to 48 inches reduces the entrance or skin dose even when the requirement for increased mAs is considered. In this textbook, the suggested SID listed on each skeletal positioning page is a minimum of 40 inches, with 44 or 48 inches recommended if the equipment and departmental protocol allow.

Calculating Magnification

To observe the effect of distance on size distortion, it is necessary to consider the magnification factor. The magnification factor (MF) indicates how much size distortion or magnification is demonstrated on a radiograph. The MF can be expressed mathematically by the following formula:

$$MF = \frac{SID}{SOD}$$


Source-
to-object
distance
(SOD)
Source-to-
image receptor
distance
(SID)
Object
Image
$MF = \frac{SID}{SOD}$

Determining Object Size

On a PA chest film taken with an SID of 72 inches and an OID of 3 inches (SOD is equal to 69 inches), the size of a round lesion in the right lung measures 1.5 inches in diameter on the radiograph. The MF has been determined to be 1.044. What is the object size of this lesion?

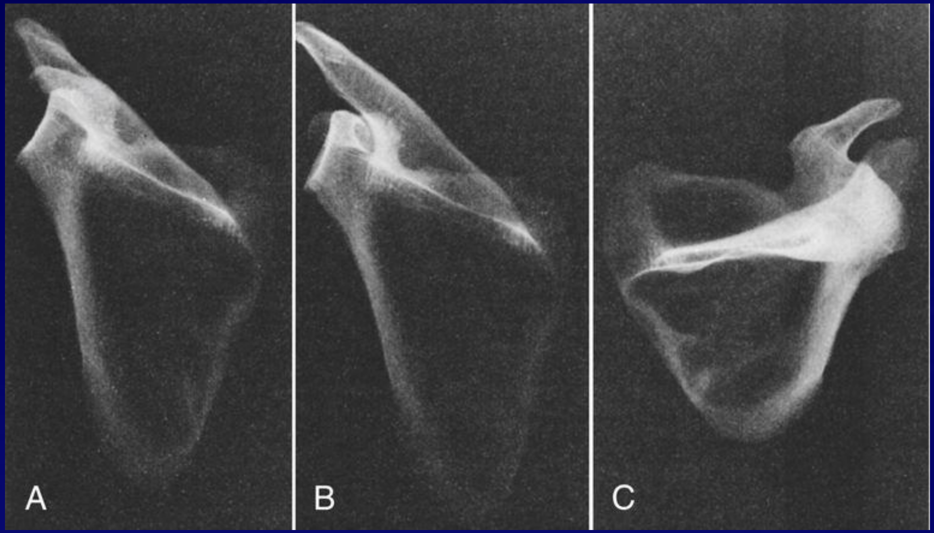
$$\text{Object size} = \frac{\text{Image size}}{\text{MF}}$$

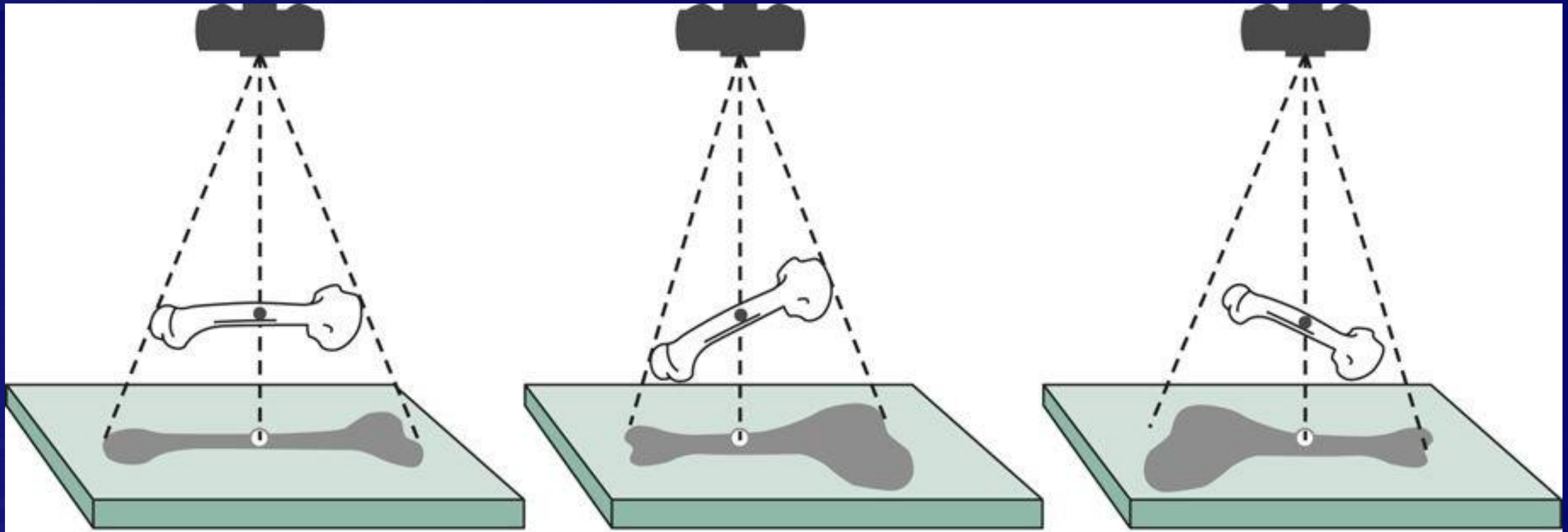
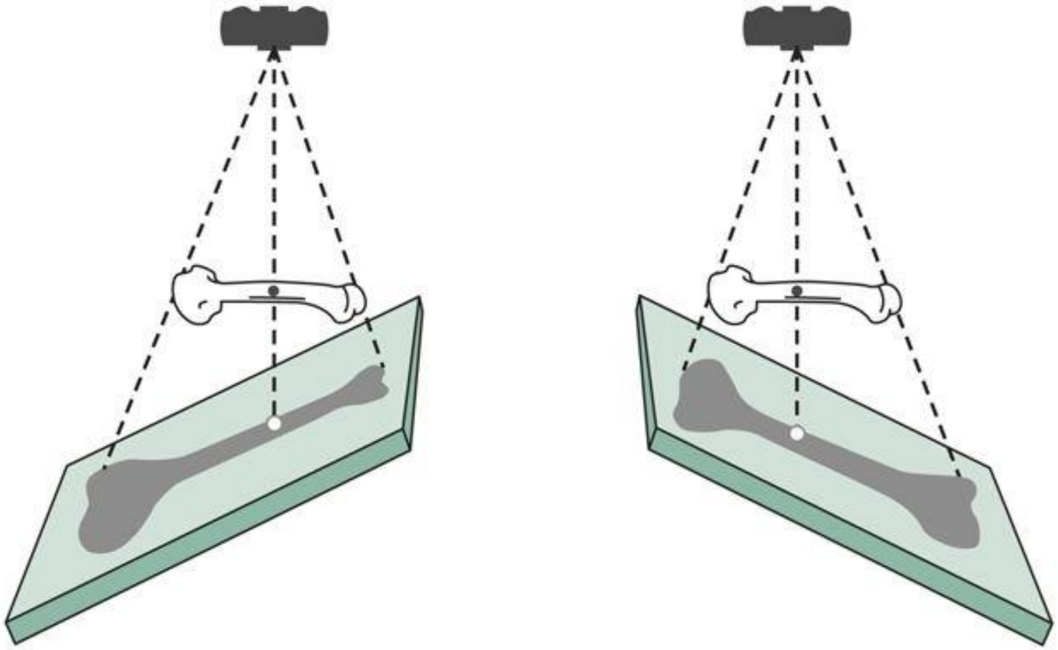
$$\text{Object size} = \frac{1.5 \text{ inches}}{1.044}$$

$$\text{Object size} = 1.44 \text{ inches}$$

SHAPE DISTORTION

In addition to size distortion, objects that are being imaged can also be misrepresented radiographically by distortion of their shape. Shape distortion can appear in two different ways radiographically: elongation or foreshortening. Elongation refers to images of objects that appear longer than the true objects. Foreshortening refers to images that appear shorter than the true objects.




A

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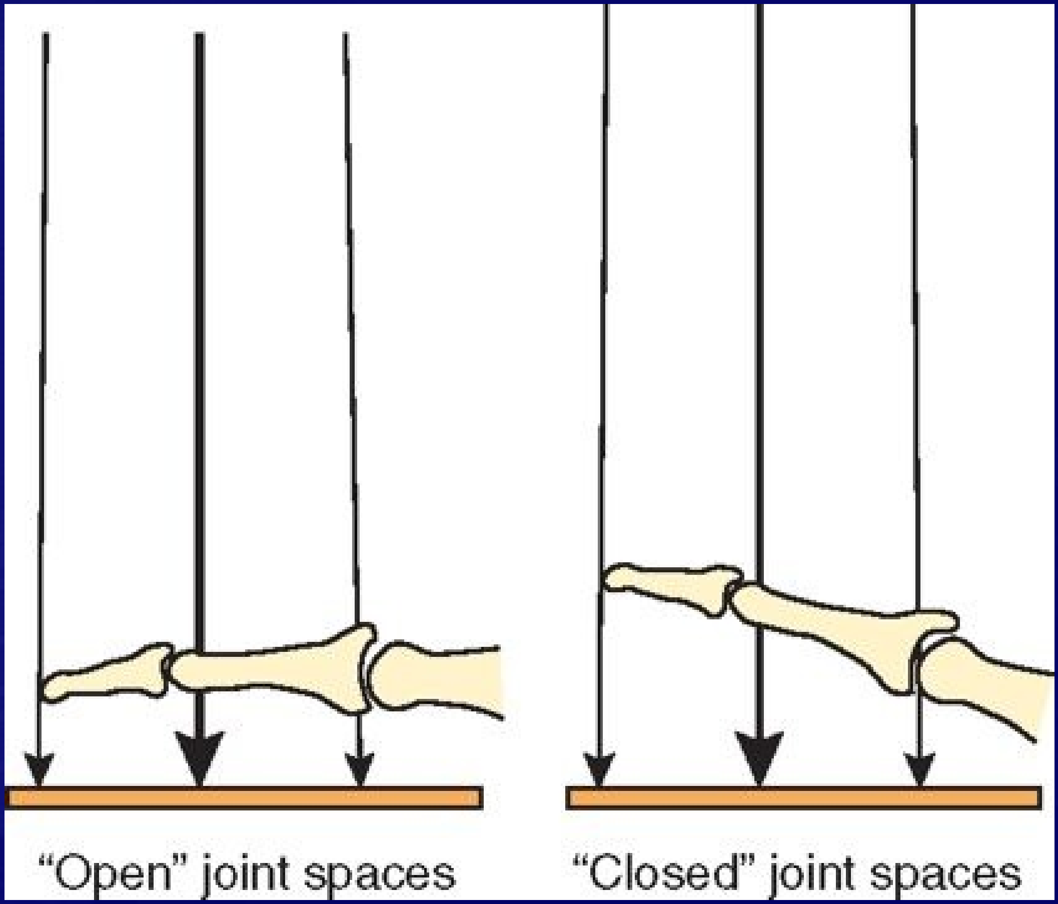
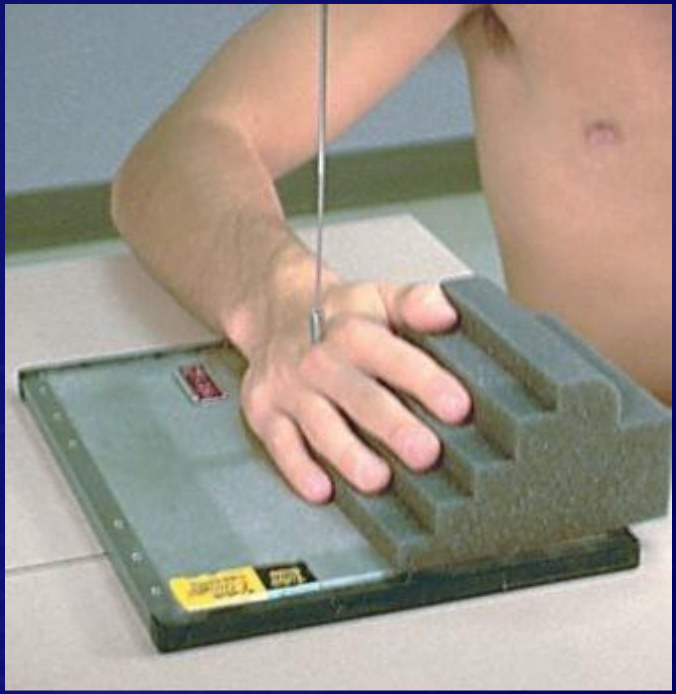
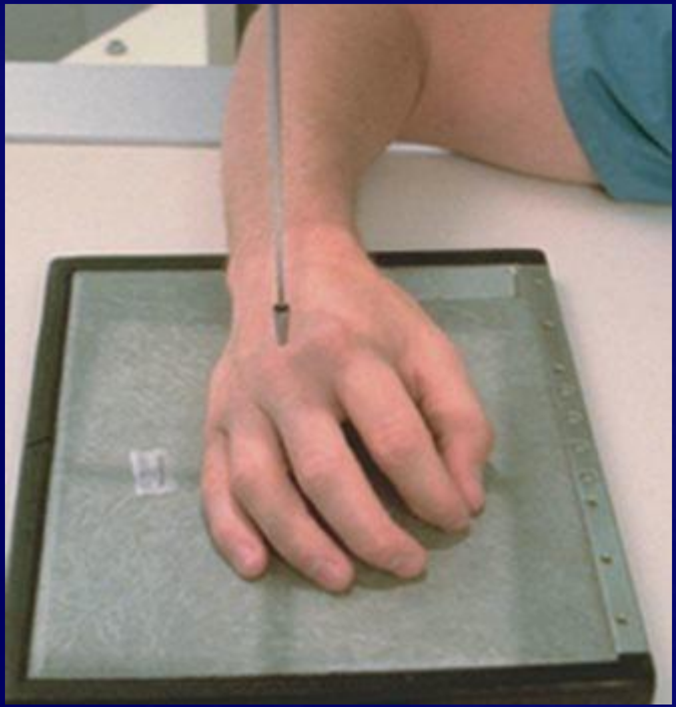

"Open" joint spaces
"Closed" joint spaces



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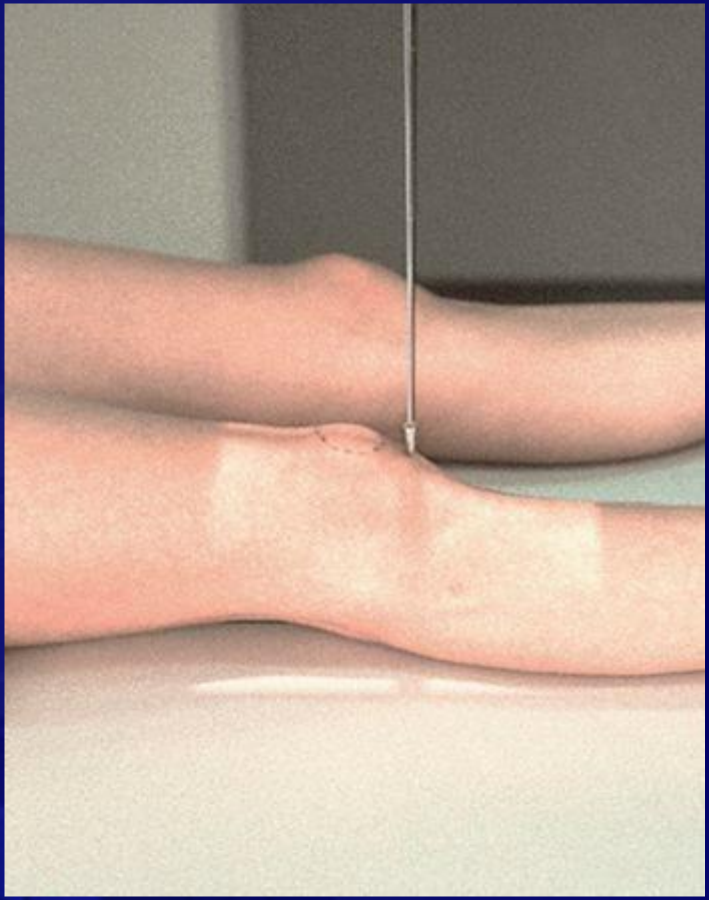
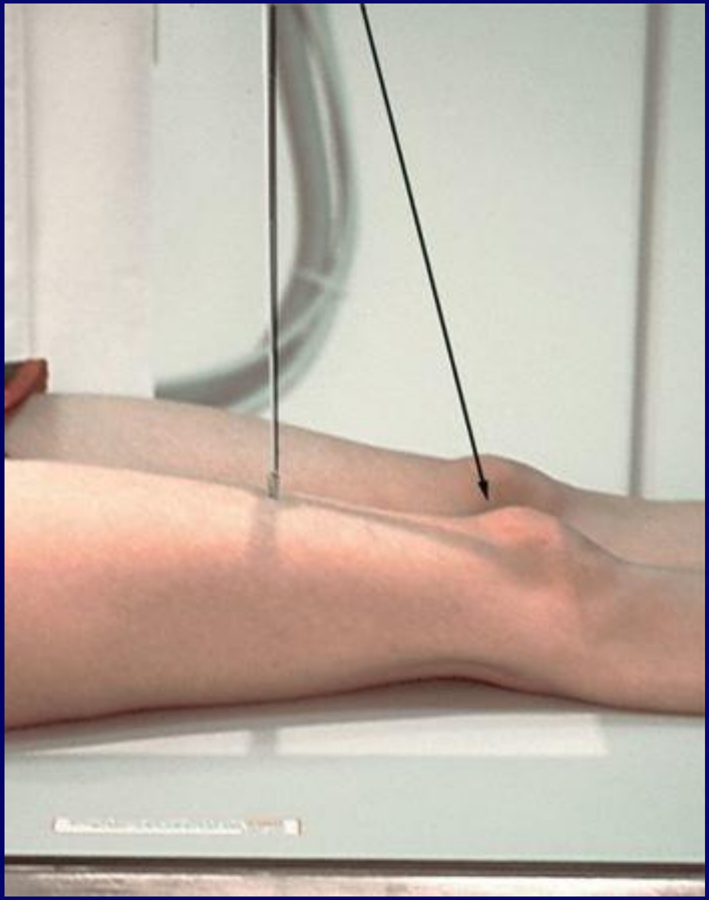
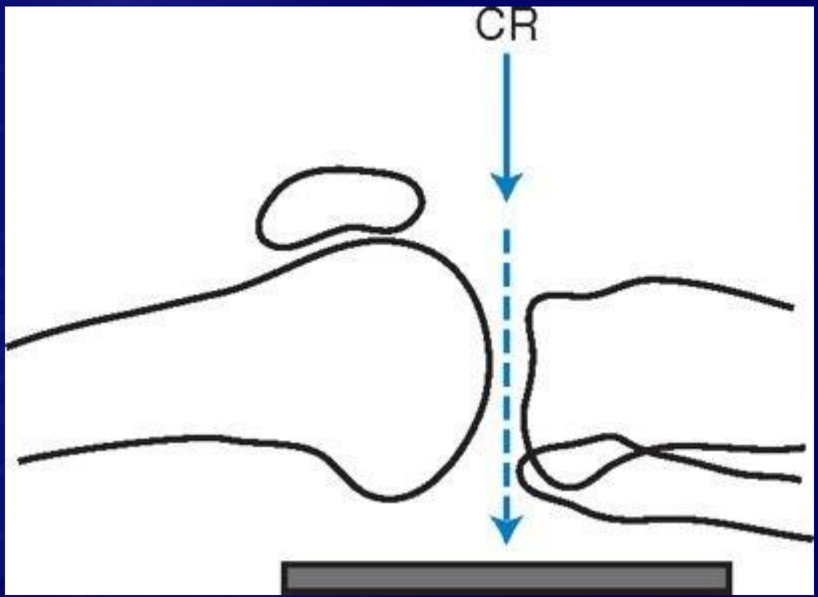
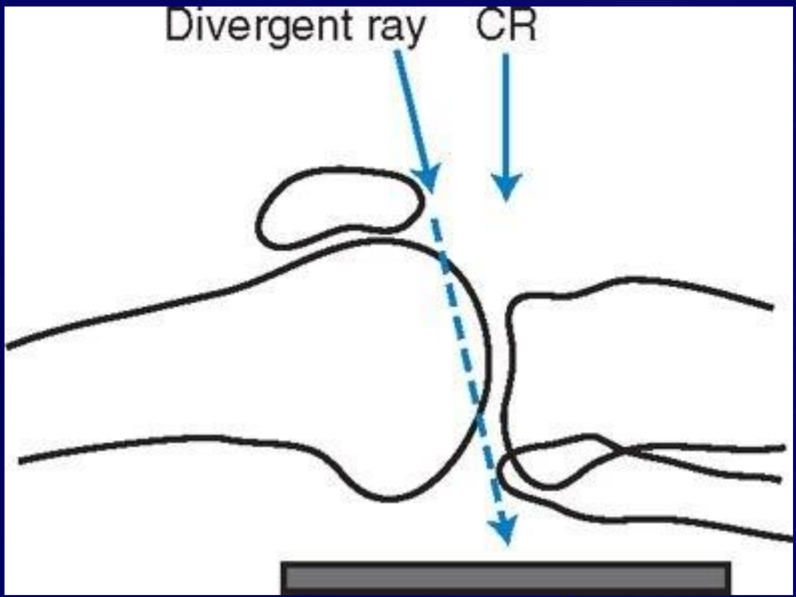
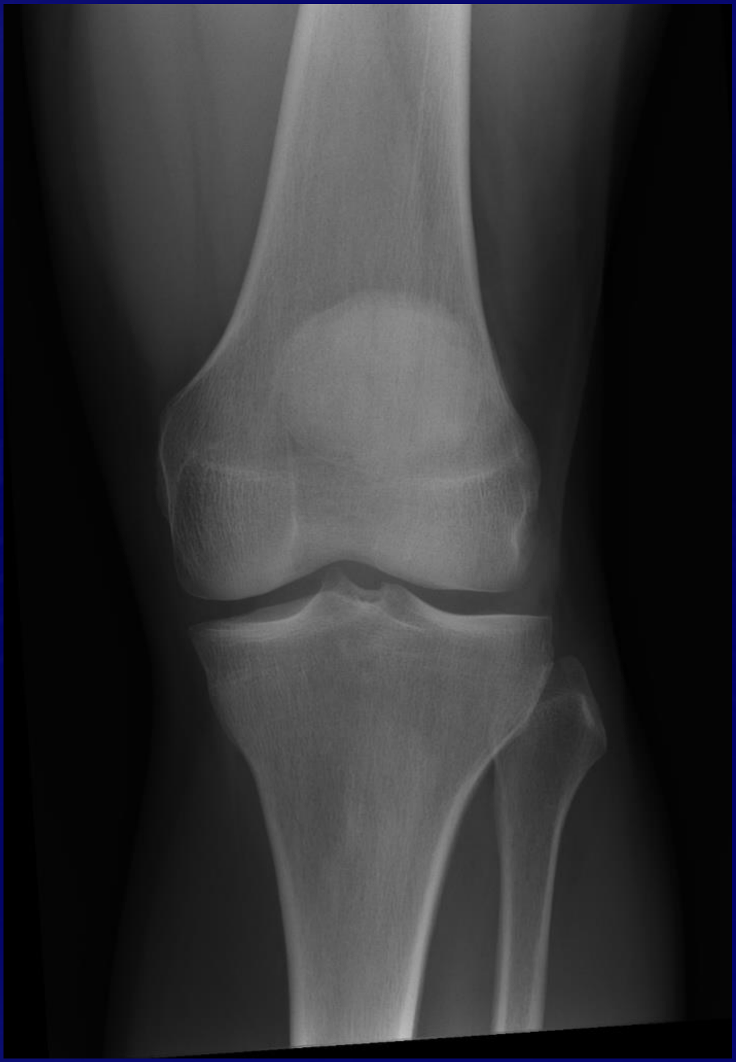





CR


Divergent ray
CR

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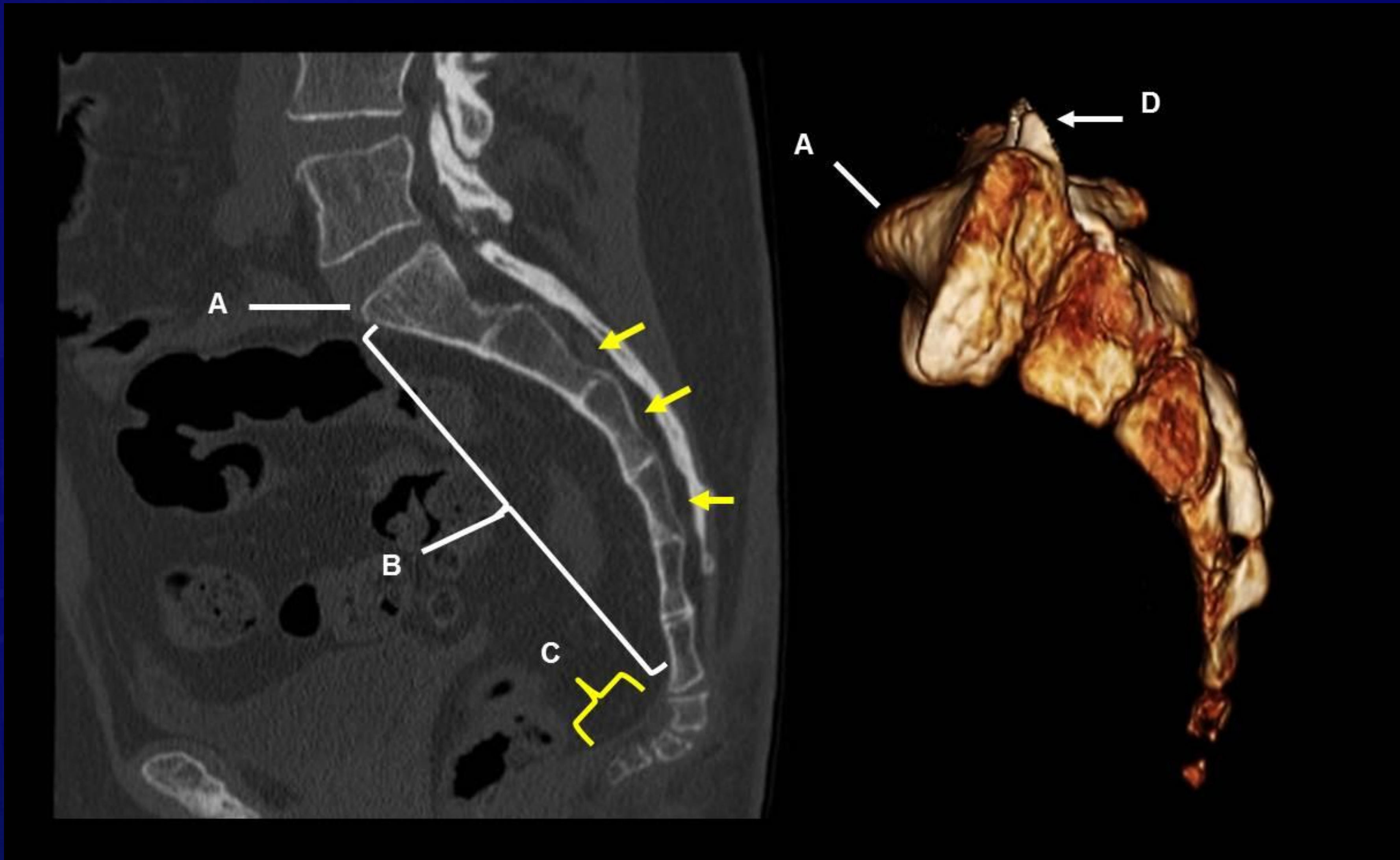
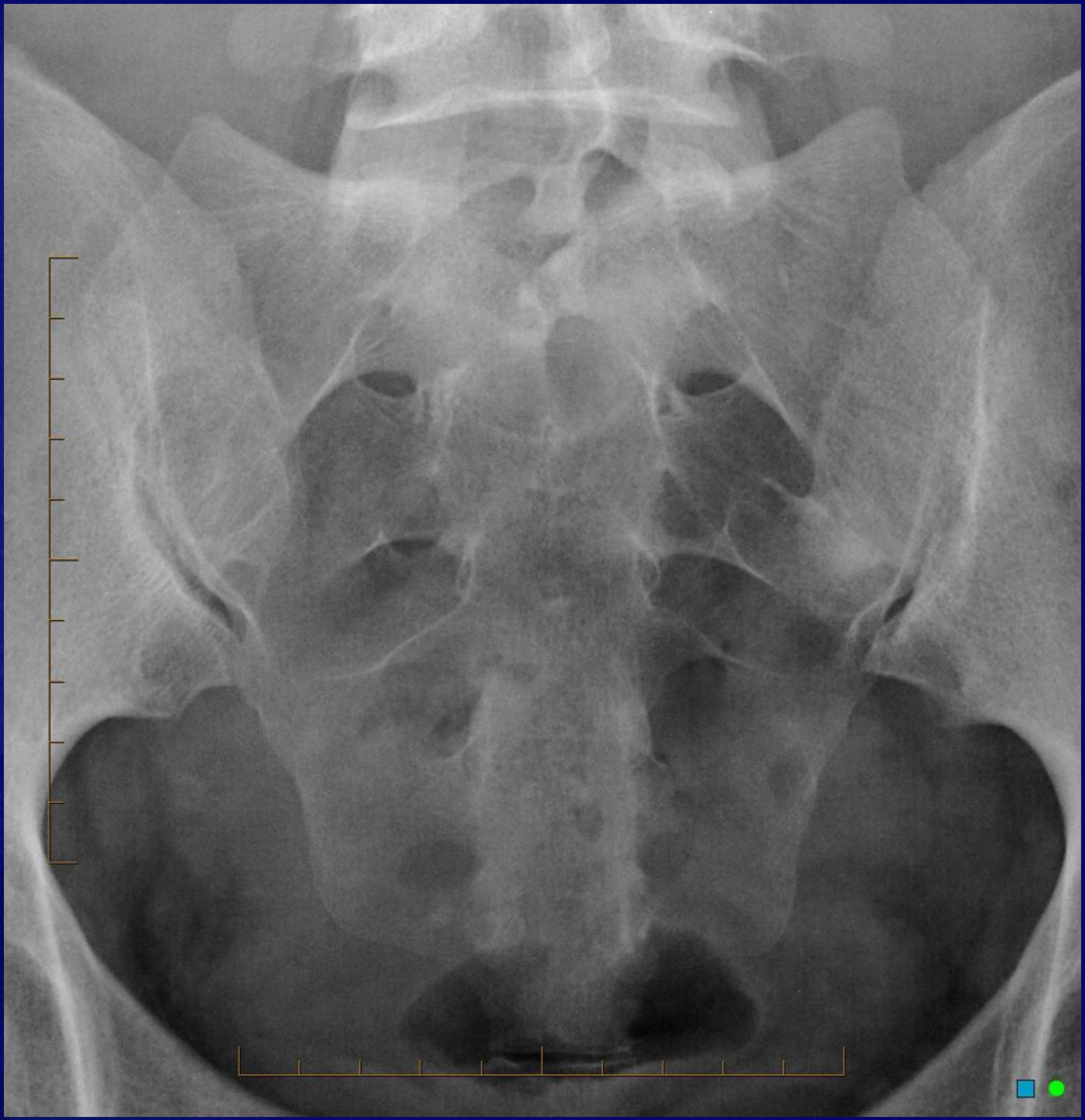

A
B
C
A
D




R
AP

Minimizing Shape Distortion

Elongation and foreshortening can be minimized by ensuring the proper CR alignment of the following:

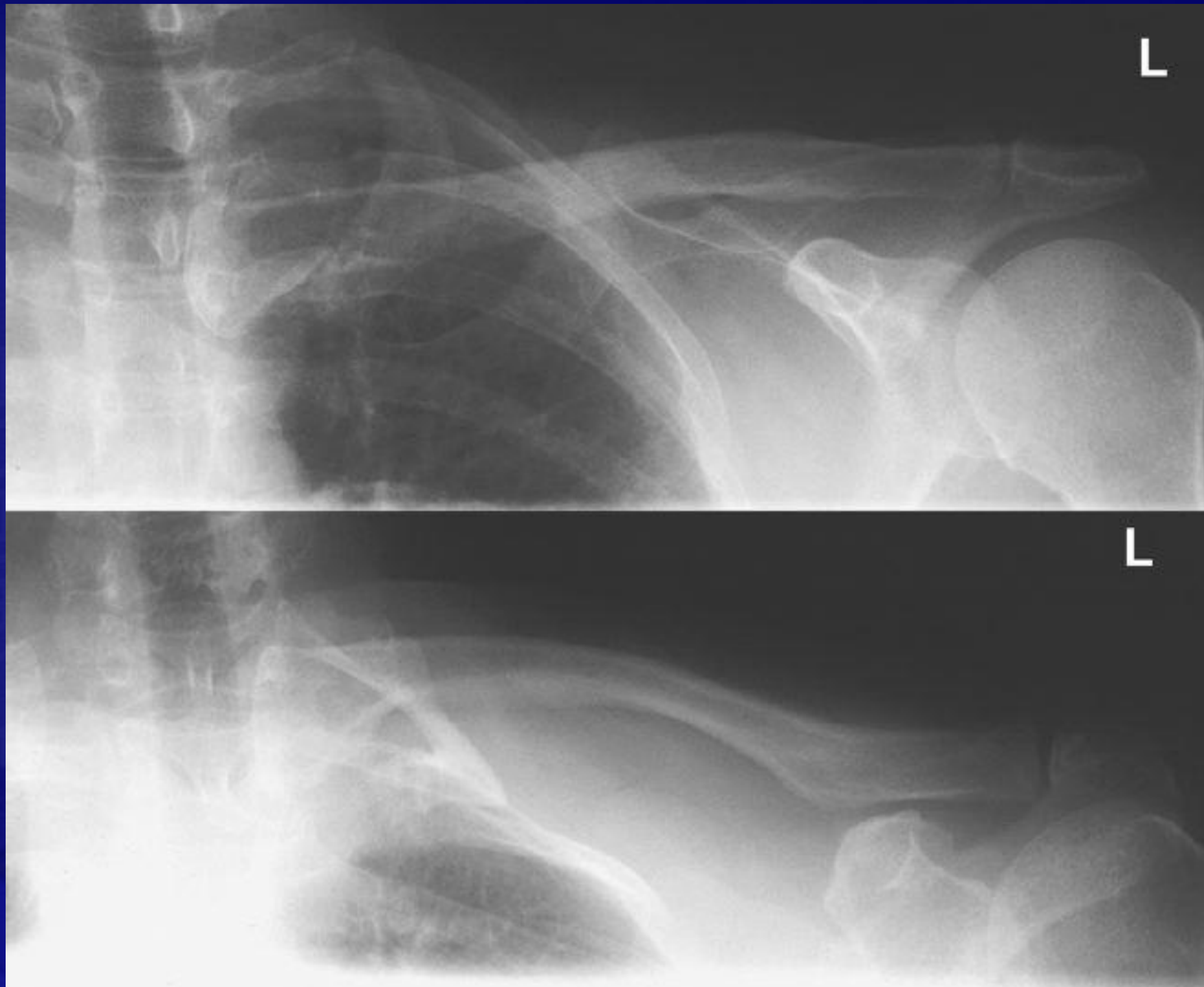
1. X-ray tube

2. Part

3. Image receptor

4. Entry or exit point of the CR

Sometimes, shape distortion is used to an advantage in particular projections or positions. CR angulation, for example, is sometimes required to elongate a part so that a particular anatomic structure can be visualized better. Also, CR angulation is sometimes required to eliminate superimposition of objects that normally would obstruct visualization of the area of interest. In general, shape distortion is not a necessary or desirable characteristic of radiographs.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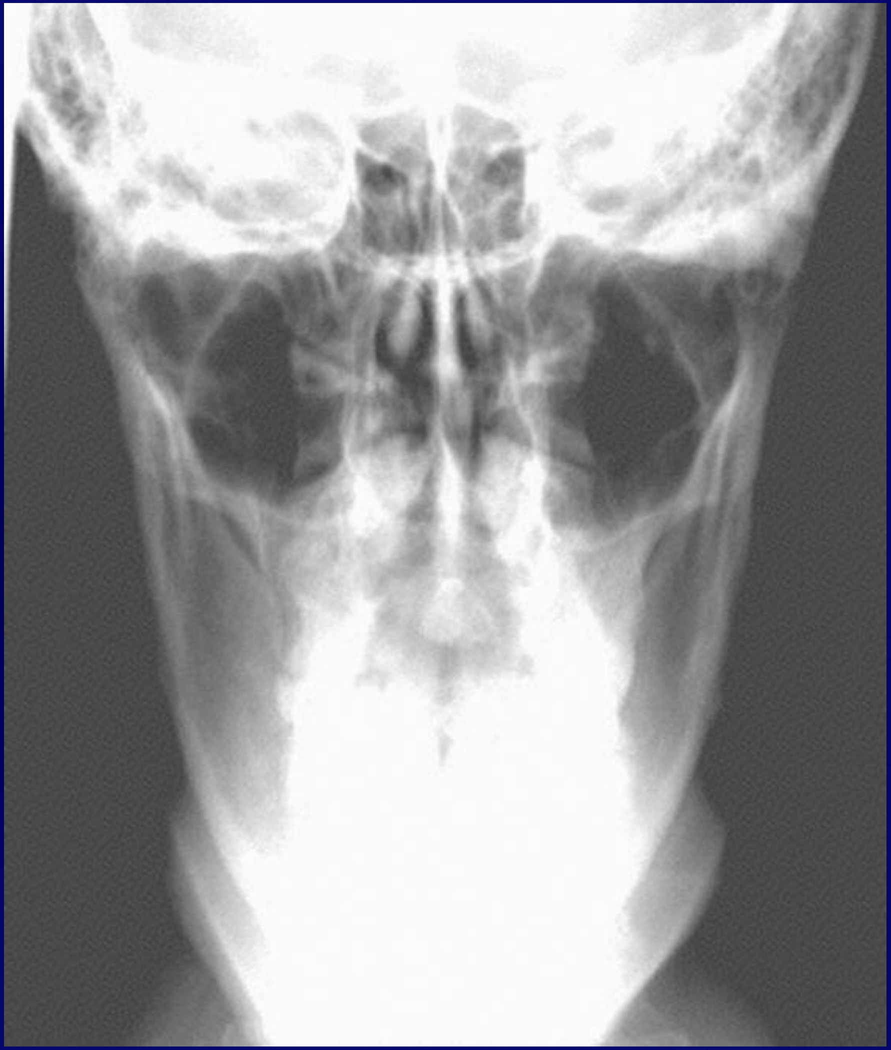


Exposure Factors Modification

By Professor Stelmark

After the lecture student will:

- Explain relationship between voltage waveform and radiographic exposure.
- List the general principles of the exposure compensation for pediatric patients.
- Utilize exposure compensation techniques for casts and splints imaging.
- Discern between patients with different body habitus.
- Define Anode Heel Effect.
- List destructive and additive pathologies.
- Explain applications of different compensating filters.

Appropriate exposure factor selection and its modification for variability in the patient are critical to the production of an optimal quality radiograph.

Effect of Voltage Waveform

There are five voltage waveforms: half-wave rectification, full-wave rectification, three-phase/six-pulse, three-phase/twelve-pulse, and high-frequency.

The relationship between x-ray quantity and type of high-voltage generator provides the basis for another rule of thumb used by radiologic technologists. If a radiographic technique calls for 72 kVp on single-phase equipment, then on three-phase equipment, approximately 64 kVp—a 12% reduction—will produce similar results.

High-frequency generators produce approximately the equivalent of a 16% increase in kVp, or slightly more than a doubling of mAs over single-phase power.

Pediatric Patients

Pediatric chest radiography requires the technologist to choose fast exposure times to stop diaphragm motion in patients who cannot or will not voluntarily suspend their breathing. This fast exposure time may eliminate the possibility of using automatic exposure control (AEC) systems for pediatric chest radiography.

MINIMUM KVP VALUES THAT ARE RECOMMENDED TO PENETRATE THE CHEST IN CHILDREN

Chronological Maturity	Minimum kVp to Penetrate the Part
Premature	50
Infant	55
Child	60

Exposure factors used for the adult skull can be used for pediatric patients 6 years of age and older because the bone density of these children has developed to an adult level. However, exposure factors must be modified for patients younger than 6 years of age. It is recommended that the radiographer decrease the kVp value by at least 15% to compensate for this lack of bone density.

For examinations of all other parts of pediatric patients' anatomy, general rules can be used for determining the proper exposure techniques. Recommendations for pediatric exposure techniques, which have been derived from technique charts established for adult.

Age (in Years)	Exposure Factor Adaptation
0-5	25% of mAs indicated for adults
6-12	50% of mAs indicated for adults

Casts and Splints

Casts and splints can be produced with materials that attenuate x-rays differently. Selecting appropriate exposure factors can be challenging because of the wide variation of materials used for these devices. The radiographer should pay close attention to both the type of material and how the cast or splint is used.

For severe fractures with significant displacement or fragmentation, a surgical procedure is required. The fracture site is exposed, and screws, plates, or rods are installed as needed to maintain alignment of the bony fragments until new bone growth can take place.

In many instances, minor fractures may be reduced in the ER and will need postreduction films once a cast is placed at the fracture site. Any limb with a cast will require an increase in exposure techniques because of the increased thickness of the part and the type of cast used. Plaster casts are thicker, heavier, and denser than fiberglass casts. Therefore, they will require the greatest increase in exposure techniques.

TYPE OF CAST	INCREASE IN EXPOSURE
Small to medium plaster cast	Increase mAs 50% to 60% or +5 to 7 kV
Large plaster cast	Increase mAs 100% or +8 to 10 kV
Fiberglass cast	Increase mAs 25% to 30% or + 3 to 4 kV

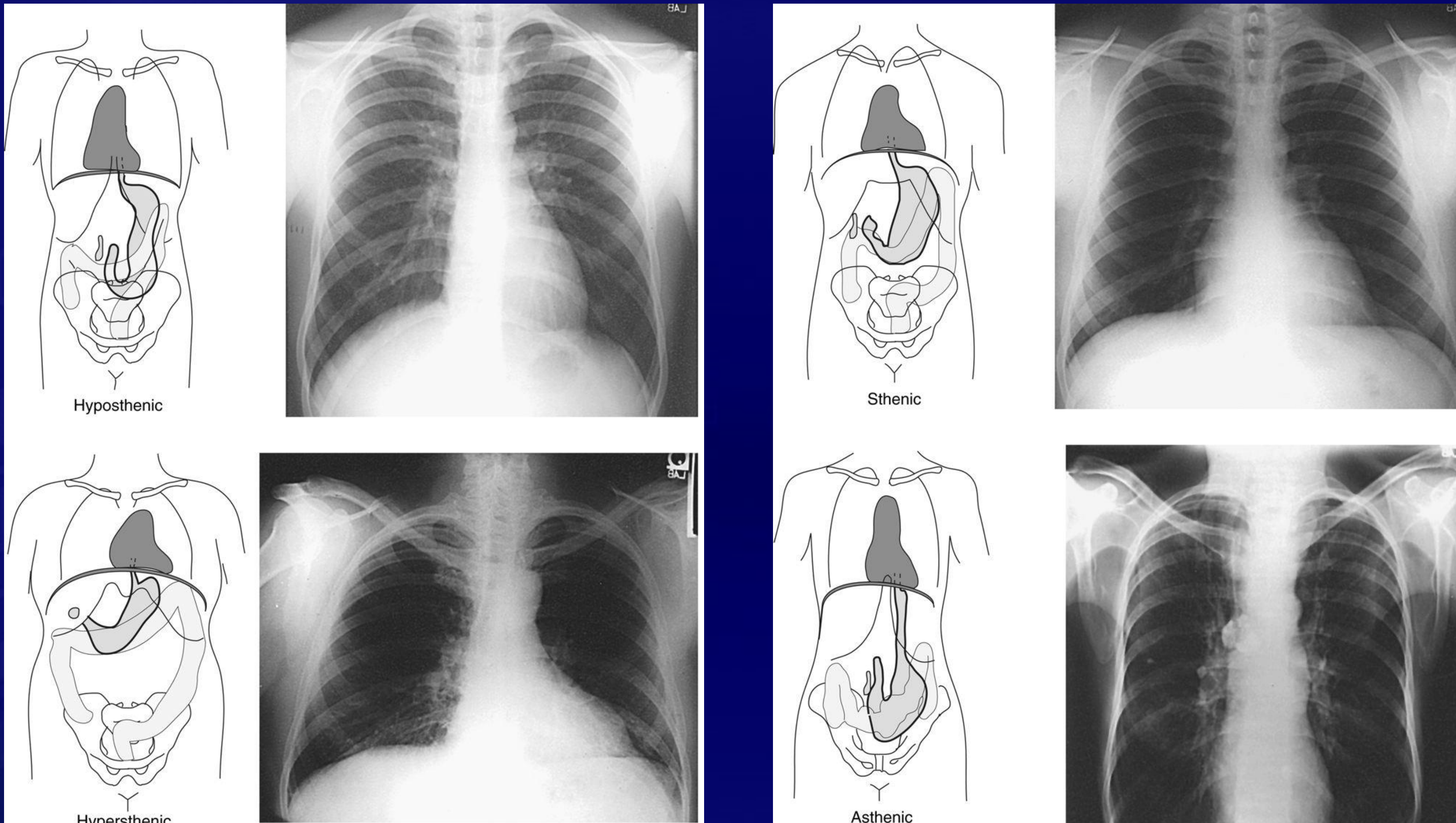
One method of approaching the exposure factor conversion is to consider whether the cast is still wet from application or whether it is dry. This approach states that an increase of 2 times the mAs is needed for dry plaster casts and an increase of 3 times the mAs is needed for wet plaster casts.

Splints

Splints present less of a problem in determining appropriate exposure factors than casts. Inflatable (air) and fiberglass splints do not require any increase in exposure. Wood, aluminum, and solid plastic splints may require that exposure factors be increased, but only if they are in the path of the primary beam. For example, if two pieces of wood are bound to the sides of a lower leg, no increase in exposure is necessary for an AP projection because the splint is not in the path of the primary beam and does not interfere with the radiographic image. Using the same example, if a lateral projection is produced, the splint is in the path of the primary beam and interferes with the radiographic imaging of the part. This necessitates an increase in mAs to produce a properly exposed radiograph.

Body Habitus

Body habitus refers to the general form or build of the body, including size. It is important for the radiographer to consider body habitus when establishing exposure techniques. There are four types of body habitus: sthenic, hyposthenic, hypersthenic, and asthenic.


Hyposthenic
Sthenic
Hypersthenic
Asthenic

Pathology

Pathologic conditions that can alter the absorption characteristics of the anatomic part being examined are divided into two categories. Additive diseases are diseases or conditions that increase the absorption characteristics of the part, making the part more difficult to penetrate. Destructive diseases are those diseases or conditions that decrease the absorption characteristics of the part, making the part less difficult to penetrate.

Generally speaking, it is necessary to increase kVp when radiographing parts that have been affected by additive diseases and to decrease kVp when radiographing parts that are affected by destructive diseases.

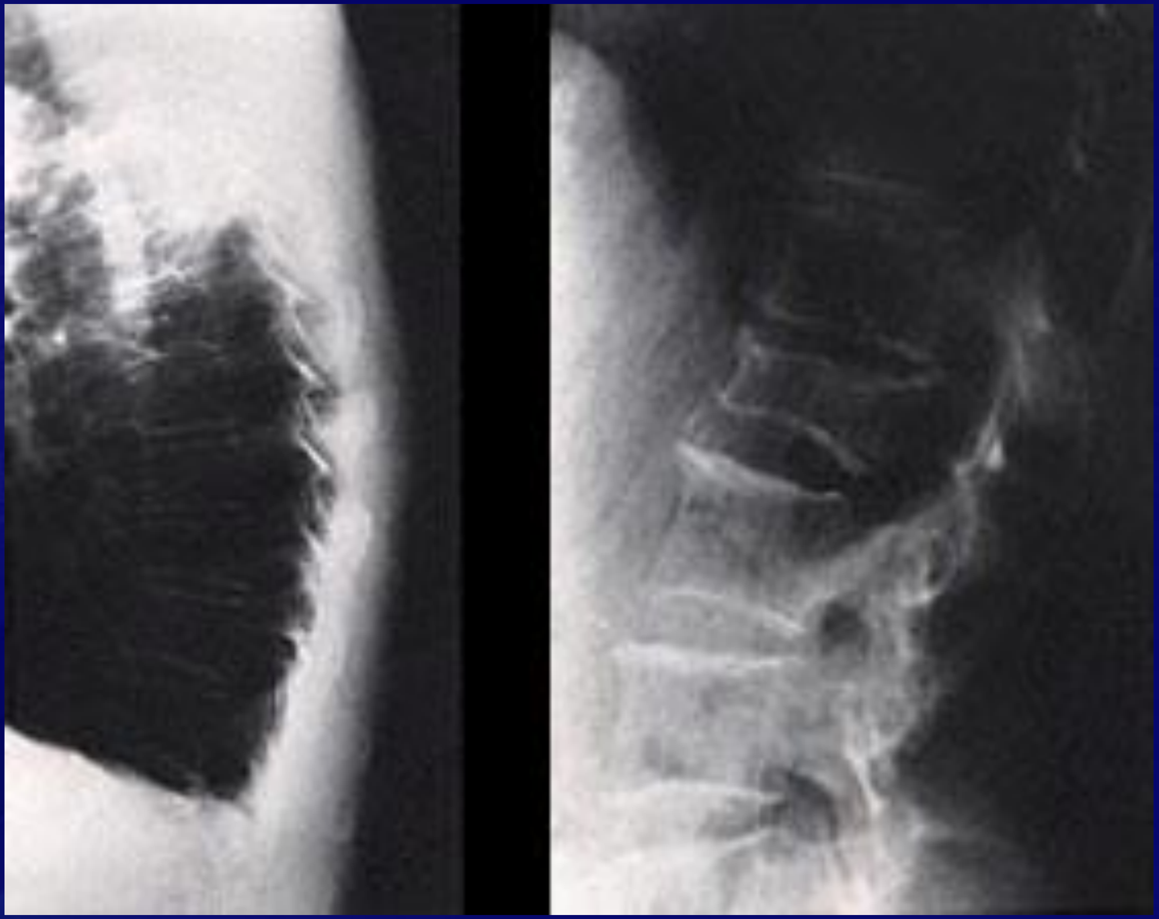
Additive Conditions	Destructive Conditions
Abdomen	
Aortic aneurysm	Bowel obstruction
Ascites	Free air
Cirrhosis	
Hypertrophy of some organs(e.g., splenomegaly)	
Chest	
Atelectasis	Emphysema
Congestive heart failure	Pneumothorax
Malignancy	
Pleural effusion	
Pneumonia	
Skeleton	
Hydrocephalus	Gout
Osteopetrosis	Osteoporosis
Nonspecific Sites	
Abscess	Atrophy
Edema	Emaciation
Sclerosis	Malnutrition

Pleural Effusion

Emphysema

Ascites

Osteoporosis



Osteopetrosis

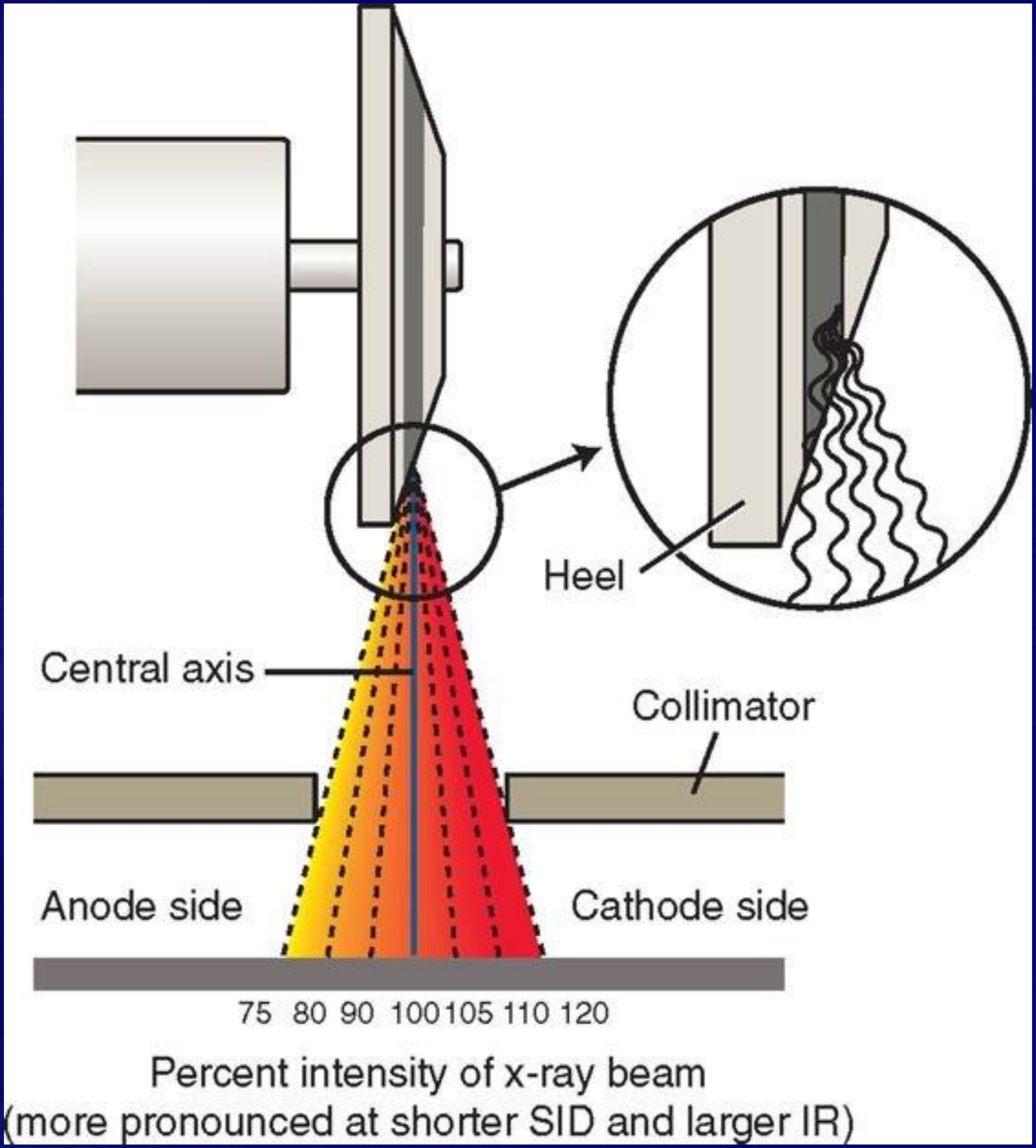
Intensity and the Anode Heel Effect

The intensity of radiation emitted from the cathode end of the x-ray tube is greater than that emitted at the anode end; this phenomenon is known as the ***anode heel*** *effect*. Greater attenuation or absorption of x-rays occurs at the **anode** end because of the angle of the **anode**; x-rays emitted from deeper within the **anode** must travel through more **anode** material before exiting; thus they are attenuated more.

Studies show that the difference in intensity from the cathode to the **anode** end of the x-ray field when a 17 inch (43 cm) image receptor (IR) is used at 40 inch (100 cm) SID can vary by as much as 45%, depending on the **anode** angle.

The **anode heel** effect is more pronounced when a short SID and a large field size are used.

Applying the **anode heel** effect to clinical practice will assist the technologist in obtaining quality images of body parts that exhibit significant variation in thickness along the longitudinal axis of the x-ray field. The patient should be positioned so that the **thicker portion of the part is at the cathode end** of the x-ray tube and the **thinner part is under the anode** (the cathode and **anode** ends of the x-ray tube usually are marked on the protective housing). The abdomen, thoracic spine, and long bones of the limbs (such as the femur and the tibia/fibula) are examples of structures that vary enough in thickness to warrant correct use of the **anode heel** effect.



Heel
Central axis
Collimator
Anode side
Cathode side
75 80 90 100 105 110 120
Percent intensity of x-ray beam
(more pronounced at shorter SID and larger IR)

PROJECTION	ANODE END	CATHODE END
Thoracic spine		
AP	Head	Feet
Femur		
AP and lateral	Feet	Head
Humerus		
AP and lateral	Elbow	Shoulder

Leg (tibia/fibula)		
AP and lateral	Ankle	Knee
Forearm		
AP and lateral	Wrist	Elbow

Compensating Filters

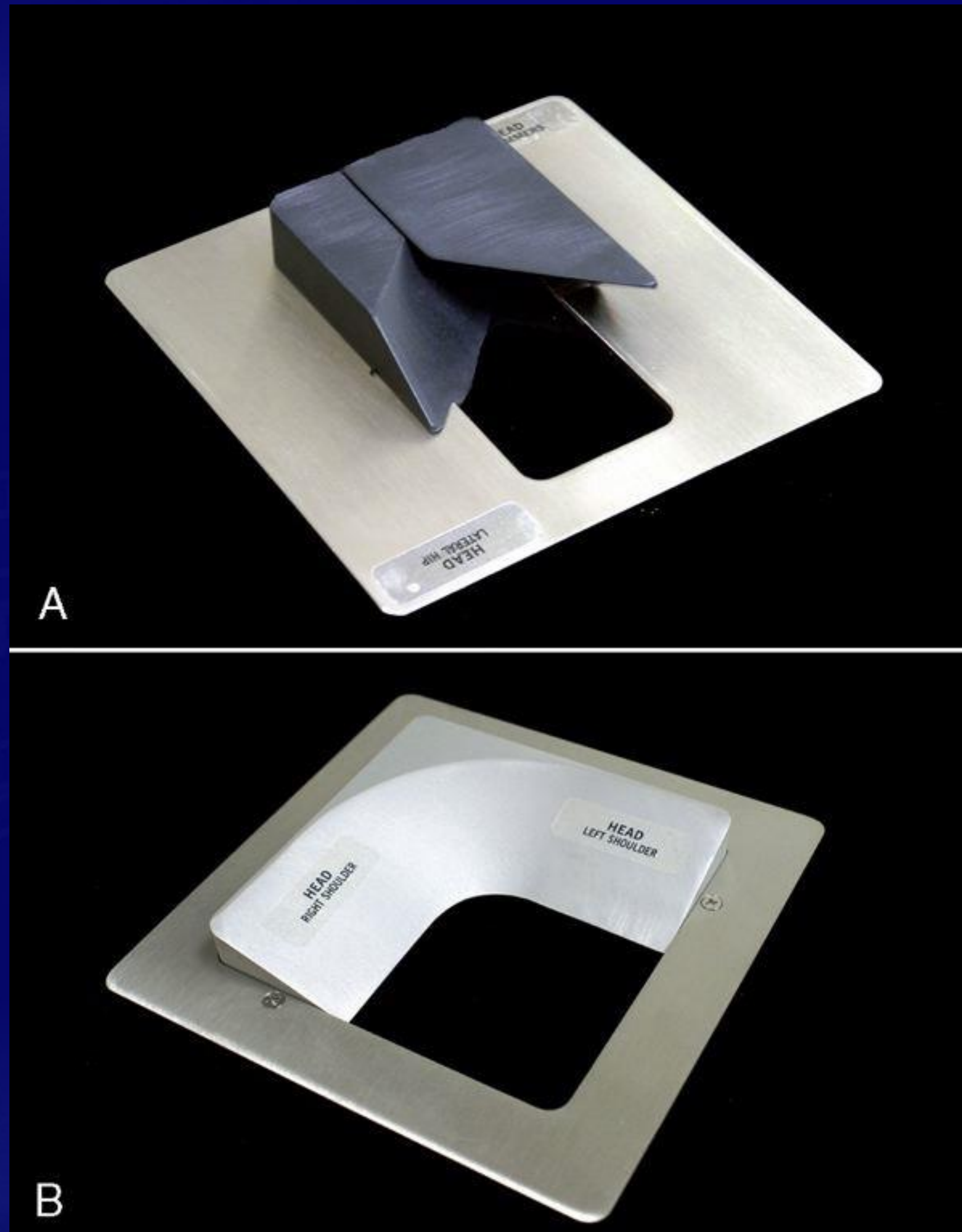
Body parts of varying anatomic density may result in an image that is partially overexposed or underexposed because the anatomic parts will attenuate the beam differently. This problem can be overcome through the use of *compensating filters*, which filter out a portion of the primary beam toward the thin or less dense part of the body that is being imaged. Several types of compensating filters are in use; most are made of aluminum; however, some include plastic as well.

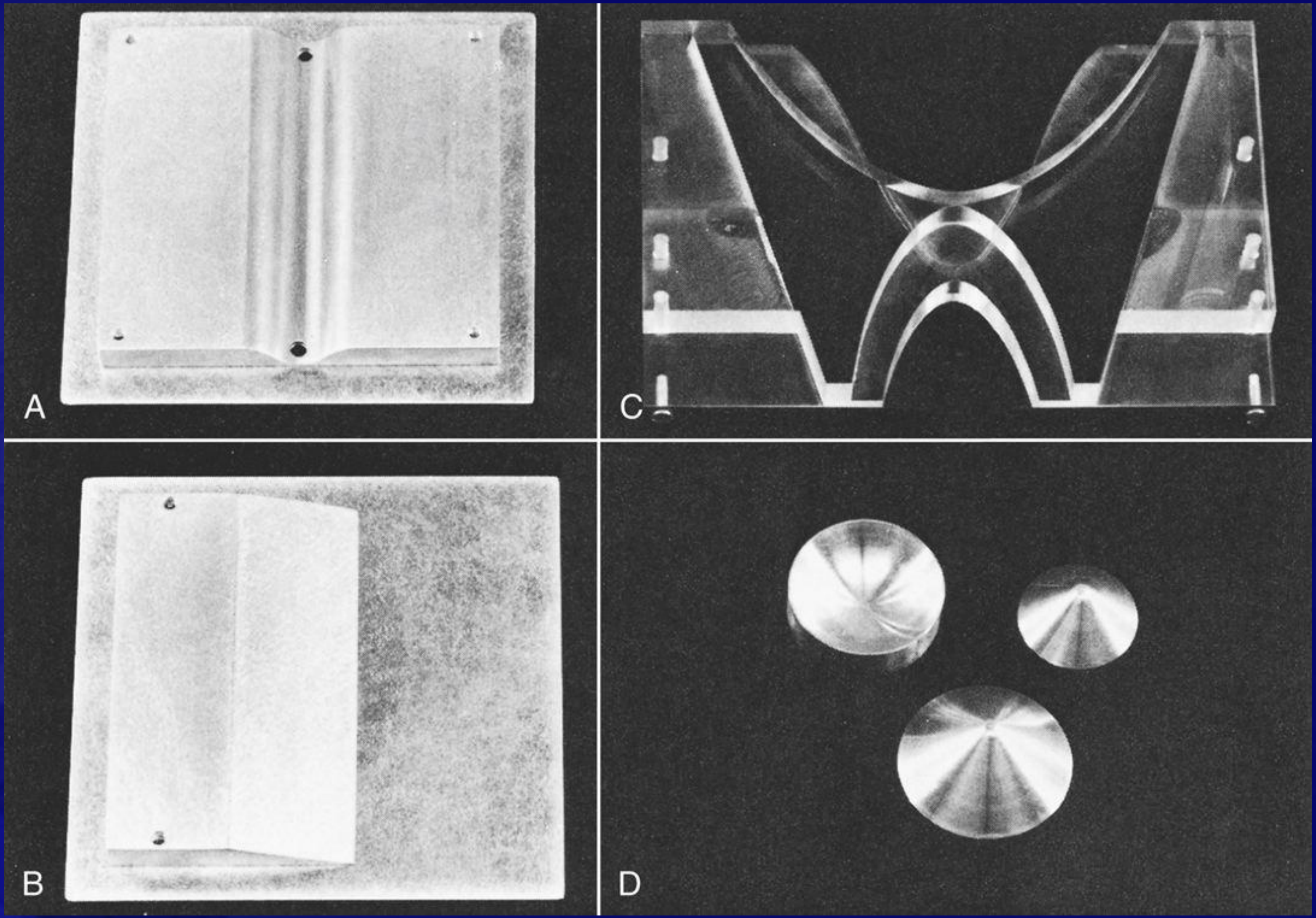
Compensating filters in common use include the following:

•Wedge filter: Mounts on the collimator; the thicker portion of the wedge is placed toward the least dense part of the anatomy to even out the densities. This filter has numerous applications; some of the most common include AP foot, AP thoracic spine, and axiolateral projection of the hip.

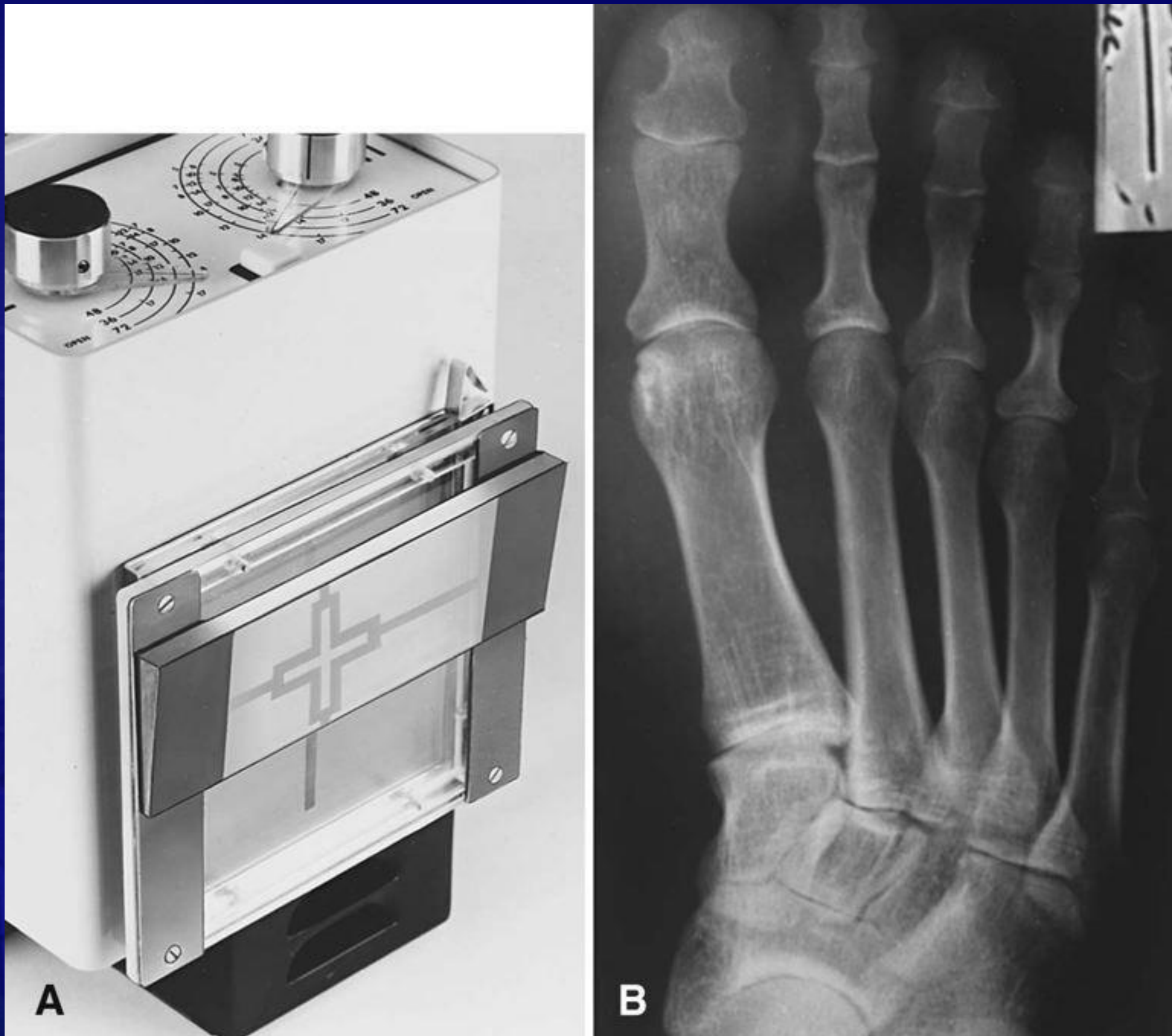
•Trough filter: Mounts on the collimator and is used for chest imaging. The thicker peripheral portions of the filter are placed to correspond to the anatomically less dense lungs; the thinner portion of the filter corresponds to the mediastinum.

•Boomerang filter: Is placed behind the patient and is used primarily for shoulder and upper thoracic spine radiography, where it provides improved visualization of soft tissues on the superior aspect of the shoulder and upper thoracic spine.


A
HEAD
LATERAL HIP
B
HEAD
RIGHT SHOULDER
HEAD
LEFT SHOULDER


A
B
C
D

Use of a wedge filter for examination of the foot


A
B


CR WITH FILTER
CR WITHOUT FILTER
AFTER - WITH FILTER
BEFORE - WITHOUT FILTER
A
B

Technique Guidance Systems

By Prof. Stelmark

Anatomic Programming

Anatomic programming, or anatomically programmed radiography (APR), refers to a radiographic system that allows the radiographer to select a particular button on the control panel that represents an anatomic area; a preprogrammed set of exposure factors is displayed and selected for use.

APR is controlled by an integrated circuit or computer chip that has been programmed with exposure factors for different projections and positions of different anatomic parts. Once an anatomic part and projection or position has been selected, the radiographer can adjust the exposure factors that are displayed.

APR and AEC are not related in their functions, other than as systems for making exposures. However, these two different systems are commonly combined on radiographic units because of their similar dependence on integrated computer circuitry. APR and AEC often are used in conjunction with one another. A radiographer can use APR to select a projection or position for a specific anatomic part and view the kVp, mA, and exposure time for manual technique.

When APR is used in conjunction with AEC on some radiographic units, the APR system not only selects and displays manual exposure factors but also selects and displays the AEC detectors to be used for a specific radiographic examination.

For example, pressing the Lungs PA button results in selection of 120 kVp, the upright Bucky, and the two outside AEC detectors. As with AEC, APR is a system that automates some of the work of radiography. However, the individual judgment and discretion of the radiographer is still required to use the APR system correctly for the production of optimal quality image.


up at the beginning of every workday.
The warm-up procedure must be repeated if no x-ray exposures have been made for more than five (5) hours.
7. Make one exposure using 70 kV, 100 mA & 1,000 ms
8. Wait 30 seconds
9. Make one exposure using 70 kV, 100 mA & 1,000 ms
PHILIPS
WARNING
RESET
AEC
77kV
200 mA
pelvis
hip
hip+femur
knee
ankle
lower leg
for.obt./ala pr
Optimus
PHILIPS

Exposure Technique Charts and Radiographic Quality

A properly designed and used technique chart standardizes the selection of exposure factors to help the radiographer produce consistent quality radiographs while minimizing patient exposure.

Exposure Technique Charts and Digital Imaging Systems

Exposure technique charts are just as important for digital imaging because digital systems have a wide dynamic range and can compensate for exposure technique errors. Technique charts should be developed and used with all types of radiographic imaging systems to maintain patient radiation exposure as low as reasonably achievable.

CONDITIONS

A technique chart presents exposure factors that are to be used for a particular examination based on the type of radiographic equipment. Technique charts help ensure that consistent image quality is achieved throughout the entire radiology department; they also decrease the number of repeat radiographic studies needed and therefore decrease the patient's exposure.

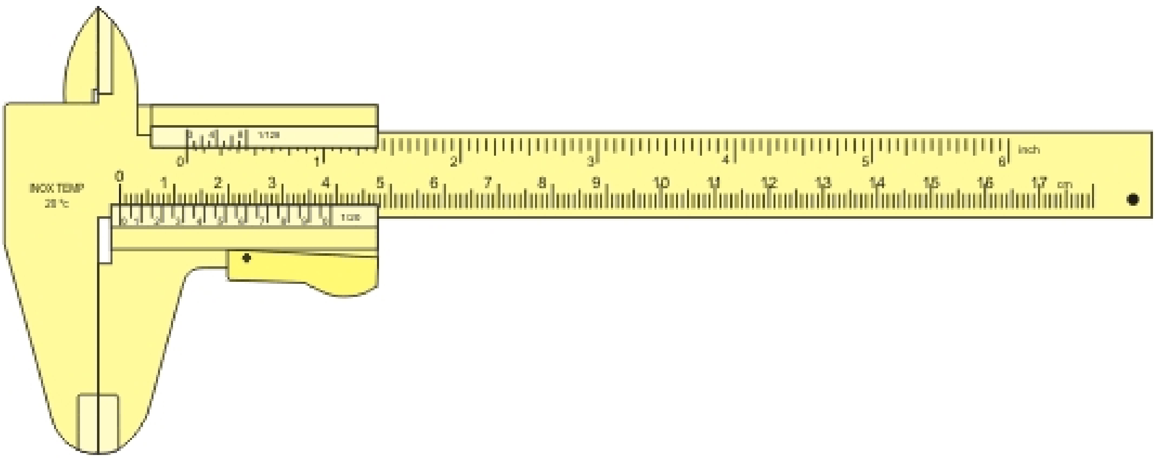
Technique charts do not replace the critical thinking skills required of the radiographer. The radiographer must continue to use individual judgment and discretion in properly selecting exposure factors for each patient and type of examination. The radiographer's primary task is to produce the highest quality radiograph while delivering the least amount of radiation exposure. Technique charts are designed for the average or typical patient and do not account for unusual circumstances. These atypical conditions require accurate patient assessment and appropriate exposure technique adjustment by the radiographer.

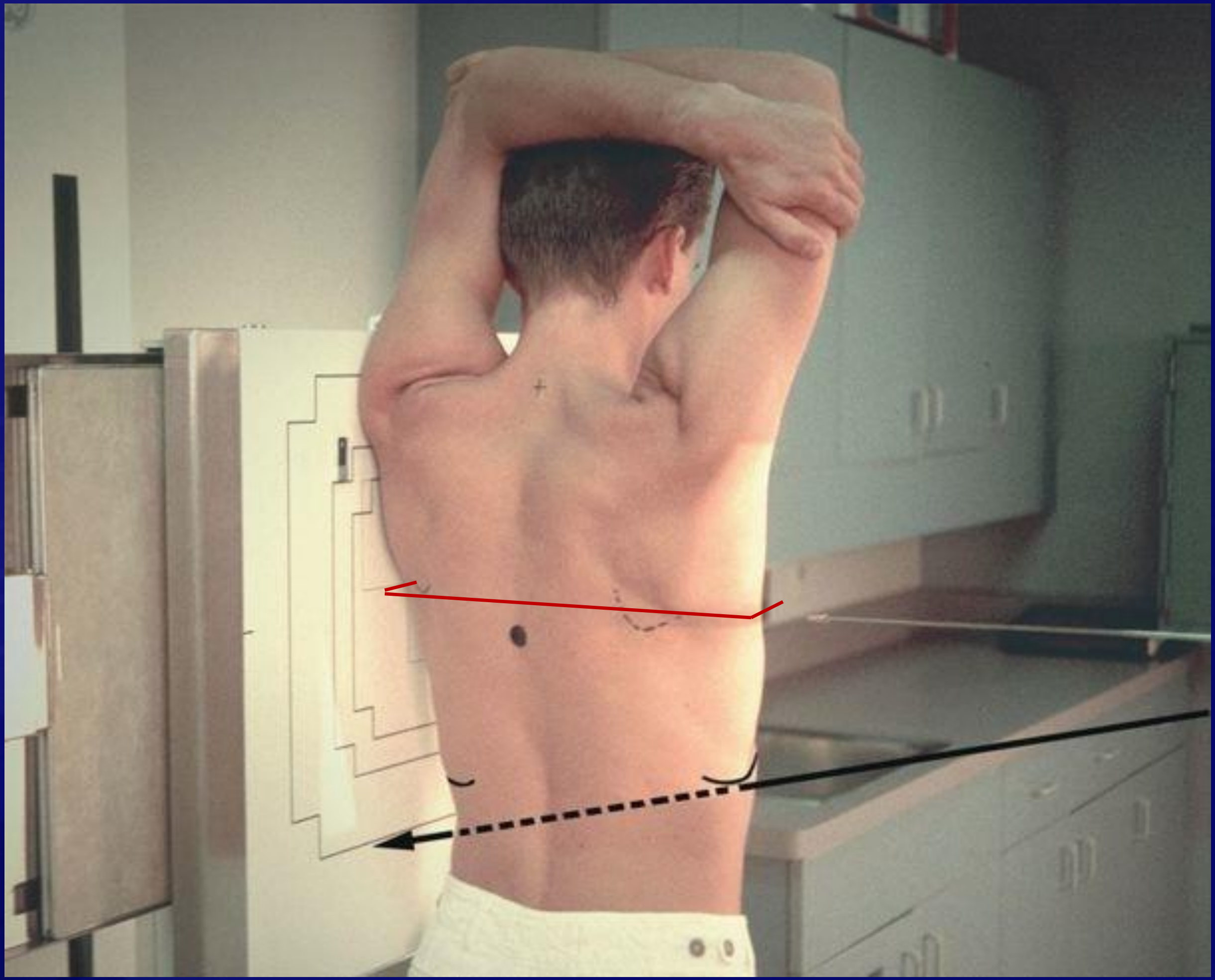
Technique Chart Formulation Requirements:

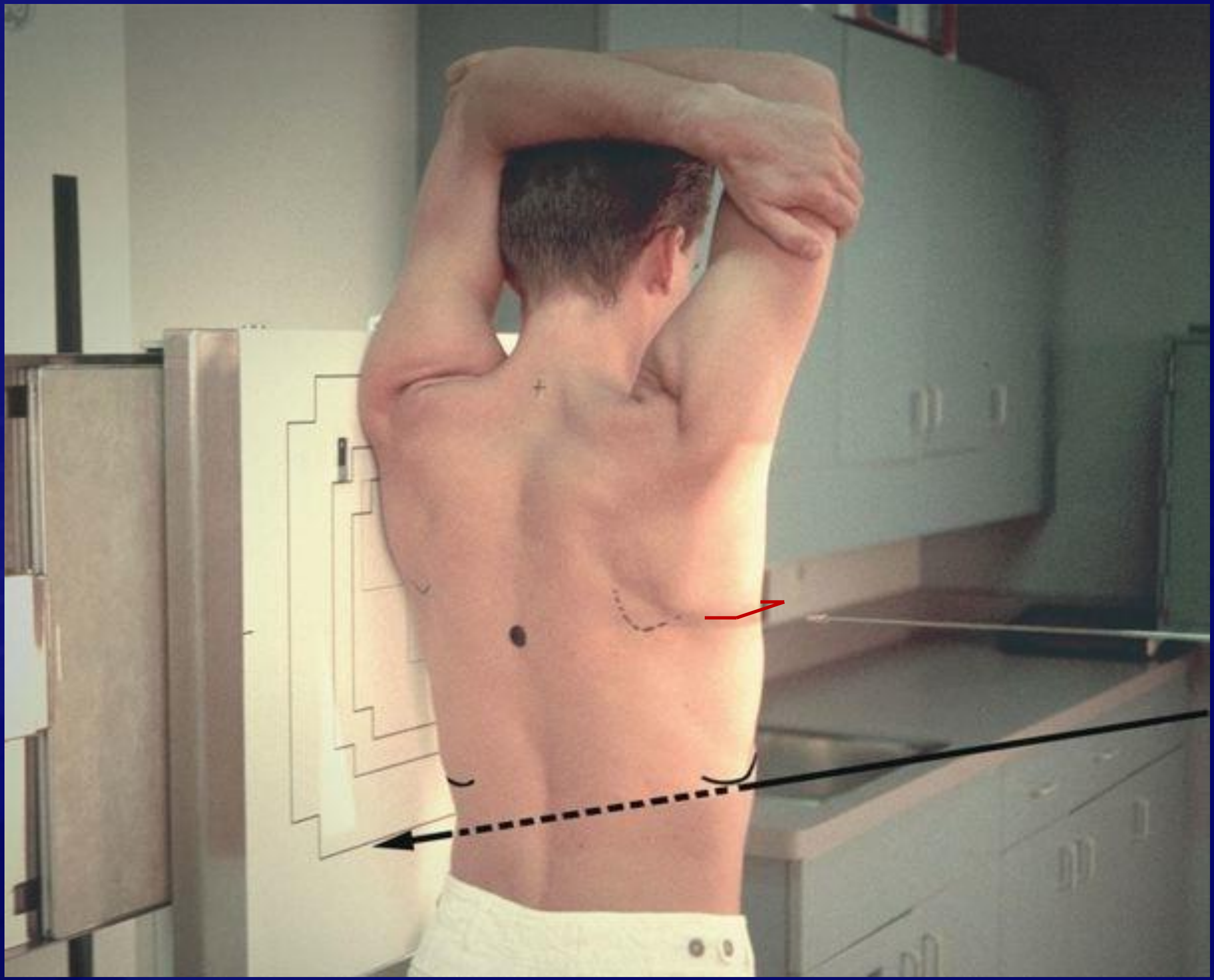
- A technique chart should be established for each x-ray tube including portable unit.
- Departmental standards for radiographic quality should be established.
- The radiographic equipment for which the charts are developed must be calibrated.
- Image processing must be consistent throughout the department to produce the proper radiographic density and contrast.

Accurate measurement of part thickness is critical to the effective use of exposure technique charts.

Calipers are devices that measure part thickness and should be readily accessible in every radiographic room. In addition, the technique chart should specify the exact location for measuring part thickness. Part measurement may be performed at the location of the CR midpoint or the thickest portion of the area to be radiographed. Errors in part thickness measurement are one of the more common mistakes made when one is consulting technique charts.


INOX TEMP
20 °C
inch
cm
1/128
1/20






LEFT

Factors Standardized in a Technique Chart:

Anatomic part:

Grid ratio

Kilovoltage peak

Milliamperage

Central ray location

Part thickness and measuring point

Type of image receptor

Position or projection

Focal spot size

Source-to-image receptor distance

Types of Technique Charts

Two primary types of exposure technique charts exist: fixed kVp/variable mAs and variable kVp/fixed mAs. Each type of chart has different characteristics, and both have advantages and disadvantages. Technique charts can be differentiated by the need for measurement precision, contrast variability, patient dose, and heat load on the x-ray tube.

Design Type	*Part Measurement*	*Radiographic Contrast*	*Patient Dose*	*Tube Heat Load*
Variable kVp/fixed mAs	Critical	Variable	Higher	Increased
Fixed kVp/variable mAs	Less critical	Uniform	Lower	Decreased

VARIABLE KVP/FIXED MAS TECHNIQUE CHART

The variable kVp/fixed mAs technique chart is based on the concept that kVp can be increased as the anatomic part size increases. Specifically, the baseline kVp is increased by 2 for every 1-cm increase in part thickness, whereas the mAs is maintained. The baseline kVp is the original kVp value predetermined for the anatomic area to be radiographed. The baseline kVp is then adjusted for changes in part thickness.

Determination of the baseline kilovoltage for each anatomic area has not been standardized. Historically, a variety of methods have been used to determine the baseline kVp value. The goal is to determine a kVp value that adequately penetrates the anatomic part when using a 2-kVp adjustment for every 1-cm change in tissue thickness. The baseline kVp value can be determined experimentally with the use of radiographic phantoms.

Anatomic part	**Knee**	Image receptor	CR
Projection	**AP**	Table top/Bucky	**Bucky**
Measuring point	**Midpatella**	Grid ratio	**12:1**
Source-to-image receptor distance	**40 inches**	Focal spot size	**Small**

cm	kVp	mAs
10	63	20
11	65	20
12	67	20
13	69	20
14	71	20
15	73	20
16	75	20
17	77	20
18	79	20

Variable kVp technique charts may be more effective for pediatric patients or when small extremities are being imaged.

FIXED KVP/VARIABLE MAS TECHNIQUE CHART

The fixed kVp/variable mAs technique chart uses the concept of selecting an optimal kVp value that is required for the radiographic examination and adjusting the mAs for variations in part thickness. Optimal kVp can be described as the kVp value that is high enough to ensure penetration of the part but not too high to diminish radiographic contrast. For this type of chart, the optimal kVp value for each part is indicated, and mAs is varied as a function of part thickness.

Anatomic part	**Knee**	Image receptor	CR
Projection	**AP**	Table top/Bucky	**Bucky**
Measuring point	**Midpatella**	Grid ratio	**12:1**
Source-to-image receptor distance	**40 inches**	Focal spot size	**Small**

cm	**kVp**	**mAs**
10–13	73	10
14–17	73	20
18–21	73	40

A general guideline is for every 4 to 5 cm 50% of the x-ray beam is attenuated

Accuracy of measurement is less critical with fixed kVp/variable mAs technique charts than with variable kVp/fixed mAs technique charts.

The fixed kVp/variable mAs technique chart has the advantages of easier use, more consistency in the production of quality radiographs, greater assurance of adequate penetration of all anatomic parts, uniform radiographic contrast, and increased accuracy with extreme variation in size of the anatomic part.

SMALL mAs **(- 5 CM)** ***1, 2, 3, 4, 5 cm***	***AVG mAs*** ***6, 7, 8, 9, 10 cm***	**LRG mAs** **(+ 5 CM)** ***11, 12, 13,14, 15 cm***

Abbreviations: GD= Grid, TT = Tabletop, NG = Non Grid, SFS= small focus, LGF = Large focus			Extremities ***Target EI = 2.4 (2.3 -2.5)*** Total mAs by Part Size				
PROCEDURE	***NOTES***	***VIEW***	**kVp**	**Avg cm**	**SMALL mAs (- 5 CM)** ***1, 2, 3, 4, 5 cm***	***AVG mAs*** ***6, 7, 8, 9, 10 cm***	**LRG mAs (+ 5 CM)** ***11, 12, 13,14, 15 cm***
Hand	PA / All fingers		**64**	8 cm	2.5	**5**	10
	SFS 40" TT	OBL	**64**	9 cm	3	**6**	12
		Fanned Lat	**64**	14 cm	5	**10**	20

Once optimal kVp values are established, fixed kVp/variable mAs technique charts alter the mAs for variations in thickness of the anatomic part. Because x-rays are attenuated exponentially, a general guideline is for every 4- to 5-cm change in part thickness; the mAs should be adjusted by a factor of 2. Using the previous example for a patient's knee measuring 10 cm and an optimal kVp, the exposure technique would be 73 kVp at 10 mAs, 400 speed image receptor with a 12:1 table Bucky grid. A patient with a knee measuring 14 cm would then require a change only in the mAs, from 10 to 20 (a 4-cm increase in part thickness requires a doubling of the mAs).

Accuracy of measurement is less critical with fixed kVp/variable mAs technique charts than with variable kVp/fixed mAs technique charts.

The fixed kVp/variable mAs technique chart has the advantages of easier use, more consistency in the production of quality radiographs, greater assurance of adequate penetration of all anatomic parts, uniform radiographic contrast, and increased accuracy with extreme variation in size of the anatomic part.

Determine the correct kVp

1. Minimum kVp (single phase) = [part thickness (cm) x 2] + 30 kVp
2. Minimum kVp (Triple phase) = [part thickness (cm) x 2] + 25 kVp

Determine the correct mAs

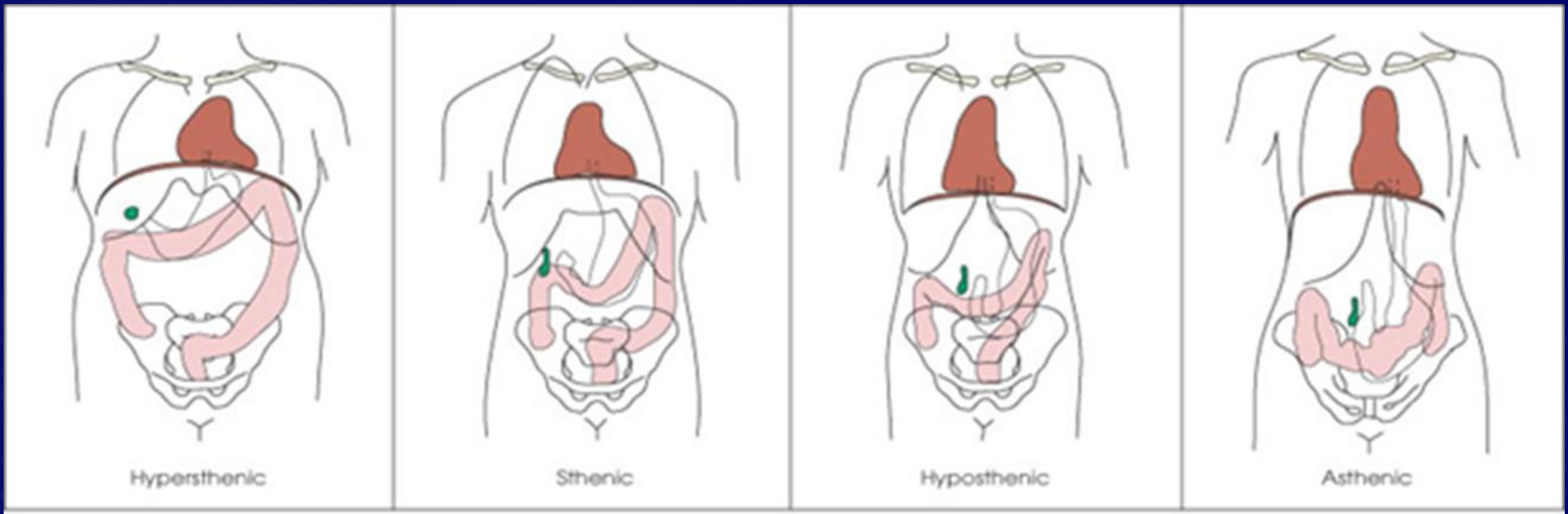
Select three possible mAs settings:

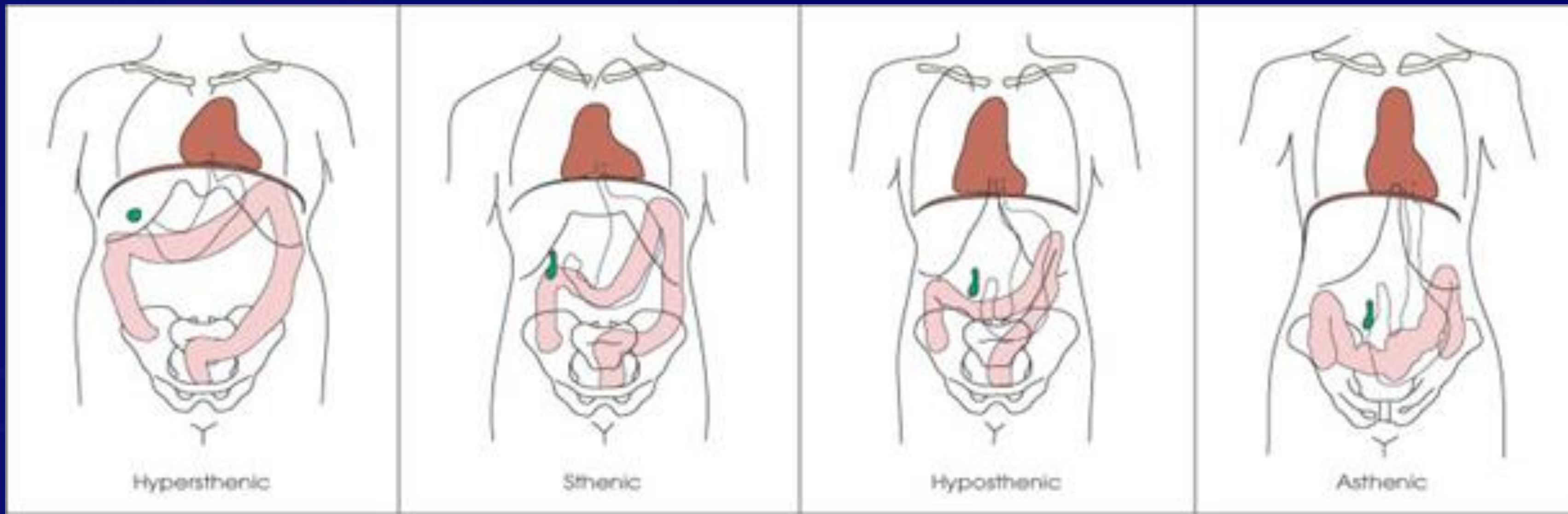
1. Expected mAs
2. Half of the expected mAs
3. Double the expected mAs

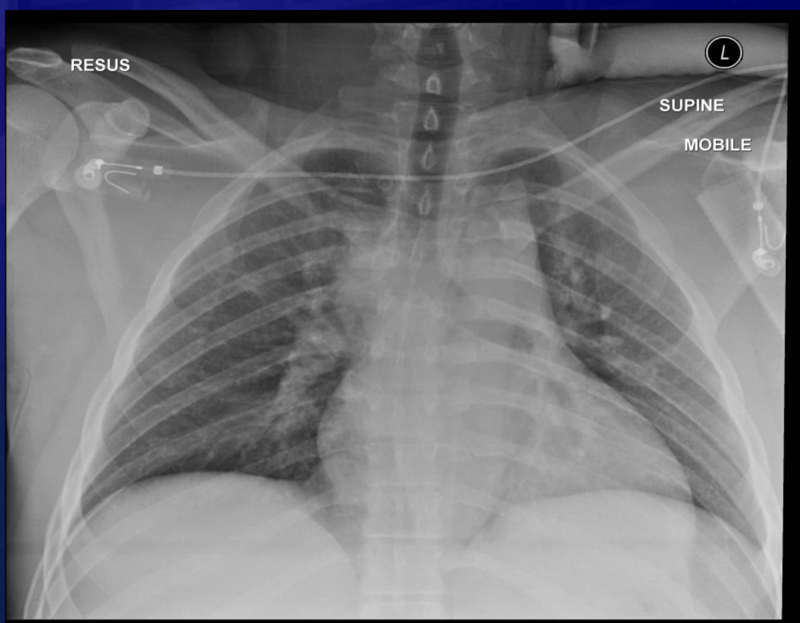
Special Considerations

Appropriate exposure factor selection and its modification for variability in the patient are critical to the production of a quality radiograph. Thus the radiographer must be able to recognize a multitude of patient and equipment variables and have a thorough understanding of how these variables affect the resulting radiograph to make adjustments to produce a quality image.

- Projection and position
- Body habitus
- Casts and splints
- Pathologic conditions


Hypersthenic
Sthenic
Hyposthenic
Asthenic


Hypersthenic
Sthenic
Hyposthenic
Asthenic


RESUS
L
SUPINE
MOBILE

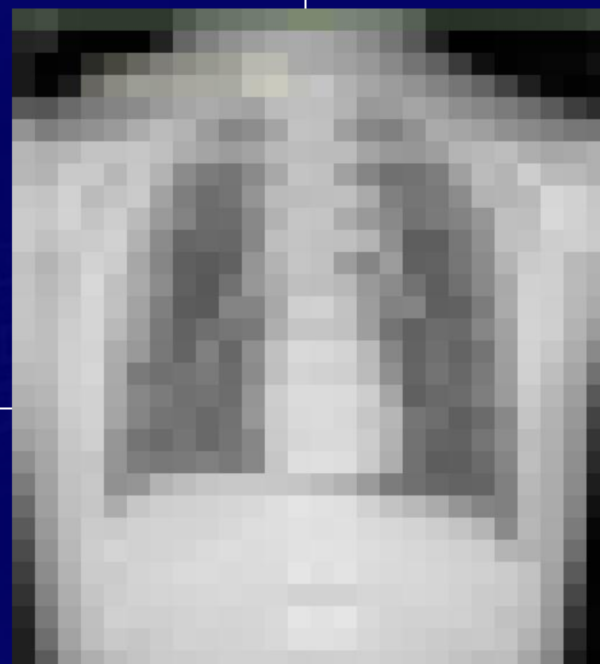
Digital Image Quality

TEMPORAL RESOLUTION

SPATIAL RESOLUTION

CONTRAST RESOLUTION

NOISE



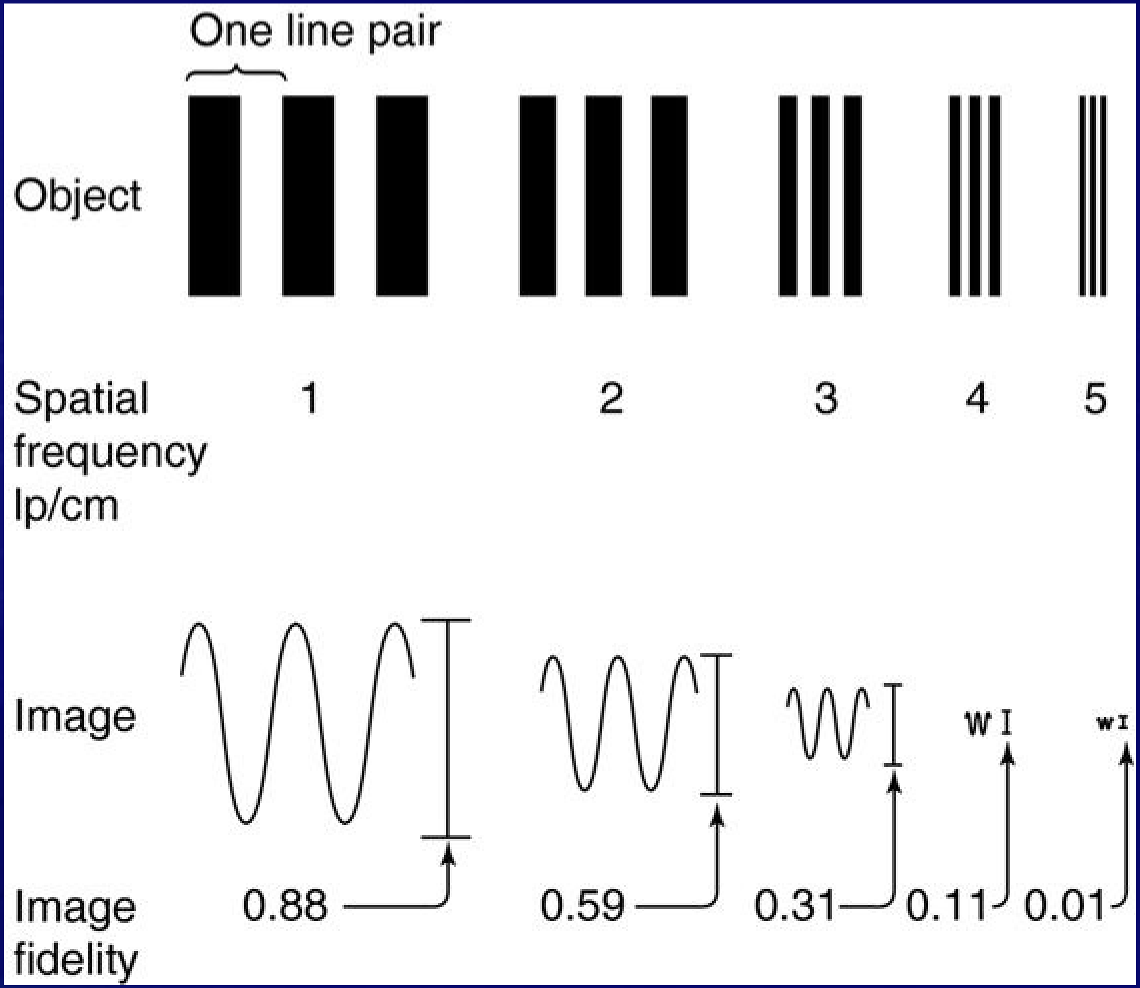
RADIATION DOSE

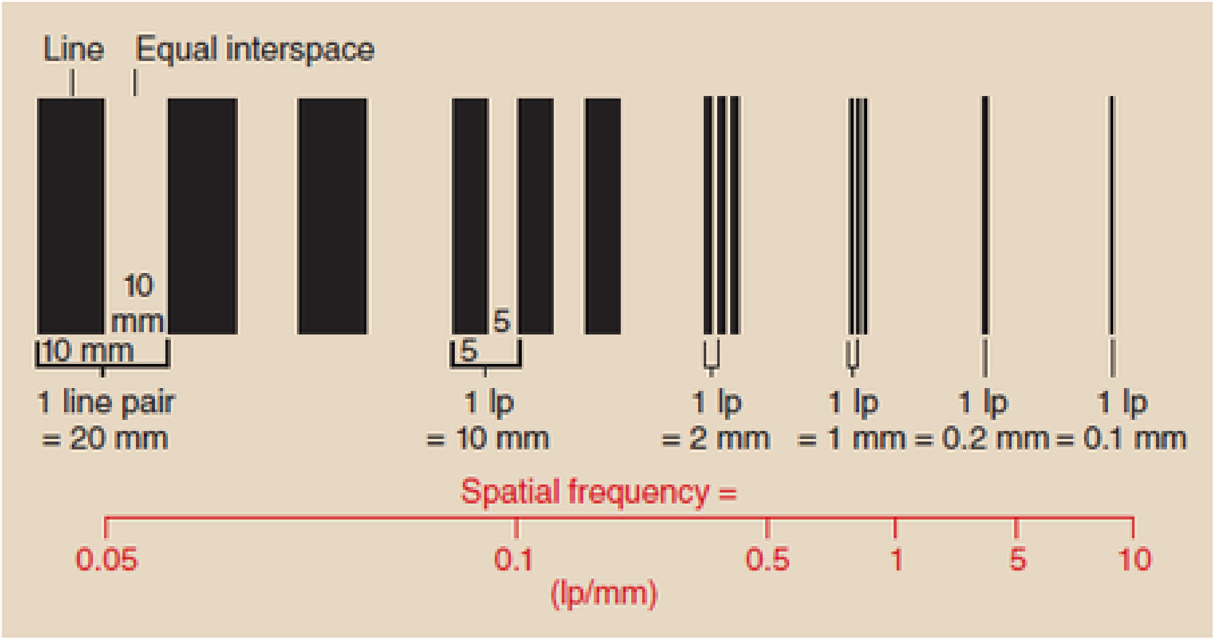
IMAGE ARTIFACTS

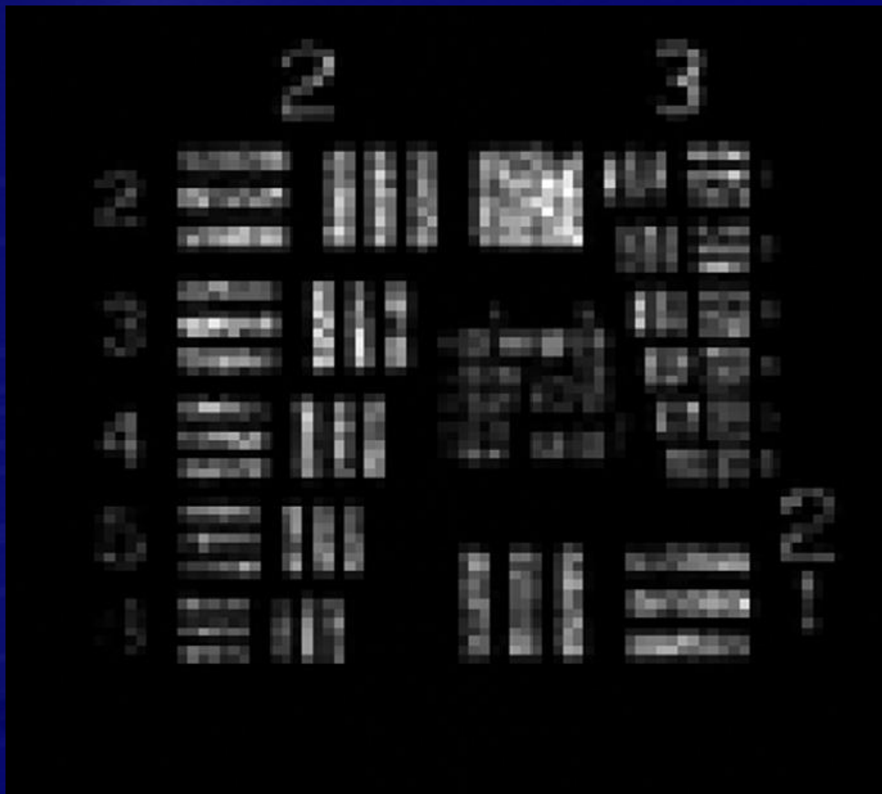
SPATIAL RESOLUTION

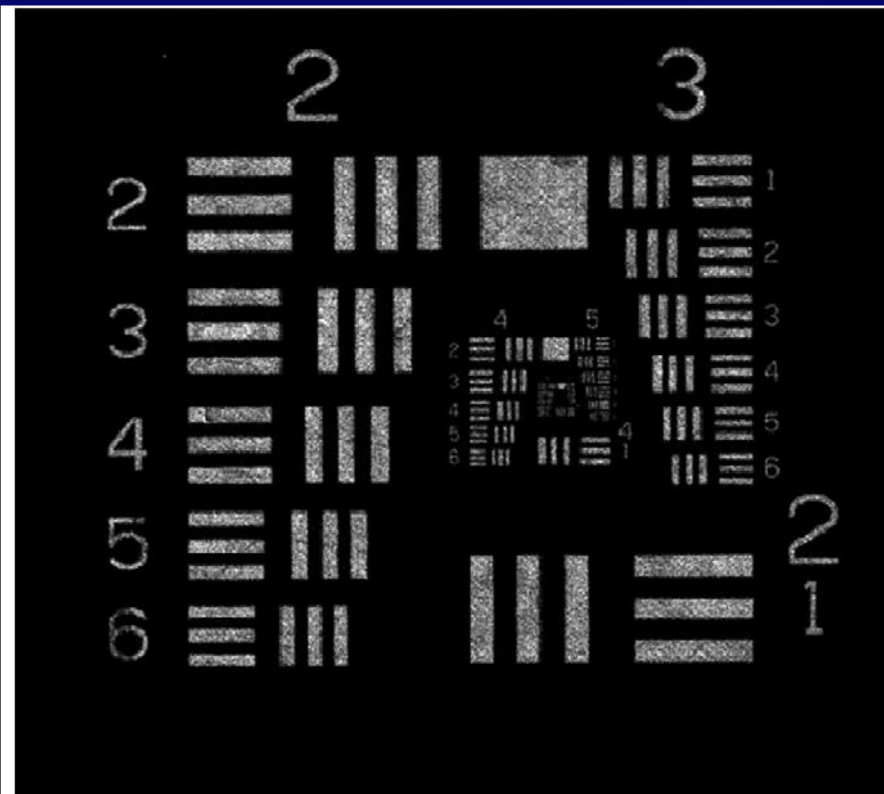
Spatial resolution of a digital system describes the system's ability to resolve closely placed objects that are significantly different from their background.

A bar pattern (object) consists of line pairs (lp, one line pair equals one bar plus one space). The number of line pairs per unit length is called the spatial frequency. Large objects have a low spatial frequency, whereas small objects have a high spatial frequency.




Line
Equal interspace
10 mm
10 mm
1 line pair = 20 mm
5
5
1 lp = 10 mm
1 lp = 2 mm
1 lp = 1 mm
1 lp = 0.2 mm
1 lp = 0.1 mm
Spatial frequency =
0.05
0.1
0.5
1
5
10
(lp/mm)


2
3
2
3
4
5
6
2
1


2
3
2
3
4
5
6
1
2
3
4
5
6
4
5
2
3
4
5
6
4
1
2
1

Factors Affecting Spatial Resolution

- Reconstruction Algorithm
- FOV
- Matrix size
- FSS
- SID
- OID
- Detector size
- Sampling frequency

Reconstruction Algorithm

smooth

standard

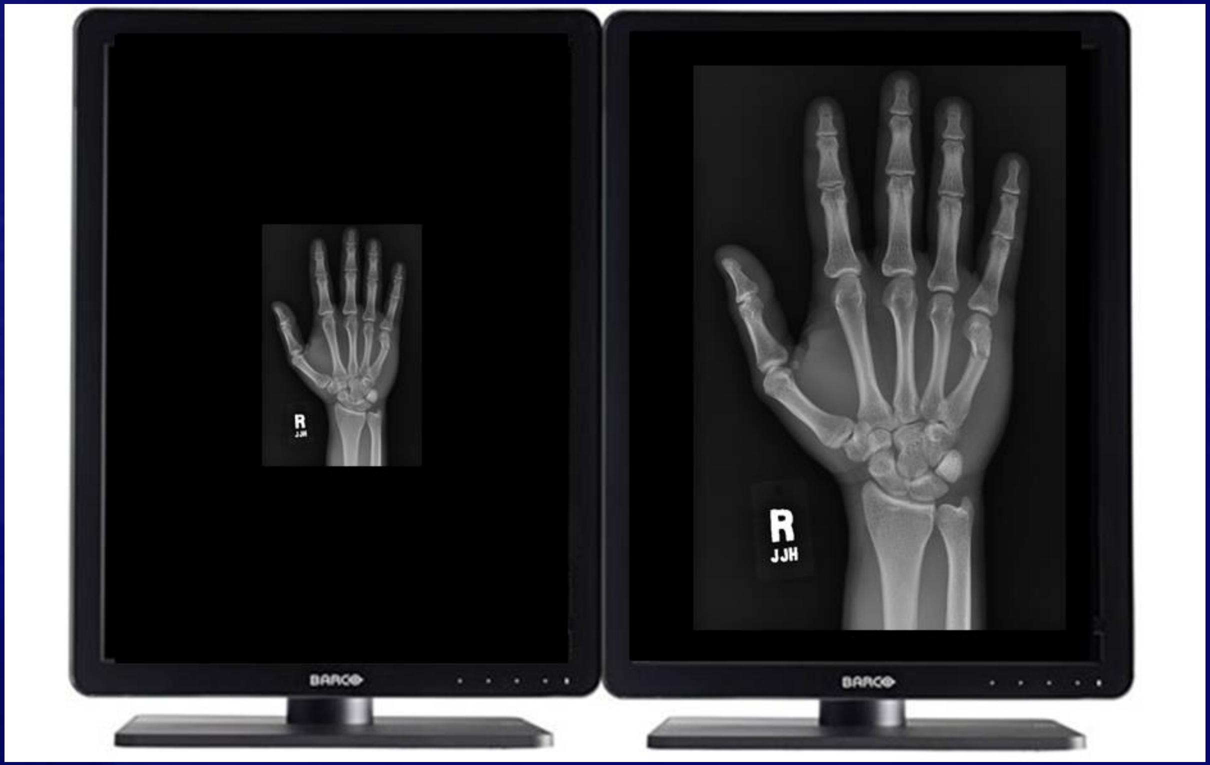
sharp

FOV

14 x 17

10 x 12

DFOV

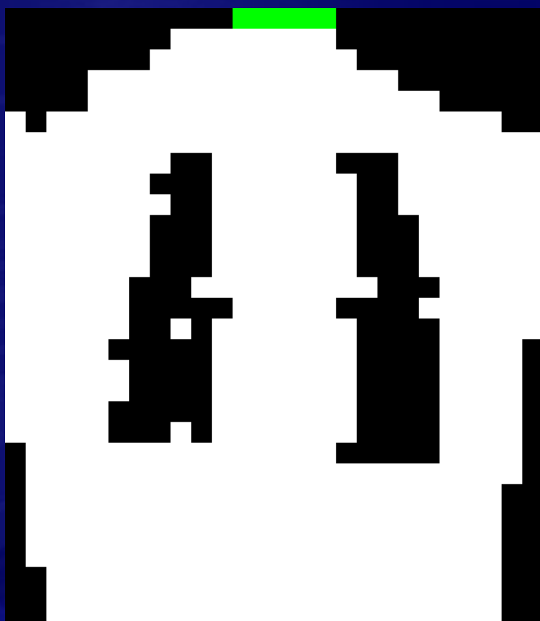




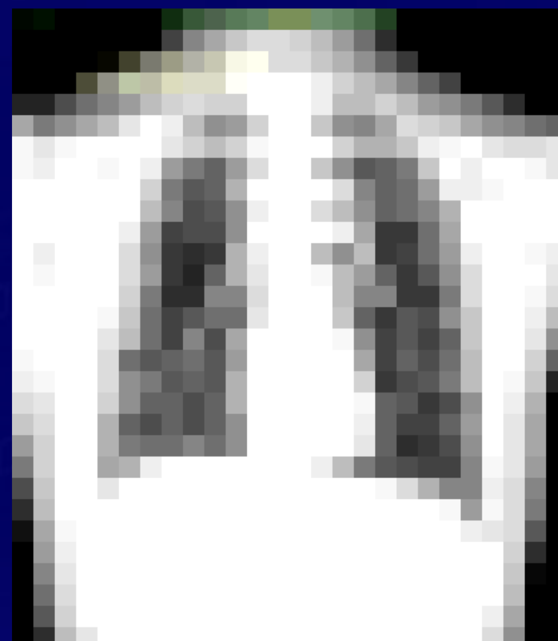


Matrix

64 x 64



256 x 256



1048 x 1048

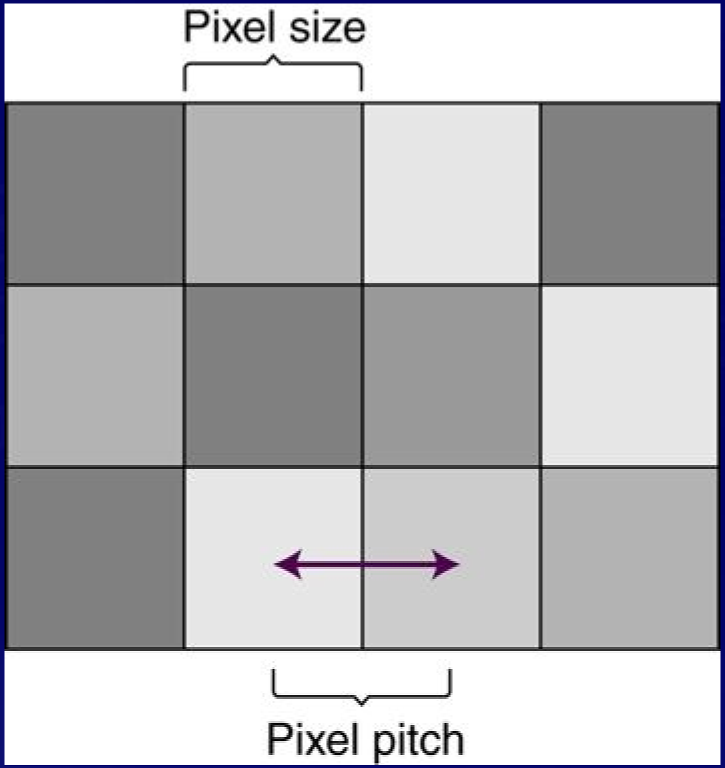
A digital image is recorded as a matrix or combination of rows and columns (array) of small, usually square, “picture elements” called pixels. The size of the pixel is measured in microns (0.001 mm). Each pixel is recorded as a single numeric value, which is represented as a single brightness level on a display monitor. The location of the pixel within the image matrix corresponds to an area within the patient or volume of tissue

For a given anatomic area, or field of view (FOV), a matrix size of 1024 × 1024 has 1,048,576 individual pixels; a matrix size of 2048 × 2048 has 4,194,304 pixels. Digital image quality is improved with a larger matrix size that includes a greater number of smaller pixels Although image quality is improved for a larger matrix size and smaller pixels, computer processing time, network transmission time, and digital storage space increase as the matrix size increases.

A system that can digitize and display a greater number of pixels has better **spatial resolution**. An image with increased spatial resolution increases the visibility of recorded detail and the ability to resolve small structures.

Pixel density
The number of pixels per unit area

The distance measured from the center of a pixel to an adjacent pixel determines the pixel pitch or pixel spacing

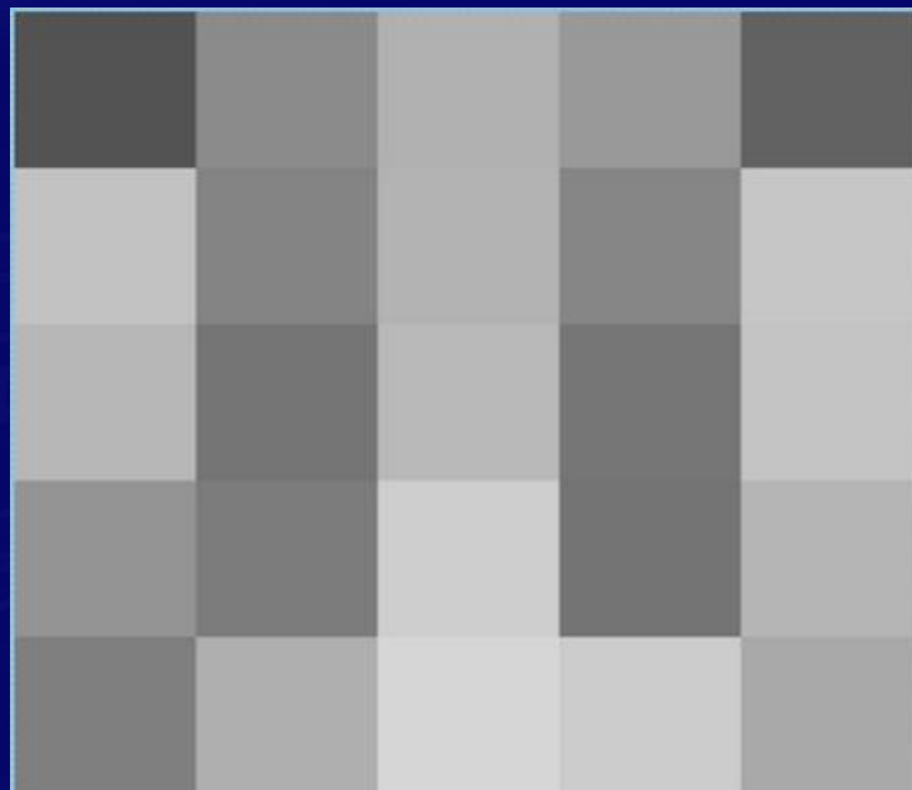


Increasing the pixel density and decreasing the pixel pitch increases spatial resolution. Decreasing pixel density and increasing pixel pitch decreases spatial resolution.

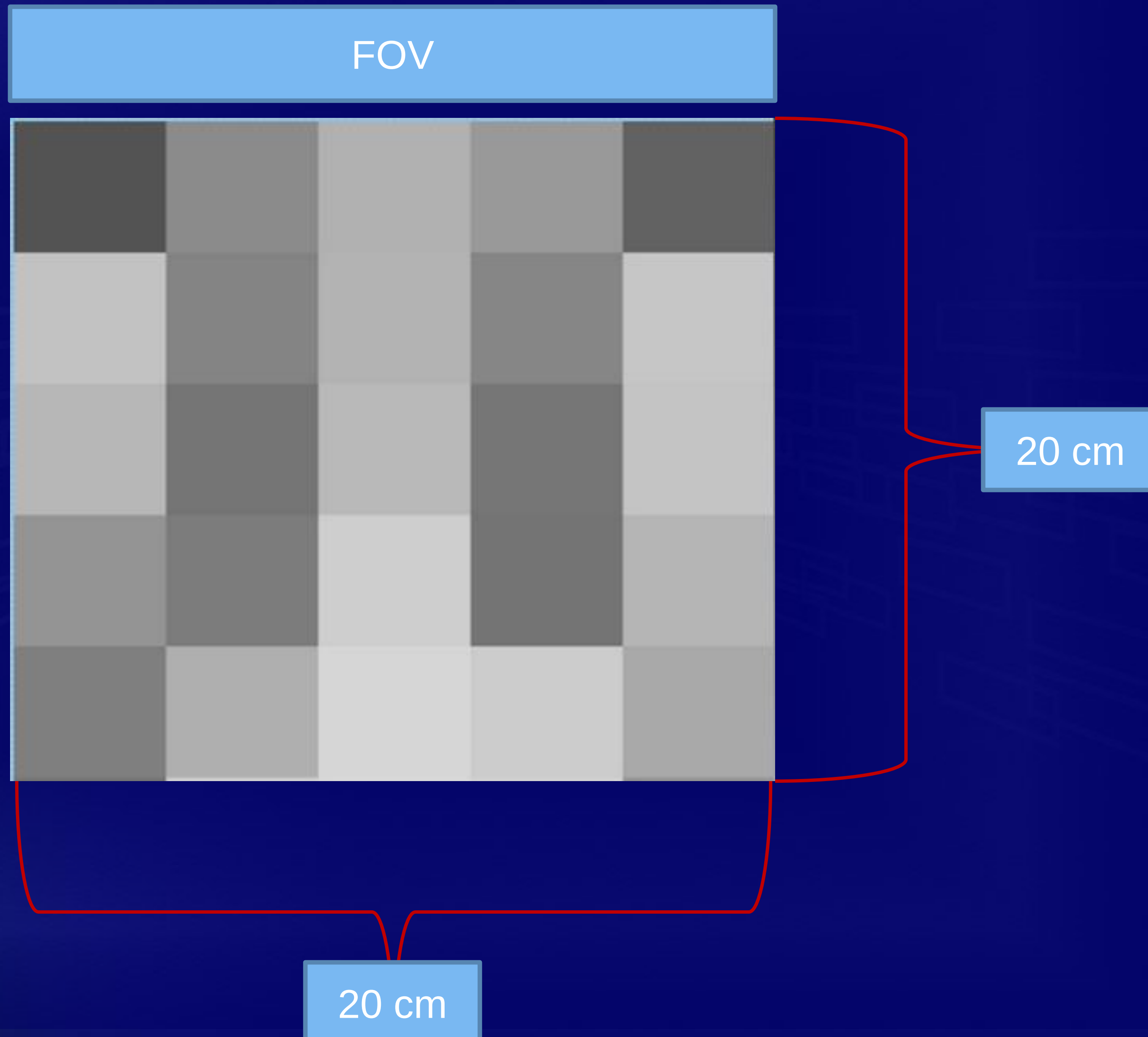
$$\text{Pixel Size} = \frac{FOV}{Matrix}$$

Matrix 5 x 5

1 2 3 4 5



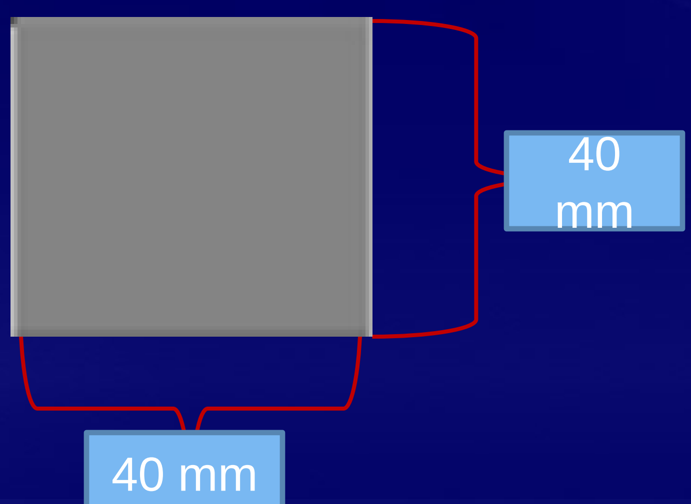
1 2 5 3 4


FOV
20 cm
20 cm

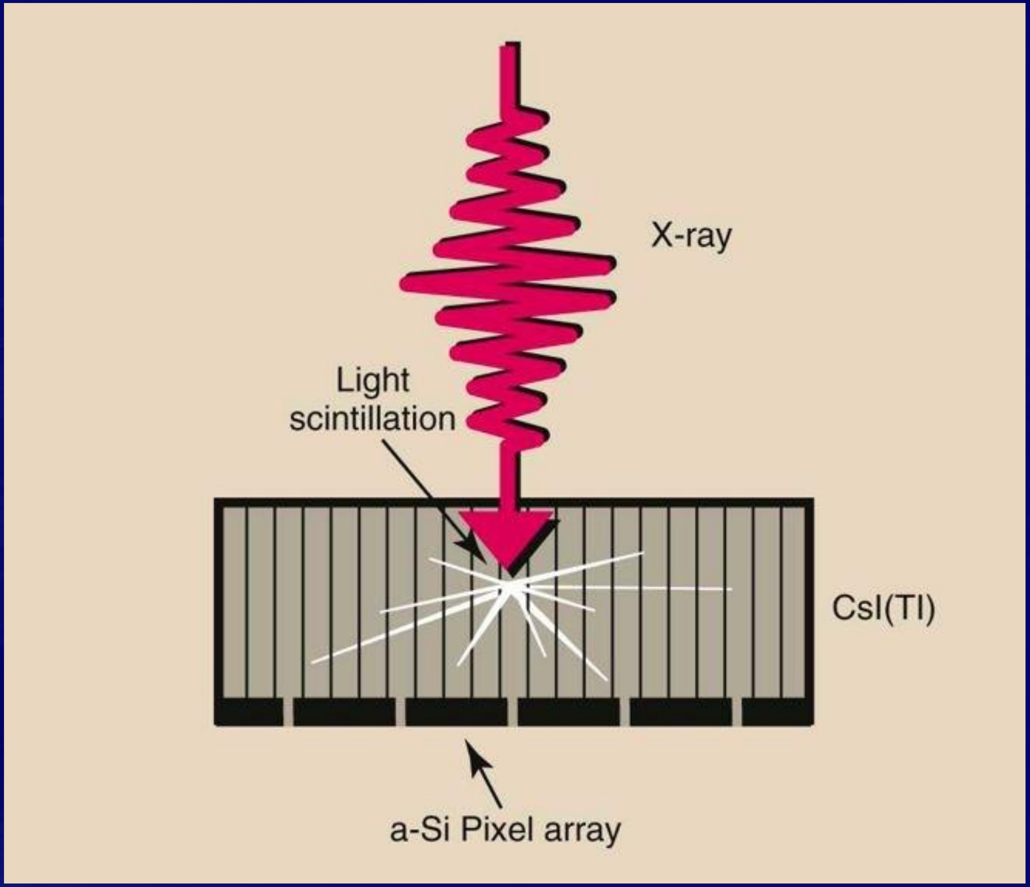
$$\text{Pixel Size} = \frac{20\ cm}{5}$$

$$\text{Pixel Size} = \frac{200\ mm}{5}$$

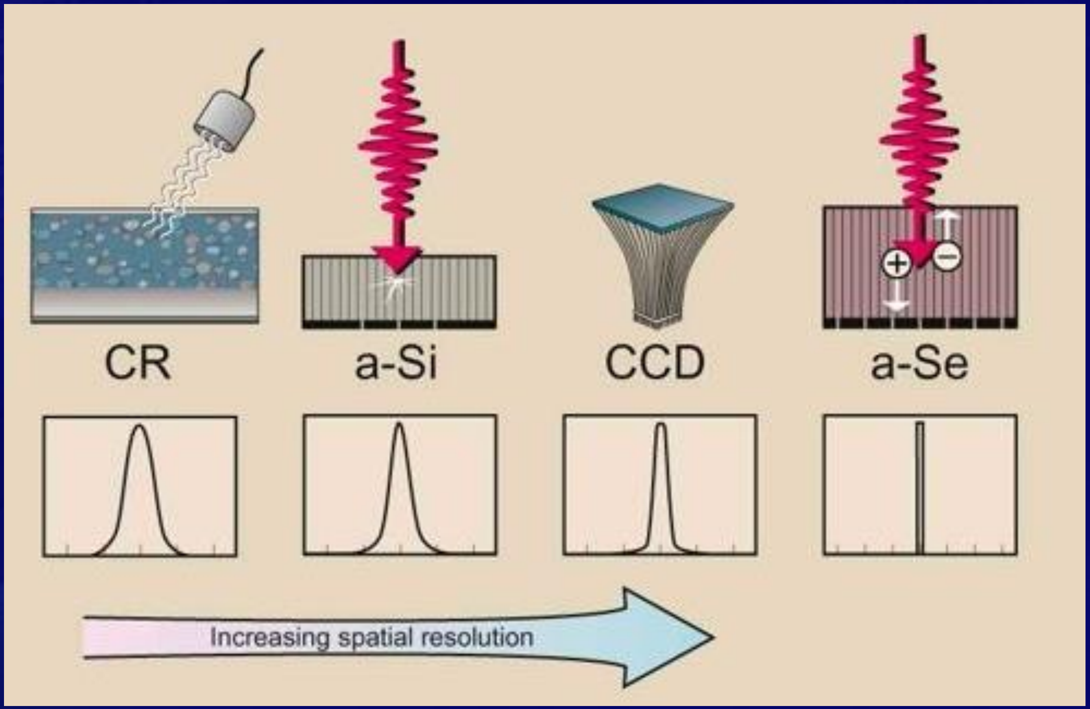
Pixel Size = $40\ mm$



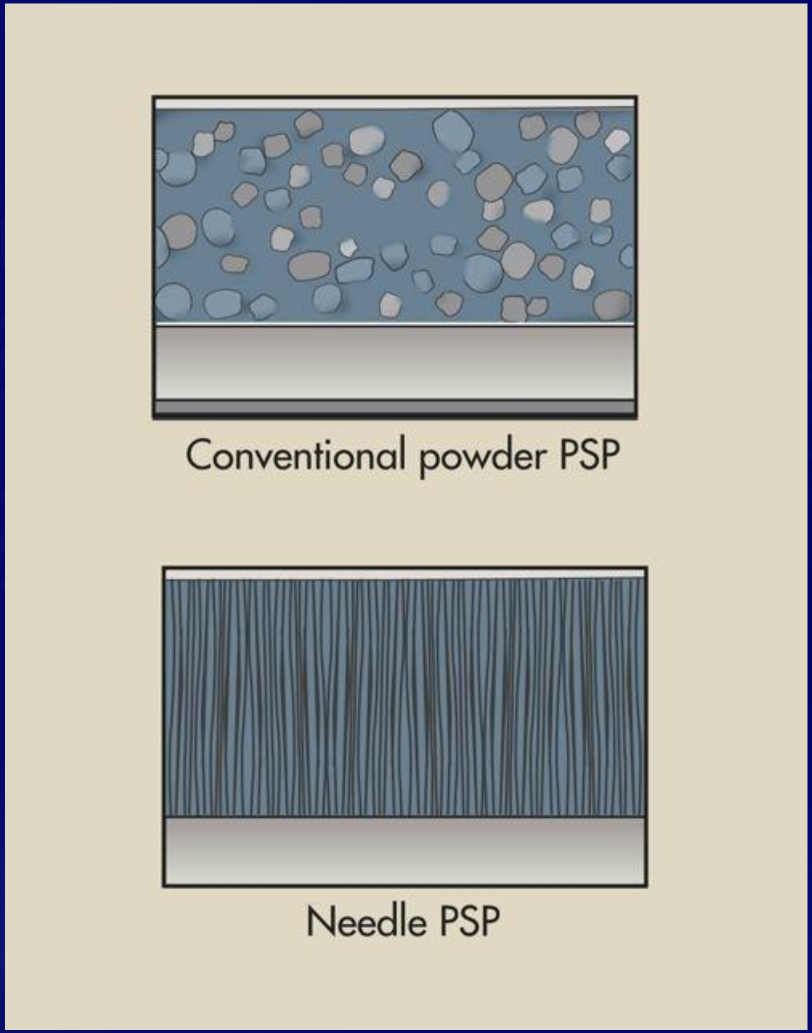
Detector Size



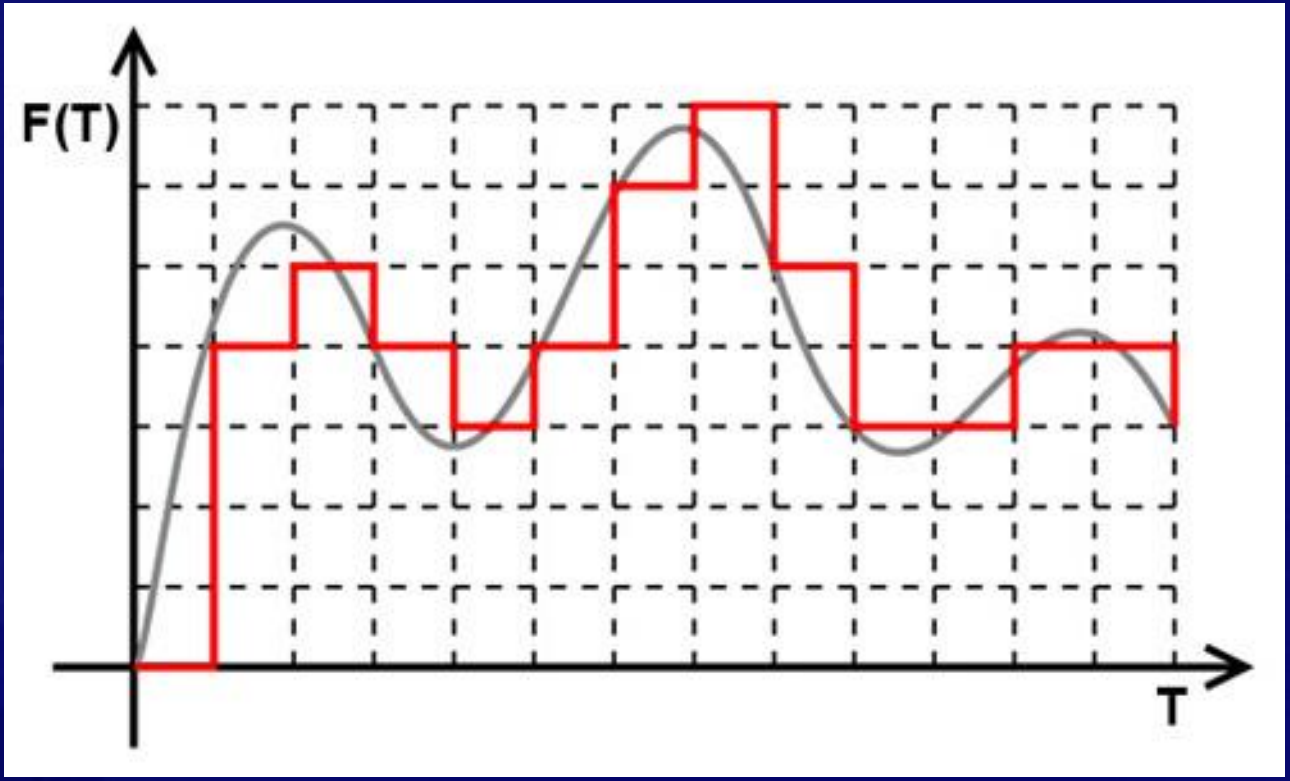
Depending on the detector’s physical characteristics, spatial resolution can vary a great deal. Spatial resolution of a-Se for direct detectors and CsI for indirect detectors is higher than CR detectors but lower than film/screen radiography. Excessive image processing, in an effort to alter image sharpness, can lead to excessive noise. Digital images can be processed to alter apparent image sharpness; however, excessive processing can lead to an increase in perceived noise. The best resolution will be achieved by using the appropriate technical factors and materials.

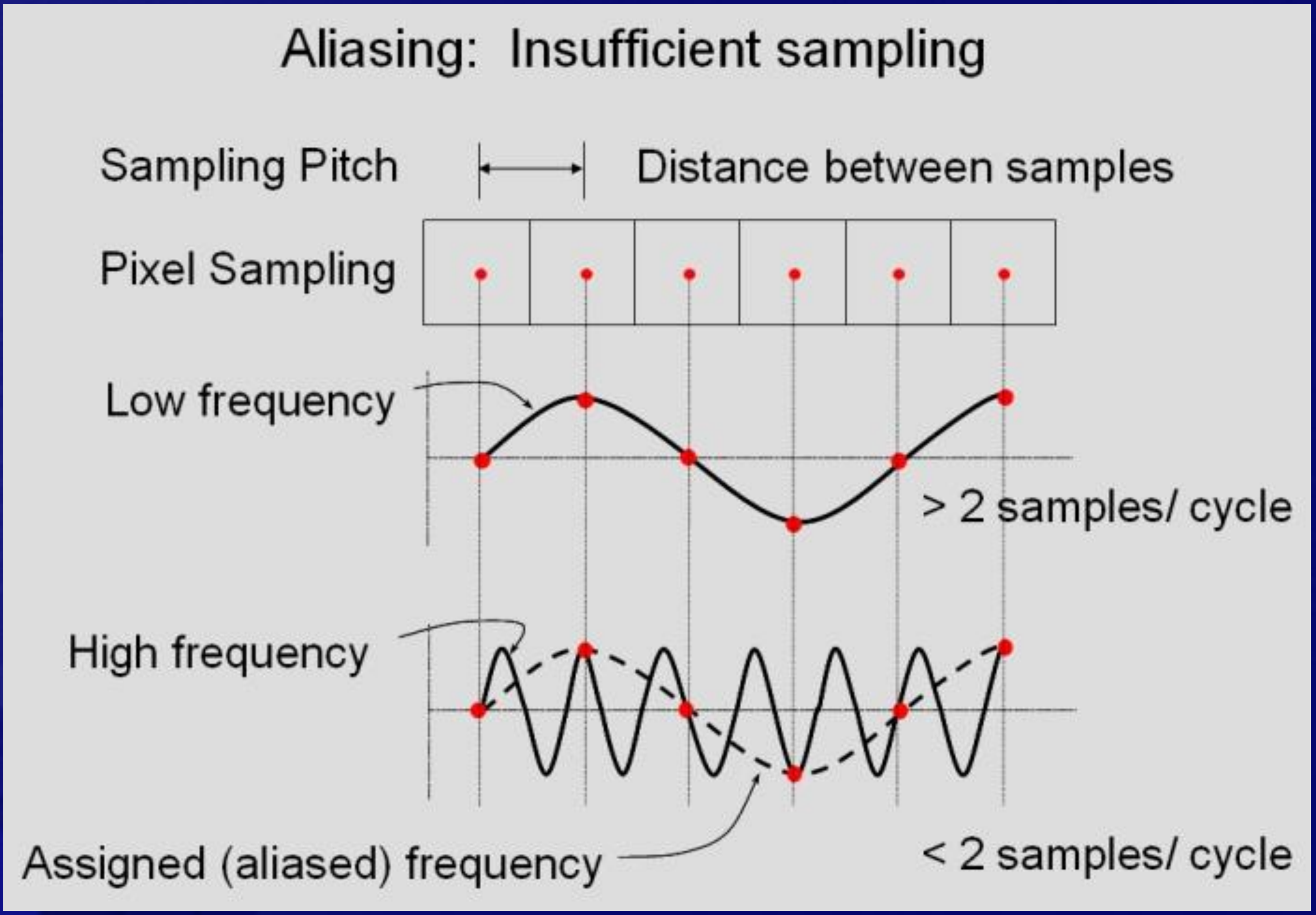


Some storage phosphor screens (SPSs) incorporate phosphors grown as linear filaments that increase the absorption of x-rays and limit the spread of stimulated emission.



Sampling



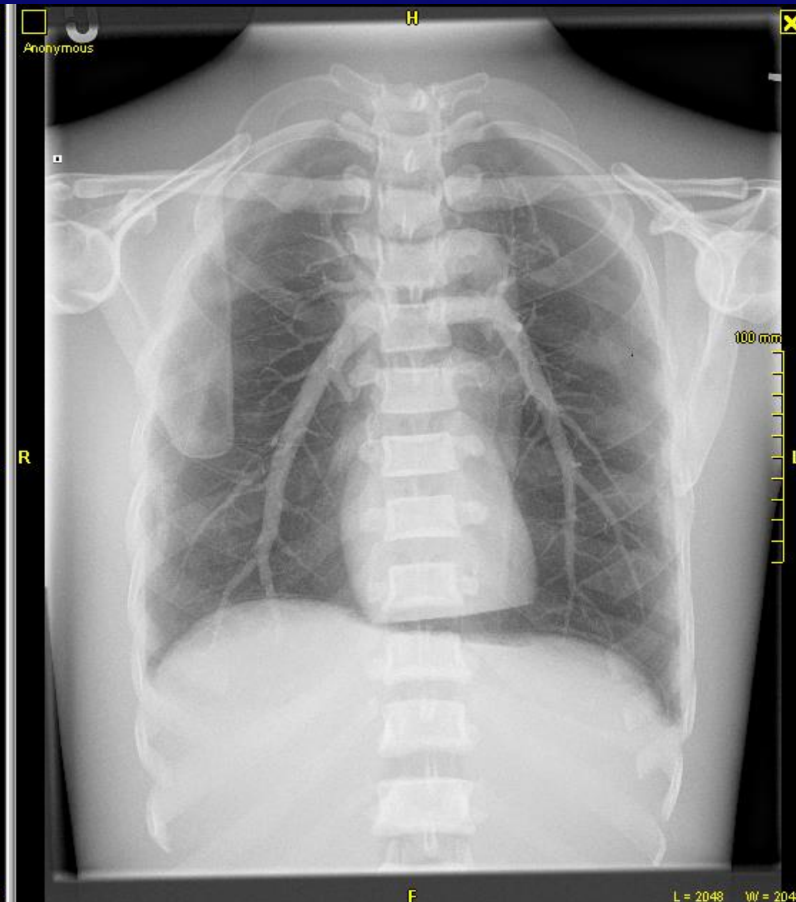

Aliasing: Insufficient sampling
Sampling Pitch
Distance between samples
Pixel Sampling
Low frequency
> 2 samples/ cycle
High frequency
Assigned (aliased) frequency
< 2 samples/ cycle

CONTRAST RESOLUTION

The ability of an imaging system to demonstrate small changes in tissue contrast.

To understand low-contrast resolution, consider three tissues of different densities and atomic number (Z). If these tissues were imaged by conventional radiography, the obtained image would have shown good contrast between bone and soft tissue (muscle and fat) only. The values of the density and Z for muscle and fat are too close to be clearly distinguished by radiography, and they appear as “soft tissue shadows.” The contrast between bone with a Z of 13.8 and soft tissue with a Z of 7.4 is apparent because of the significant difference between the densities and Z of these two tissues.

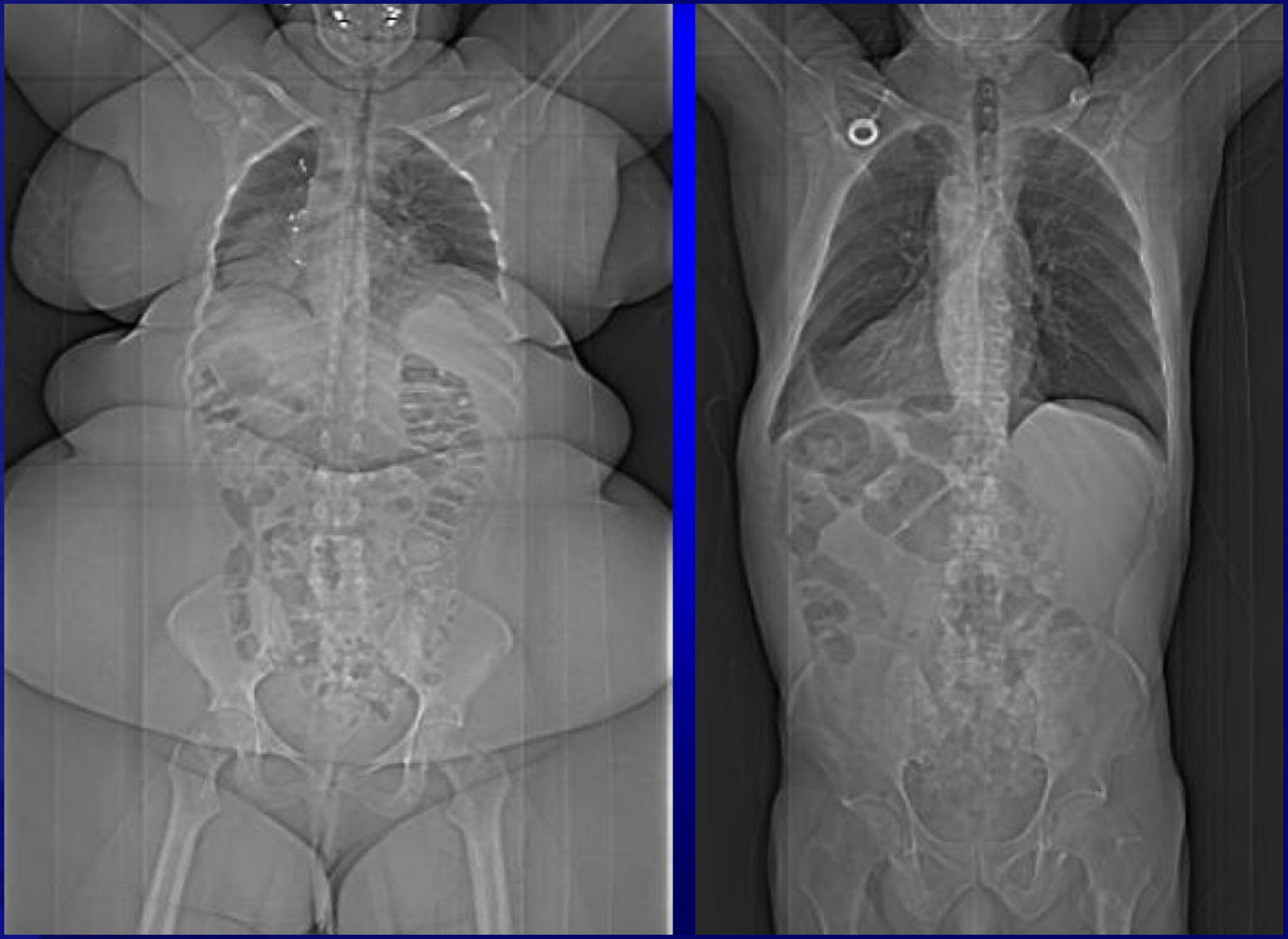

H
Anonymous
C
L
100 mm
R
L
F


H
Anonymous
100 mm
R
L
F
L = 2048 W = 2048

Factors Affecting Contrast Resolution

- Patient size
- mA
- Time
- Scatter control
- Algorithm
- Noise

Patient Size



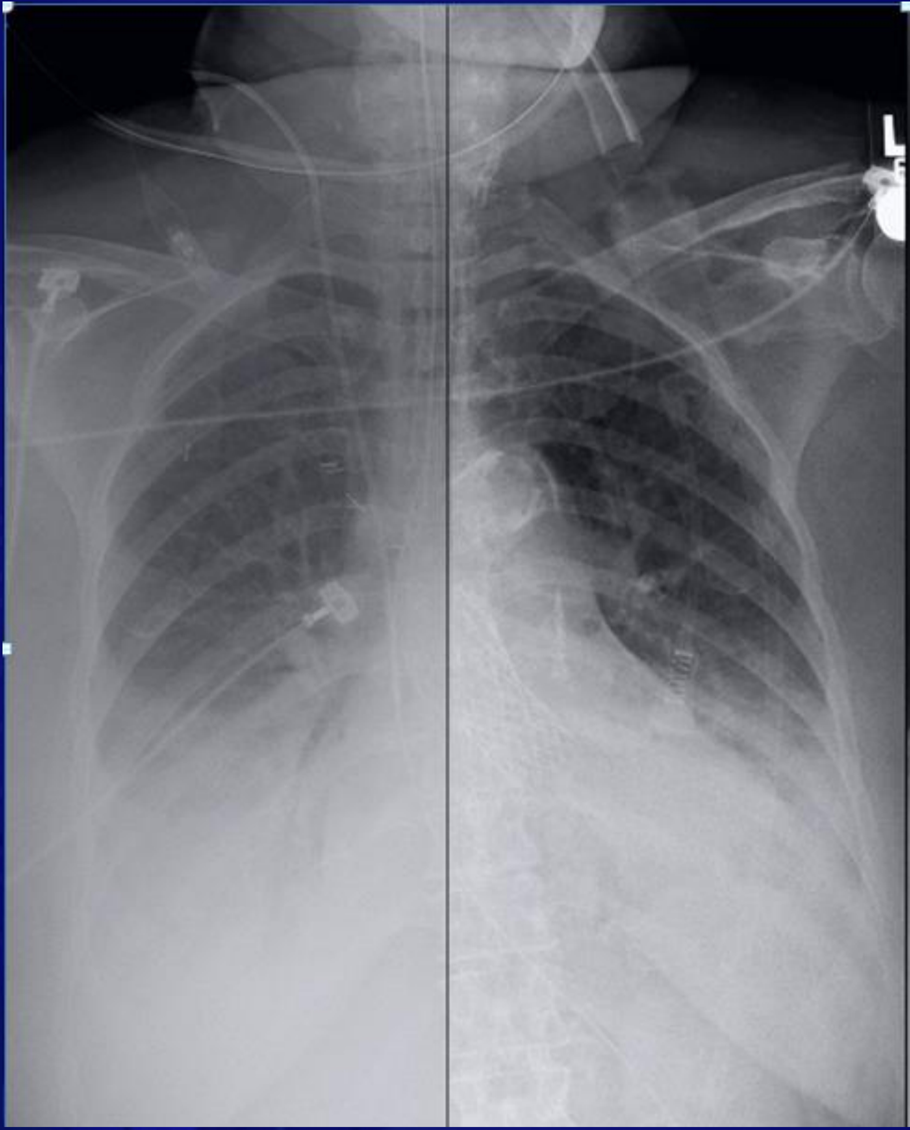
mA/mAs

100 mAs

300 mAs

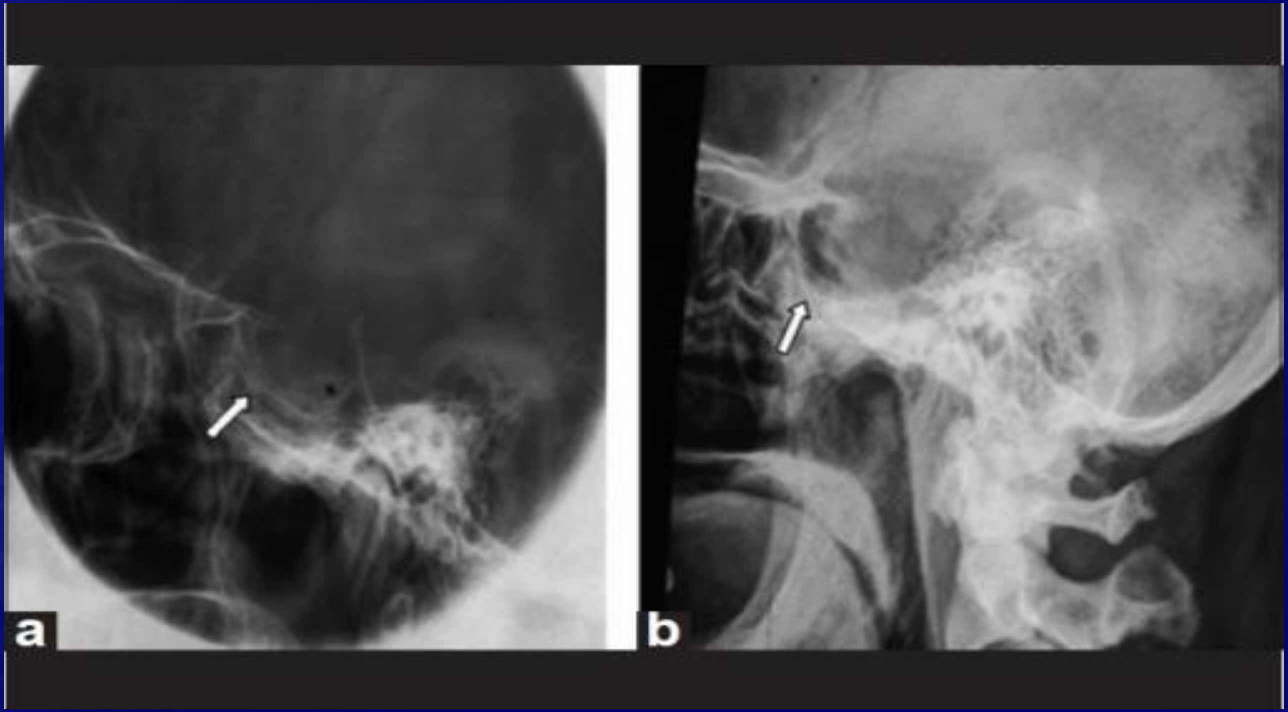
Scatter Control

No Grid



No Grid

Collimation



Algorithm

standard

sharp

TEMPORAL RESOLUTION

Temporal resolution is an indication of a CT system's ability to freeze motions of the scanned object. An oversimplified analogy is the “shutter” speed of a camera. When a photo is taken at a sports event, a higher shutter speed should be used to reduce the blurring effects caused by the moving athletes.