# Image Production 1

X-ray tube, Primary Exposure Factors, and X-ray Production

15% Rule and Effect

Exposure Indices

Digital Image Characteristic and Manipulation

Automatic Exposure Control

Grids

Artifacts 1

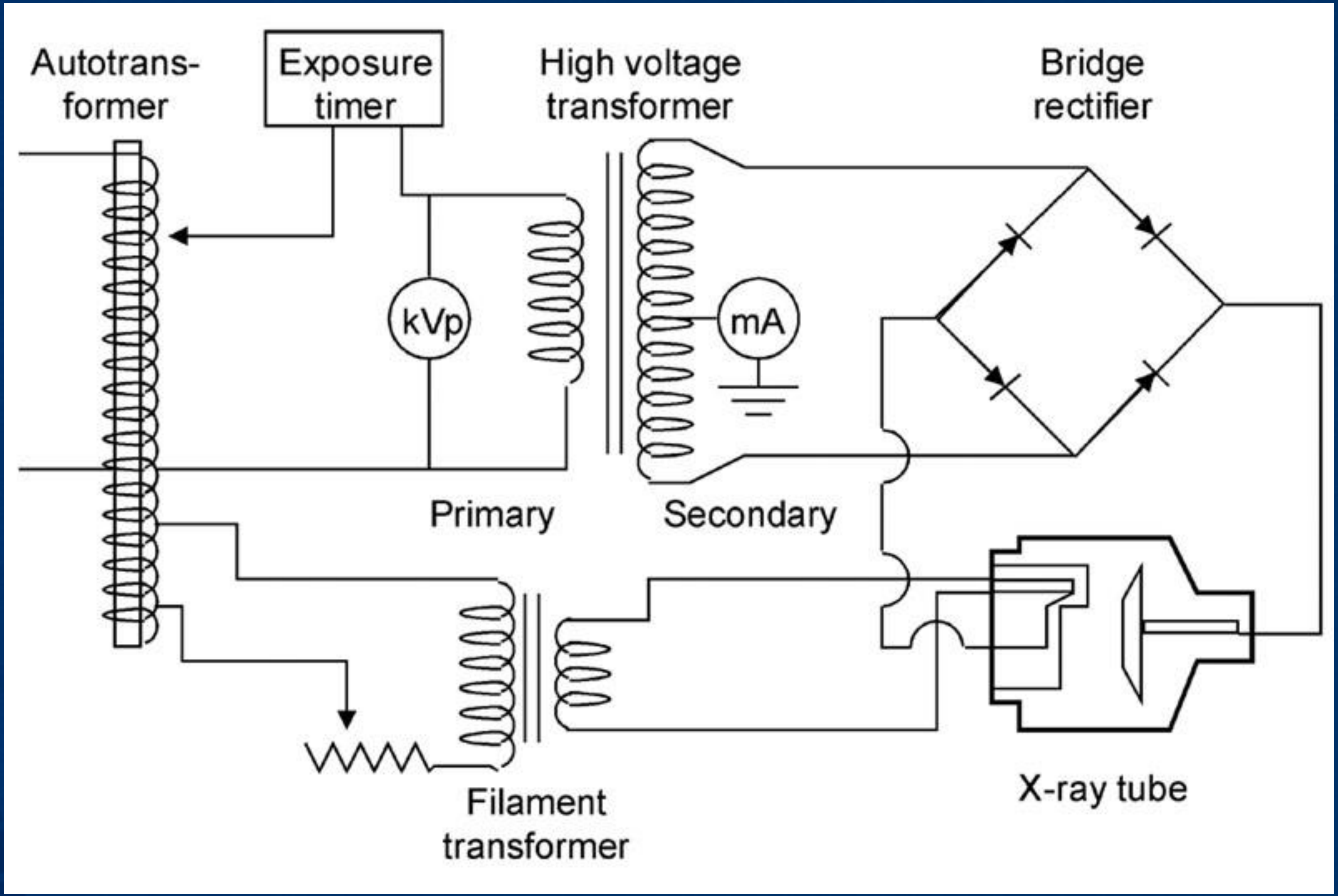
# Prime Radiographic Exposure Factors

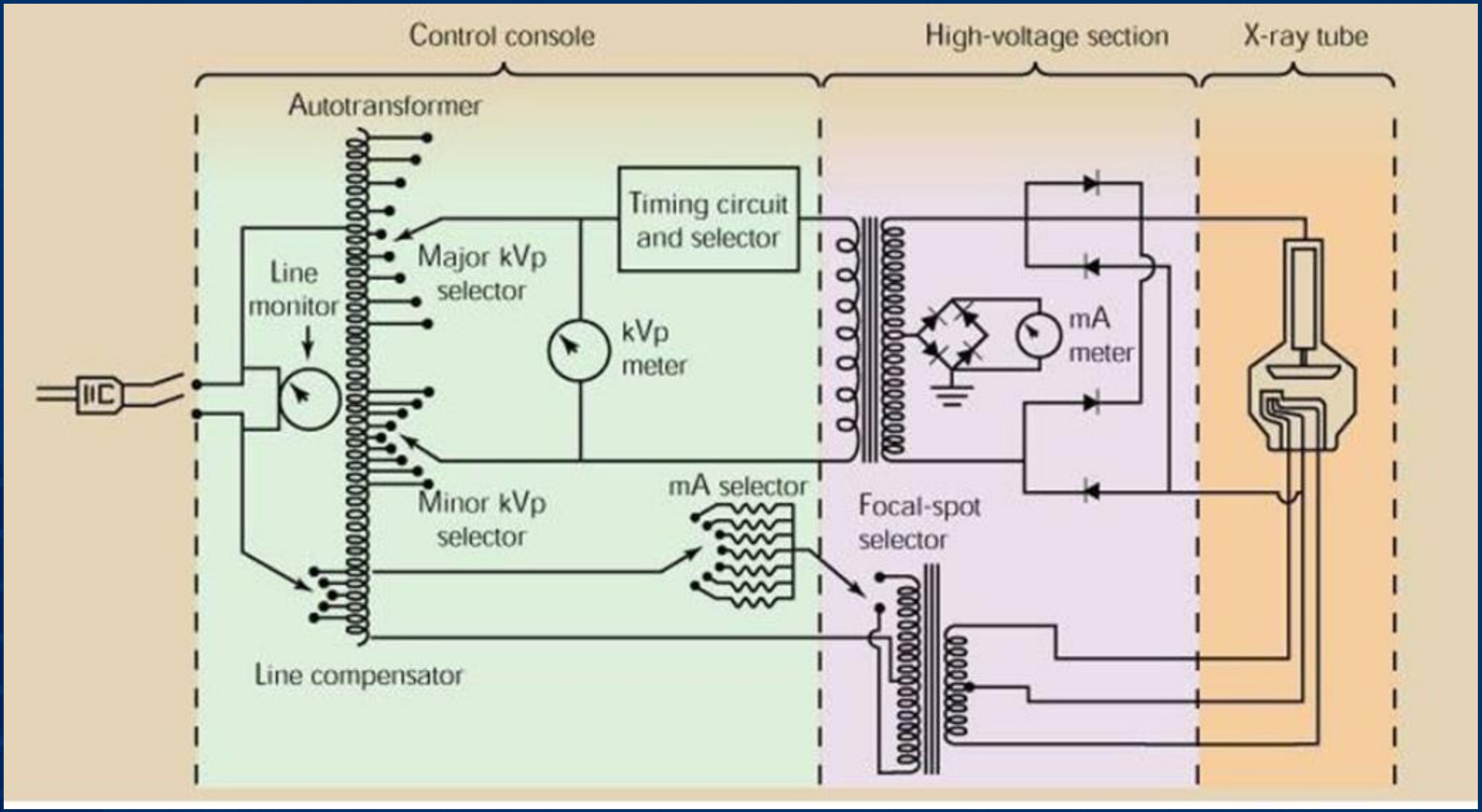
By Professor Stelmark

**Primary Factors**

The primary exposure technique factors the radiographer selects on the control panel are milliamperage, time of exposure, and kilovoltage peak (kVp). Depending on the type of control panel, milliamperage and exposure time may be selected separately or combined as one factor, milliamperage/second (mAs). Regardless, it is important to understand how changing each separately or in combination affects the radiation reaching the IR and the radiographic image.

- Milliamperage mA
- Exposure time
- Kilovoltage


Autotrans-
former
Exposure
timer
High voltage
transformer
Bridge
rectifier
kVp
mA
Primary
Secondary
Filament
transformer
X-ray tube


Control console
High-voltage section
X-ray tube
Autotransformer
Timing circuit and selector
Major kVp selector
Line monitor
kVp meter
mA meter
Minor kVp selector
mA selector
Focal-spot selector
Line compensator

# Milliamperage

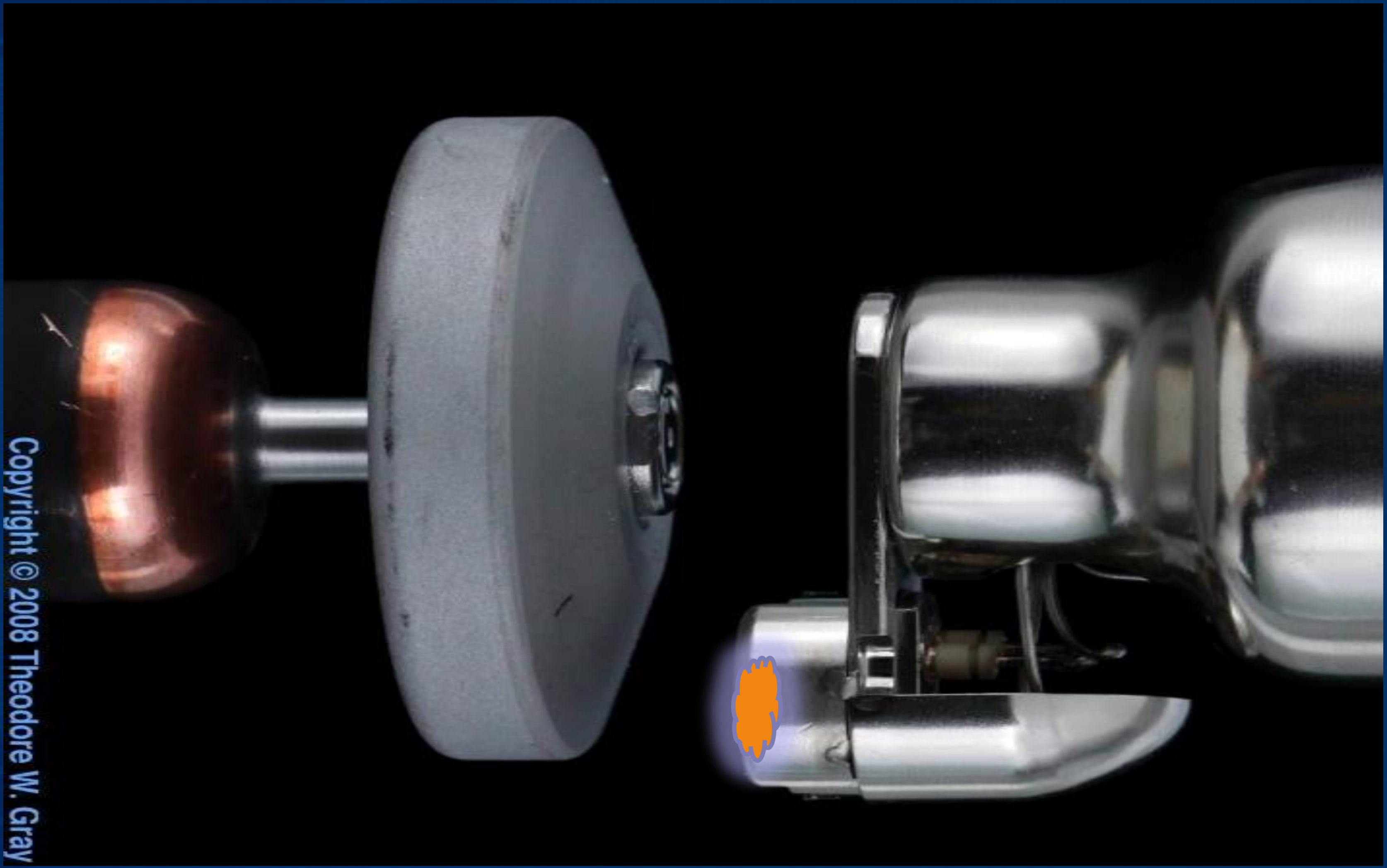
The **Electric current** is a flow of electric charge through a conductive medium.
In electric circuits this charge is often carried by moving electrons in a wire
The SI unit for measuring the rate of flow of electric charge is the ampere or milliampere. (1/1,000)

In radiography mA controls the number of electrons in transit between cathode and anode per unit of time (second). mA setting is associated with the specific temperature of the filament and the number of electrons being liberated. mA is the unit of tube current.

The higher the mA the more x-rays are produced

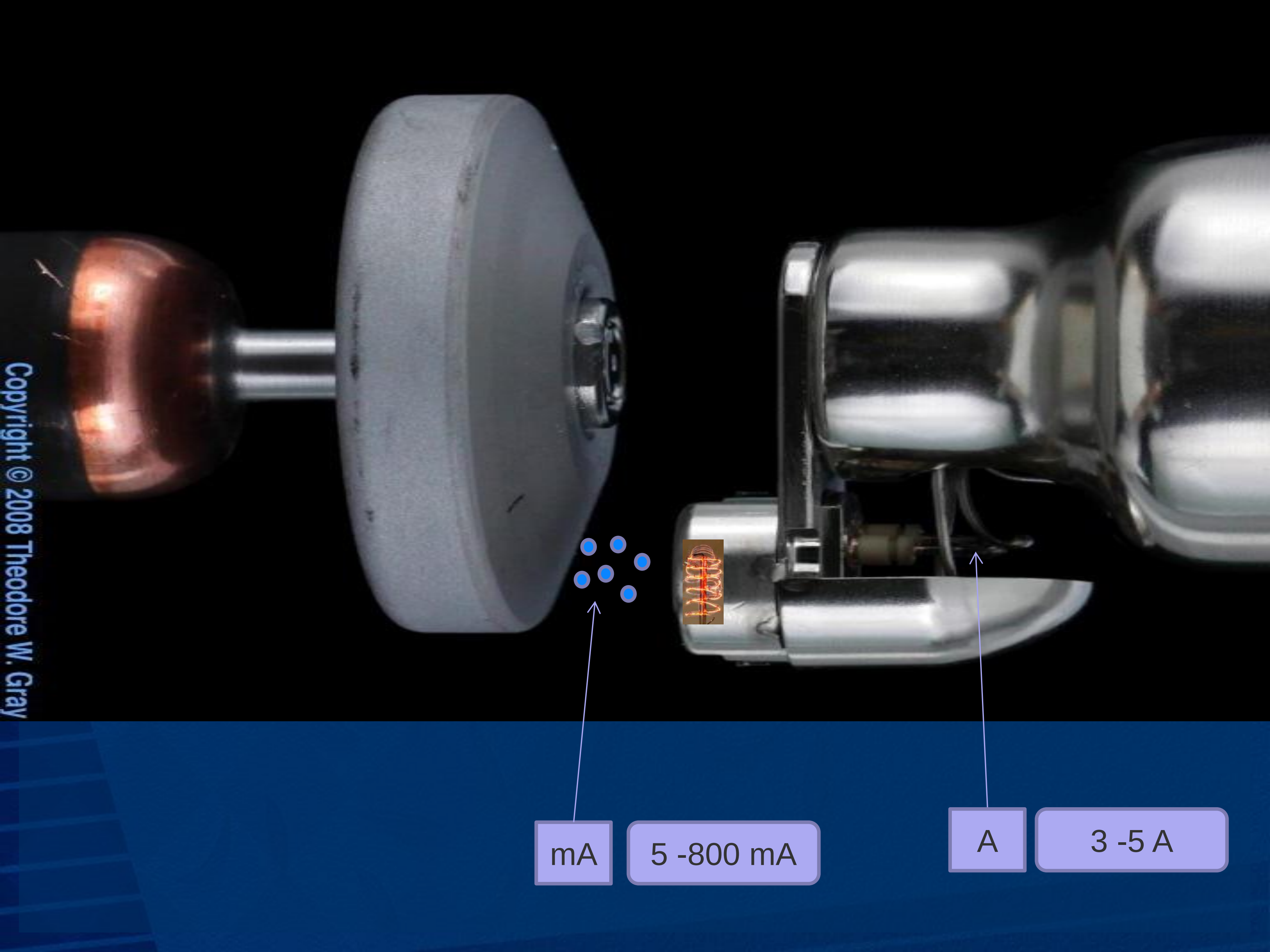

50 mA


100 mA




400 mA


630 mA


Copyright © 2008 Theodore W. Gray
mA
5 -800 mA
A
3 -5 A

mA affects the quantity of x-rays produced, it also affects the intensity and the total exposure or primary signal. mA is doubled – exposure is doubled – intensity is doubled.

$$\text{mA} \propto \text{Exposure}$$

# Exposure Time

Duration of the tube current and radiographic exposure. How long the electrons are flowing between the cathode and the anode. The exposure time ids directly proportional to the number of x-rays generated.

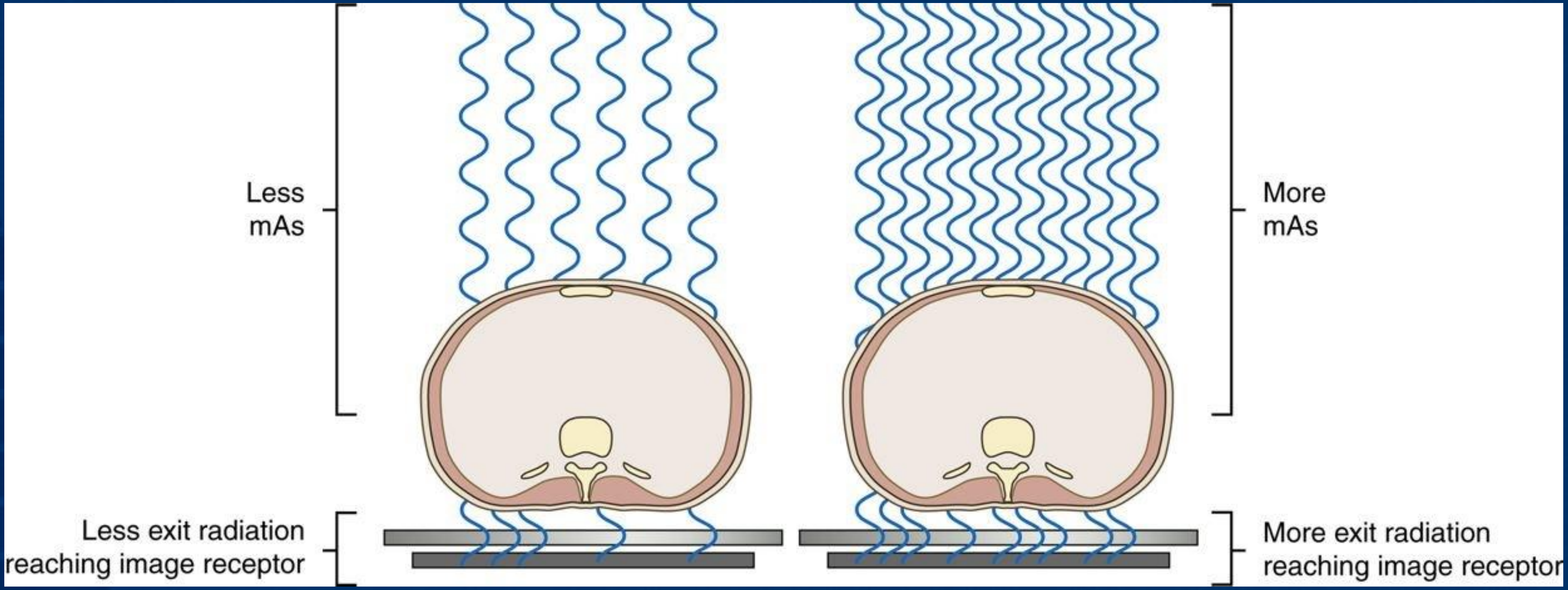
Exposure time affects the quantity of x-rays produced
It does NOT affect the intensity

mA $\propto$ Exposure

The quantity of x-ray photons in an exposure cannot be determined by either the mA or the exposure time alone. Although mA determines the rate of x-ray production, it does not indicate the total quantity, because it does not indicate how long the exposure lasts. Exposure time does not indicate the total quantity either, because it does not measure the rate of x-ray production. To determine the quantity of radiation involved in an exposure, both mA and time must be considered.

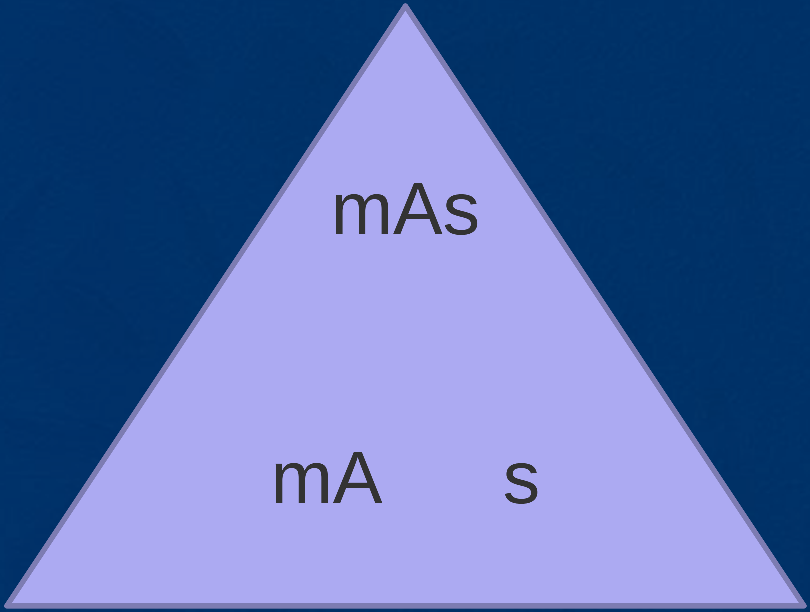
mA x Time (sec) = mAs

As the mAs is increased, the quantity of radiation reaching the IR is increased. As the mAs is decreased, the amount of radiation reaching the IR is decreased.



mAs is the primary controlling factor of the x-ray beam quantity

# mAs formula calculations



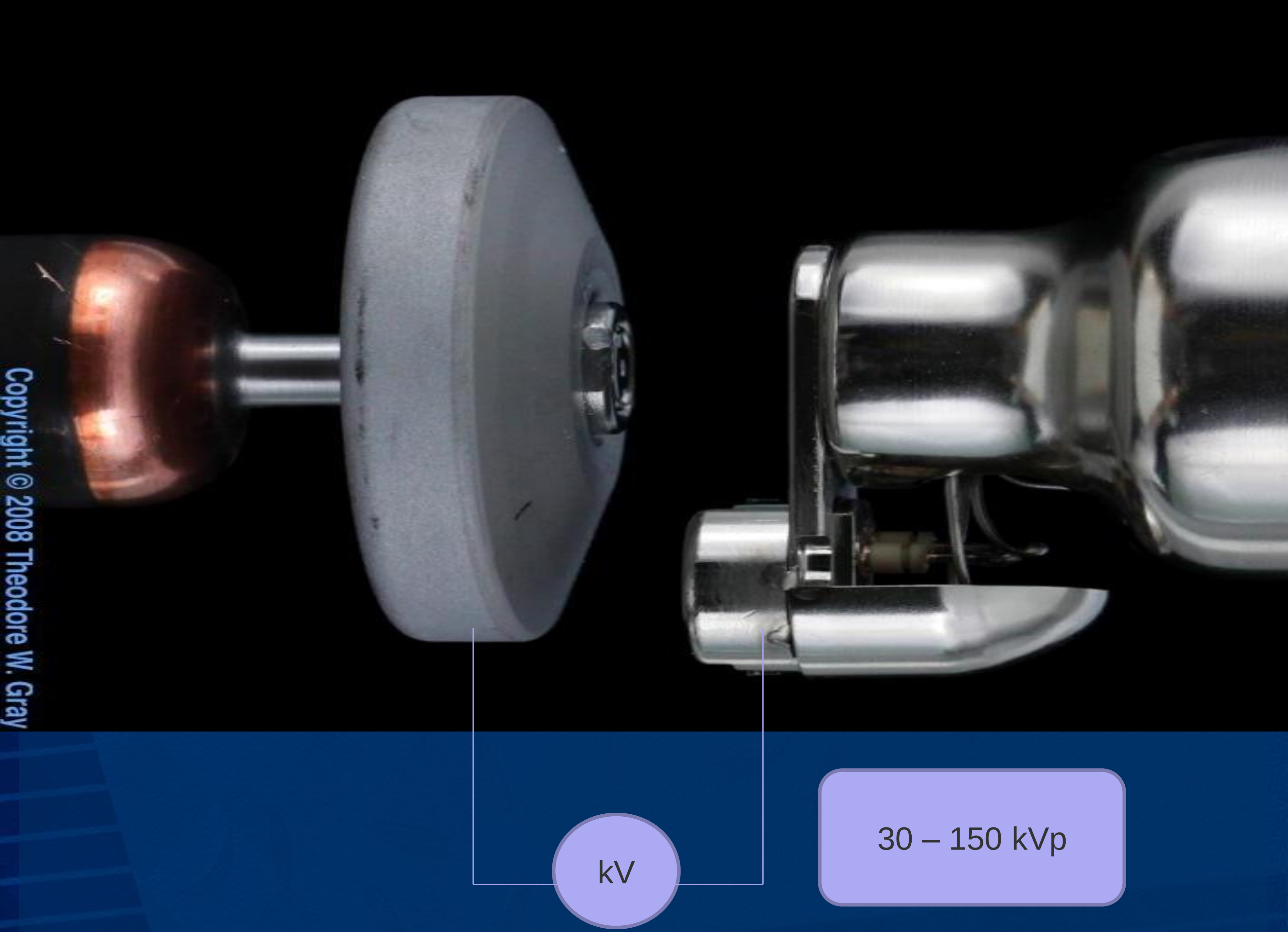

mA x s = mAs

mA = mAs/s

s = mAs/mA

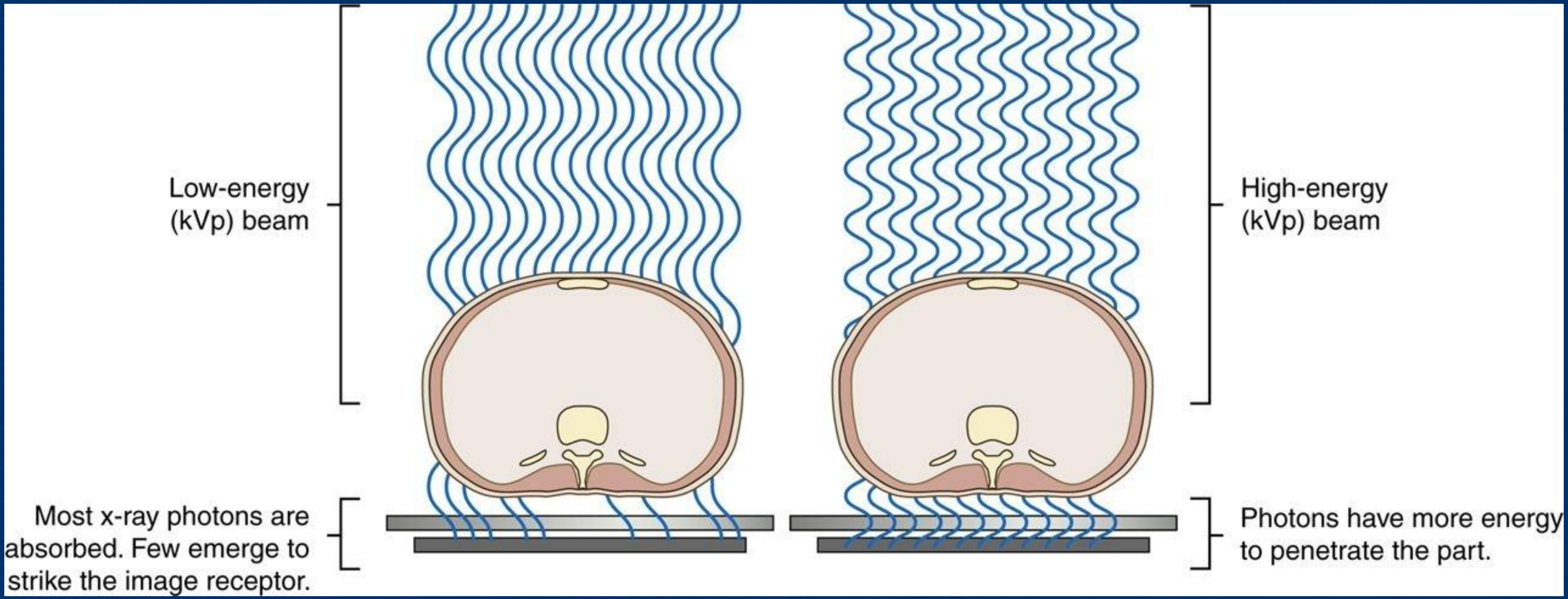
# Kilovoltage

When the kVp is increased at the control panel, a larger potential difference occurs in the x-ray tube, giving more electrons the kinetic energy to produce x-rays and increasing the kinetic energy overall. The result is more photons (quantity) and higher energy photons (quality).




30 – 150 kVp

The kVp affects the exposure to the IR because it alters the amount and penetrating ability of the x-ray beam.




Altering the penetrating power of the x-ray beam affects its absorption and transmission through the anatomic tissue being radiographed. Higher kVp increases the penetrating power of the x-ray beam and results in less absorption and more transmission in the anatomic tissues kVp is the primary controlling factor of the x-ray beam quality

$kVp^2 \propto$ Exposure

# Primary Exposure Factors and Image Brightness

mA increase

mA decrease

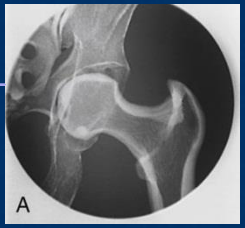
Time increase

Time decrease

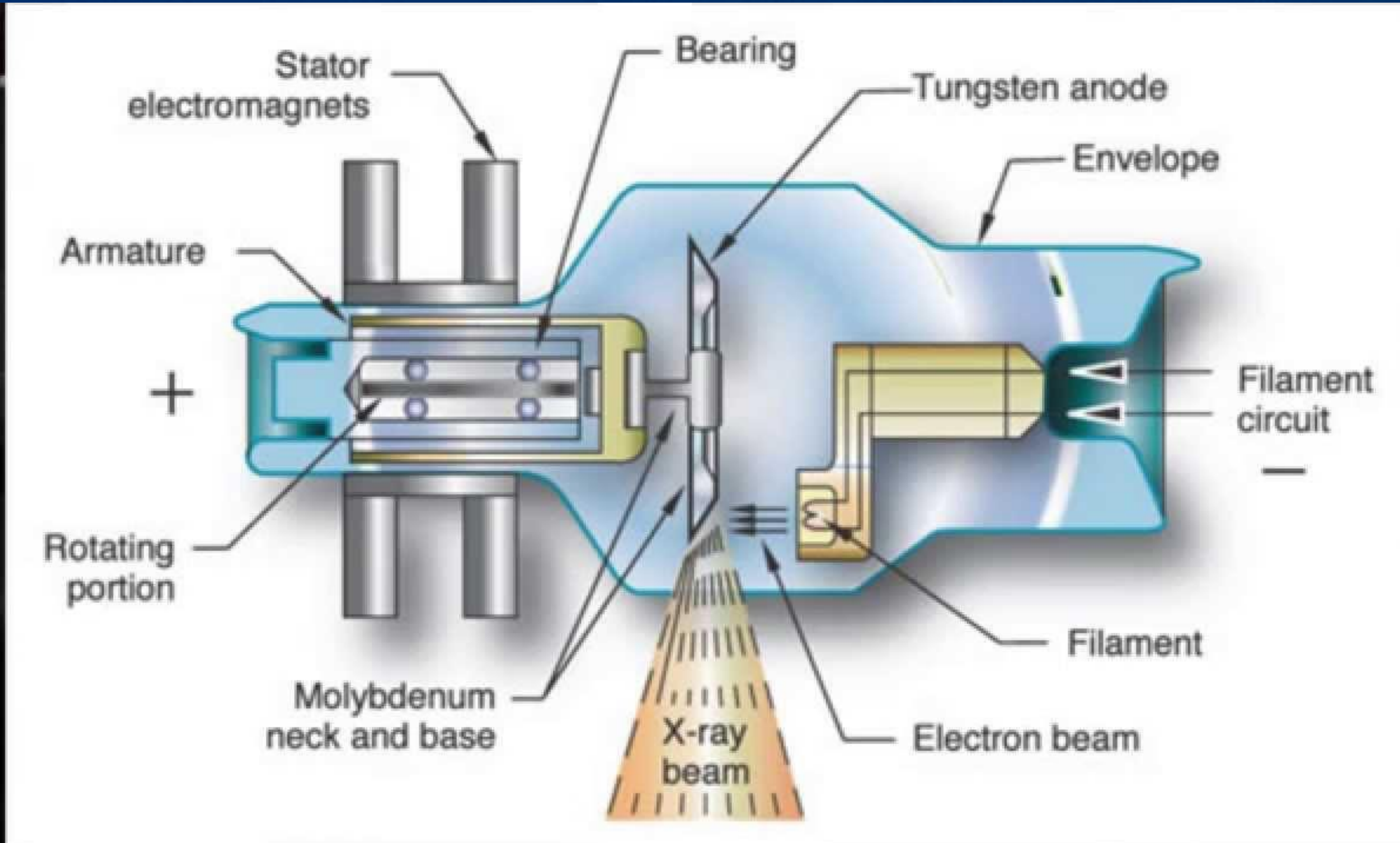
kVp increase

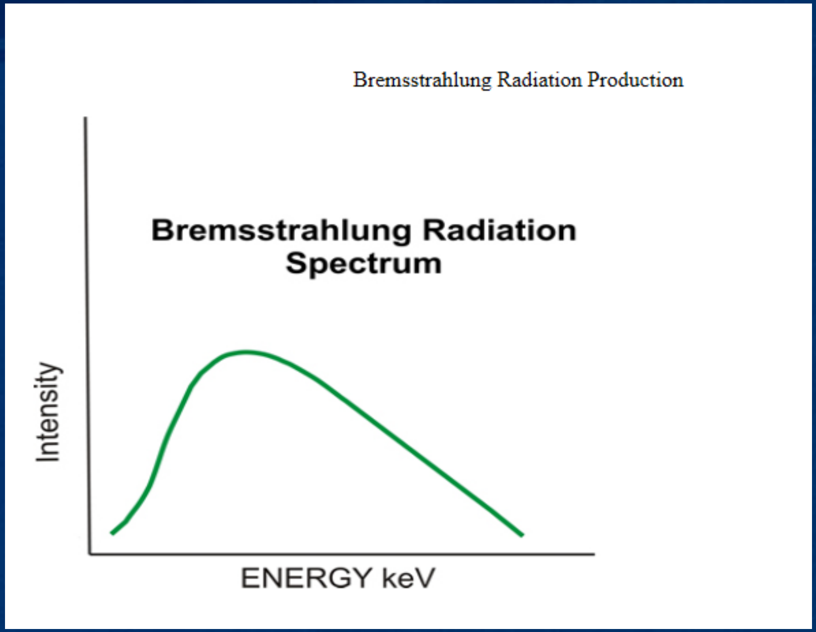
kVp decrease

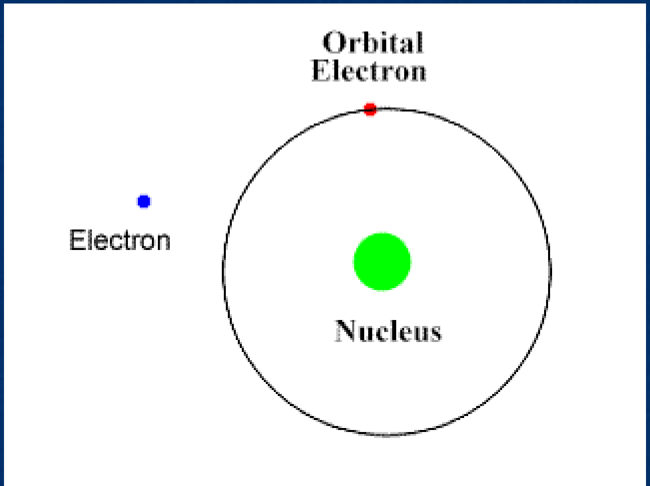
Same

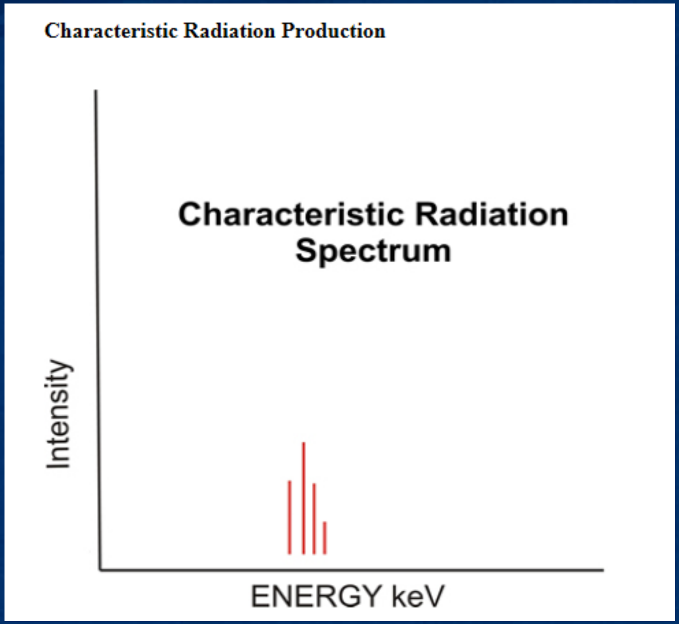


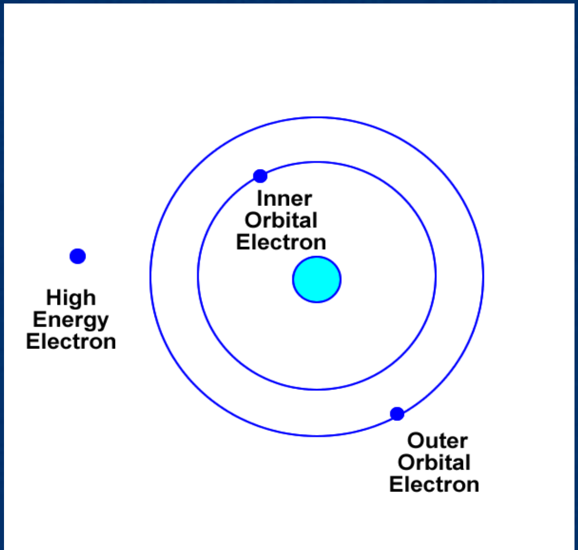

Digital System


Stator electromagnets
Bearing
Tungsten anode
Envelope
Armature
+
Filament circuit
−
Rotating portion
Filament
Molybdenum neck and base
X-ray beam
Electron beam

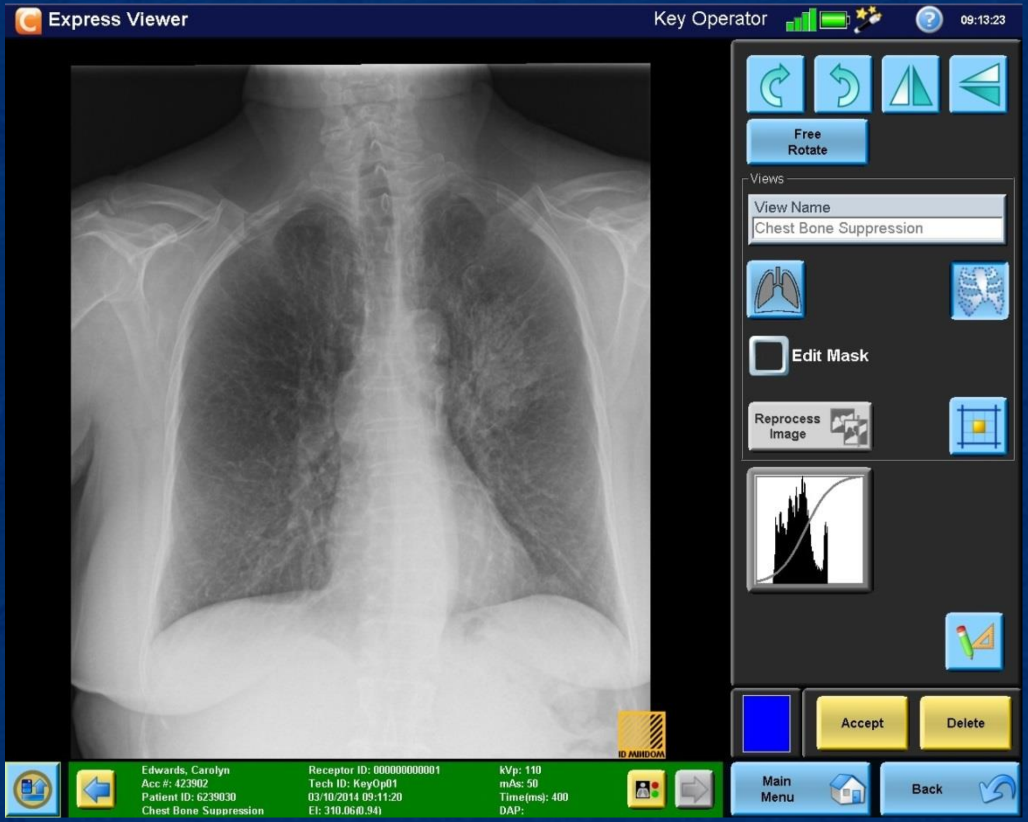

Bremsstrahlung Radiation Production
Bremsstrahlung Radiation Spectrum
Intensity
ENERGY keV


Orbital Electron
Electron
Nucleus


Characteristic Radiation Production
Characteristic Radiation
Spectrum
Intensity
ENERGY keV


Inner
Orbital
Electron
High
Energy
Electron
Outer
Orbital
Electron

# Computed Radiography Exposure Indices



For the Fuji (Tokyo, Japan), Philips (Eindhoven, The Netherlands), and Konica Minolta (Tokyo, Japan) systems, the exposure indicator is known as the S or sensitivity number. It is the amount of luminescence emitted at 1mR at 80kVp and has a value of 200. The higher the S number with these systems, the lower the exposure.

For example, an S number of 400 is half the exposure of an S number of 200, and an S number of 100 is twice the exposure of an S number of 200. The numbers have an inverse relationship to the amount of exposure so that each change of 200 results in a change in exposure by a factor of 2.

Kodak (Rochester, NY) uses exposure index (EI) as the exposure indicator. A 1-mR exposure at 80kVp combined with aluminum/copper filtration yields an EI number of 2000. An EI number plus 300 (EI + 300) is equal to a doubling of exposure, and an EI number of –300 is equal to halving the exposure.

The numbers for the Kodak system have a direct relationship to the amount of exposure, so that each change of 300 results in change in exposure by a factor of 2.

The term for exposure indicator in an Agfa (Mortsel, Belgium) system is the logarithm of the median exposure (lgM). An exposure of 20μGy at 75kVp with copper filtration yields a lgM number of 2.6. Each step of 0.3 above or below 2.6 equals an exposure factor of 2

# Recommended Exposure Indices

| | Overexposure | Underexposure | Adult: Nongrid and Grid | Distal Extremities Nongrid |
|---|---|---|---|---|
| Kodak (EI) | >2500 | <1600 tabletop; <1800 Bucky | 1800–2100 | 2200–2400 |
| Agfa (Lgm) | >2.9 | <2.1 | 2.1–2.3 | 2.4–2.6 |
| Fuji/Philips/ (S) Konica Minolta | <100 | >250 tabletop; >400 Bucky | 200–300 | 75–125 |

| | Kodak | Agfa | Fuji/Philips/Konica |
|---|---|---|---|
| Sensitivity value | 2000 | 2.6 | 200 |
| Relative sensitivity | +300 = 2x 2300 | +0.3 = 2x 2.9 | ½ S = 2x 100 |
| x = exposure | –300 = ½ x 1700 | –0.3 = ½ x 2.3 | 2x S = ½ x 400 |

# Digital Radiography Exposure Indices

Kodak (Rochester, NY) uses exposure index (EI) as the exposure indicator. A 1-mR exposure at 80kVp combined with aluminum/copper filtration yields an EI number of 2000.

An EI number plus 300 (EI + 300) is equal to a doubling of exposure, and an EI number of –300 is equal to halving the exposure.

The numbers for the Kodak system have a direct relationship to the amount of exposure, so that each change of 300 results in change in exposure by a factor of 2.

The customer has to decide on exposures settings using the ALARA principle. The dose level used corresponds with the noise level the customer accepts.

**Agfa can only give guidelines**

## Problem

- Each Manufacturer has their own way of indicating exposure to the detector
  - Some values increase when the exposure is increased, some decrease
  - Some values change in a linear fashion (Fuji, Canon)
  - Some values change in a logarithmic fashion (Agfa, Kodak)
  - Some change in an unusual fashion
- Results very confusing for the user

- A standard way to measure the exposure to a Digital detector

  Developed by IEC - International Electrotechnical Commission

- Designed to monitor exposure consistency within an exam type
  - Consists of three values
    - Exposure Index – EI
    - Target Exposure Index - TEI
    - Deviation Index - DI

# What the EI can do

- The Exposure Index can be used to confirm that the exposure at the detector is at the proper level to produce acceptable *image quality*, as established by the radiology department.

- The Exposure Index provides feedback to the operator so that the exposure consistency can be monitored and excessive under or over exposure prevented.

# What the

- The EI is not related to patient dose. Patient dose is influenced by other factors as well (e.g. patient size, use of filters, use of a anti-scatter grid, beam quality,  dependency of the detector, X-Ray beam collimation).

- The EI CAN NOT be used to calculate patient dose!

- Exposure Index – EI
  - Exposure index is linear in relation to detector dose
  - As exposure to the plate increases, the Exposure Index increases
- Target Exposure Index – TEI
  - The reference exposure index for a particular exposure
  - Can be determined by statistical averaging (50 exposures)→ preferred scenario
  - Can be preset (fixed) by the user
- Deviation Index - DI
  - Expresses how far the exposure is away from a reference value
  - Provides a relative indication for under/over exposure
  - 3 deviation units equals 2x exposure or ½ exposure (+3 or -3)

# EI & DI Numbers with mAs

| EI | TEI | DI | Exposure Factor | % Change | mAs change |
|---|---|---|---|---|---|
| 1600 | 400 | 6.0 | 4.00 | 300% | 120 |
| 1400 | 400 | 5.2 | 3.50 | 250% | 105 |
| 1200 | 400 | 4.5 | 3.00 | 200% | 90 |
| | | | | 199% | |
| 1000 | 400 | 4.0 | 2.50 | 150% | 75 |
| 900 | 400 | 3.5 | 2.25 | 125% | 67.5 |
| | | | | 101% | |
| 800 | 400 | 3.0 | 2.00 | 100% | 60 |
| | | | | 61% | |
| 640 | 400 | 2.0 | 1.60 | 60% | 48 |
| 504 | 400 | 1.0 | 1.26 | 26% | 37.8 |
| 400 | 400 | 0.0 | 1.00 | 0% | 30 |
| | | | | -1% | |
| 320 | 400 | -1.0 | 0.80 | -20% | 24 |
| | | | | -21% | |
| 248 | 400 | -2.0 | 0.62 | -38% | 18.6 |
| 200 | 400 | -3.0 | 0.50 | -50% | 15 |
| | | | | -51% | |
| 180 | 400 | -3.5 | 0.45 | -55% | 13.5 |
| 160 | 400 | -4.0 | 0.40 | -60% | 12 |
| 136 | 400 | -4.5 | 0.34 | -66% | 10.2 |
| 100 | 400 | -6.0 | 0.25 | -75% | 7.5 |

Green = Very Good - Between 0% and +60%

Blue = Within Range - Between +61% thru +100%

Yellow = Significant - Between +101% thru +199%

Red = Excessive - From +200% and up

Purple = Potential Mottle - Between -1% thru -20%

Orange = Probable Mottle - Between -21% thru -50%

Pink = Probable Repeat - From -51% and down

The value of the Target Exposure Index (TEI) varies with body part and equipment and is set by

# 15% Rule in Digital Imaging

# Kilovoltage

The area of interest must be adequately penetrated before the mAs can be adjusted to produce a quality radiographic image. When adequate penetration is achieved, further increasing the kVp results in more radiation reaching the IR. Unlike mAs, the kVp affects the amount of radiation exposure to the IR and radiographic contrast.

kVp is the main controlling factor of radiographic contrast

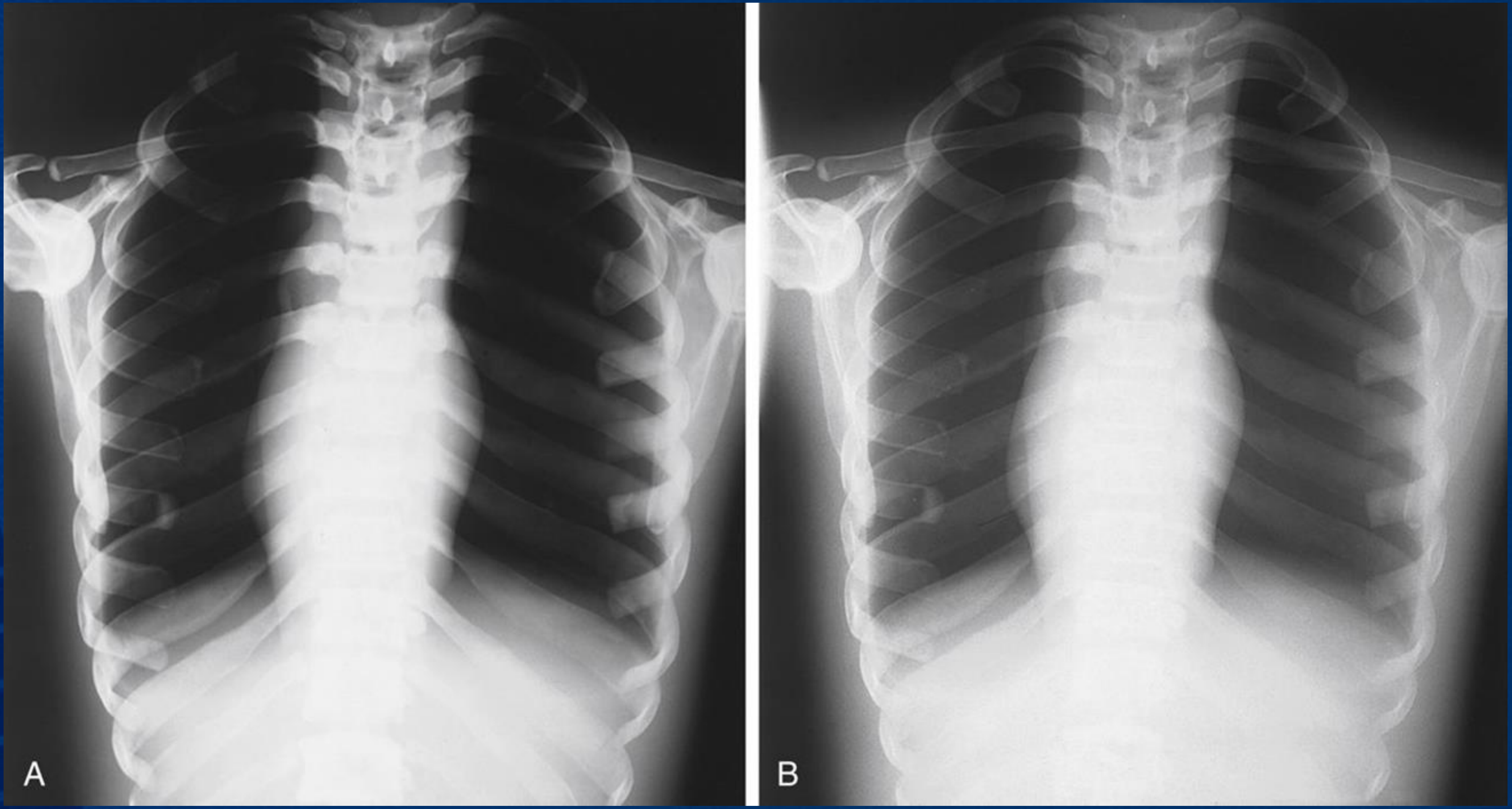
A high kVp results in less absorption and more transmission in the anatomic tissues, which results in less variation in the x-ray intensities exiting the patient (remnant), producing a low-contrast (long-scale) image. A low kVp results in more absorption and less transmission in the anatomic tissues, but with more variation in the x-ray intensities exiting the patient, resulting in a high-contrast (short-scale) image.

Low kVp

High Contrast

High kVp

Low Contrast



Maintaining or adjusting exposure to the IR can be accomplished with kVp by using the 15% rule. The 15% rule states that changing the kVp by 15% has the same effect as doubling the mAs, or reducing the mAs by 50%.

*For example:*
*Increasing the kVp from 82 to 94 (15%) produces the same exposure to the IR as increasing the mAs from 10 to 20.*

There are really 2 main reasons why someone would do the 15% Rule with mAs compensation:

- Dose reduction
- Time reduction

The second reason would be to cut the time for the exposure. This is really only needed on portable machines that have a built in 100 mA station (which is most portables on the market). 100 mA means if your technique has 200 mAs then your exposure time will be 2 seconds, a 50 mAs exposure would be 1/2 a second and so on. This usually happens when doing portable abdomens on a patient who is unable to follow breathing instructions and your exposure time is over 1/4 of a second long.

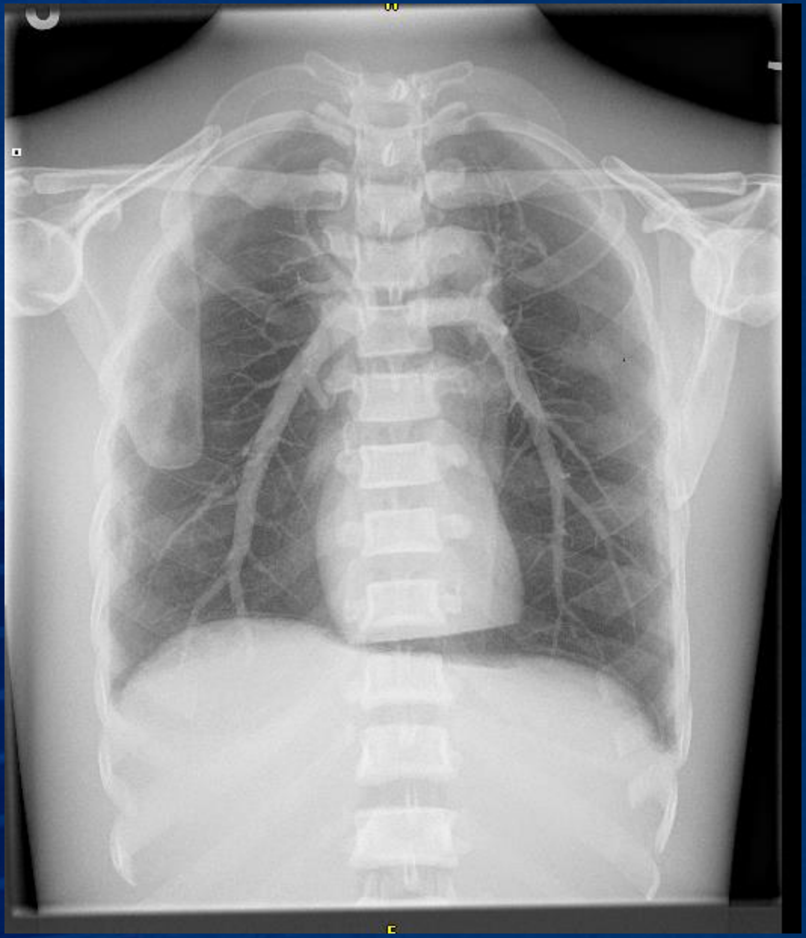
We are going to do is use half of the 15% Rule. Since it’s easier to see it with actual techniques, let’s start with:

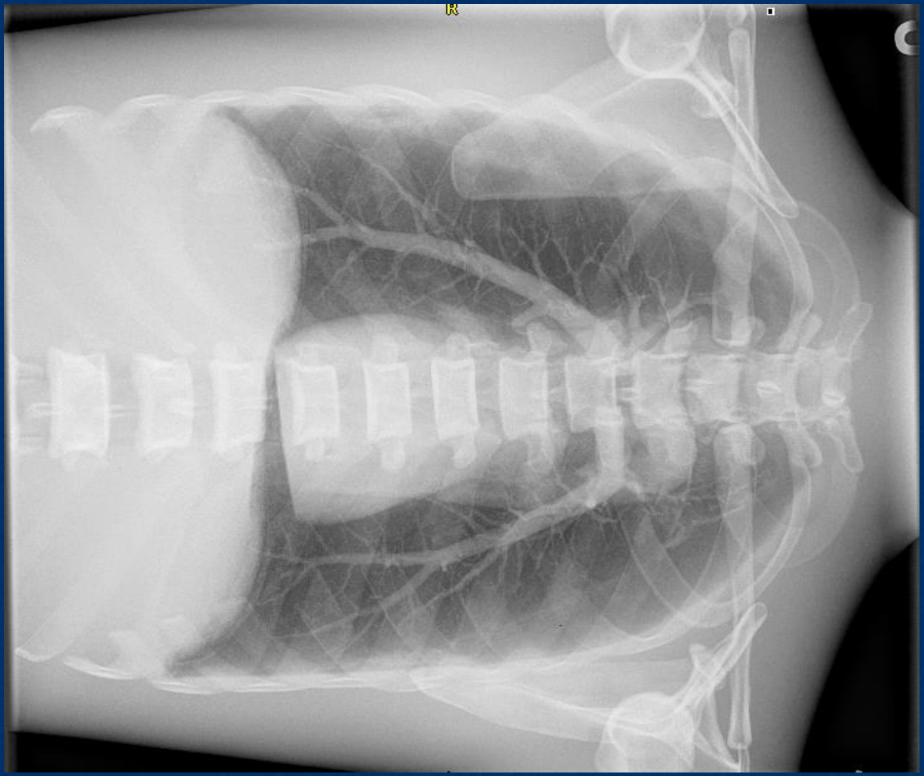
80 kV @ 40 mAs

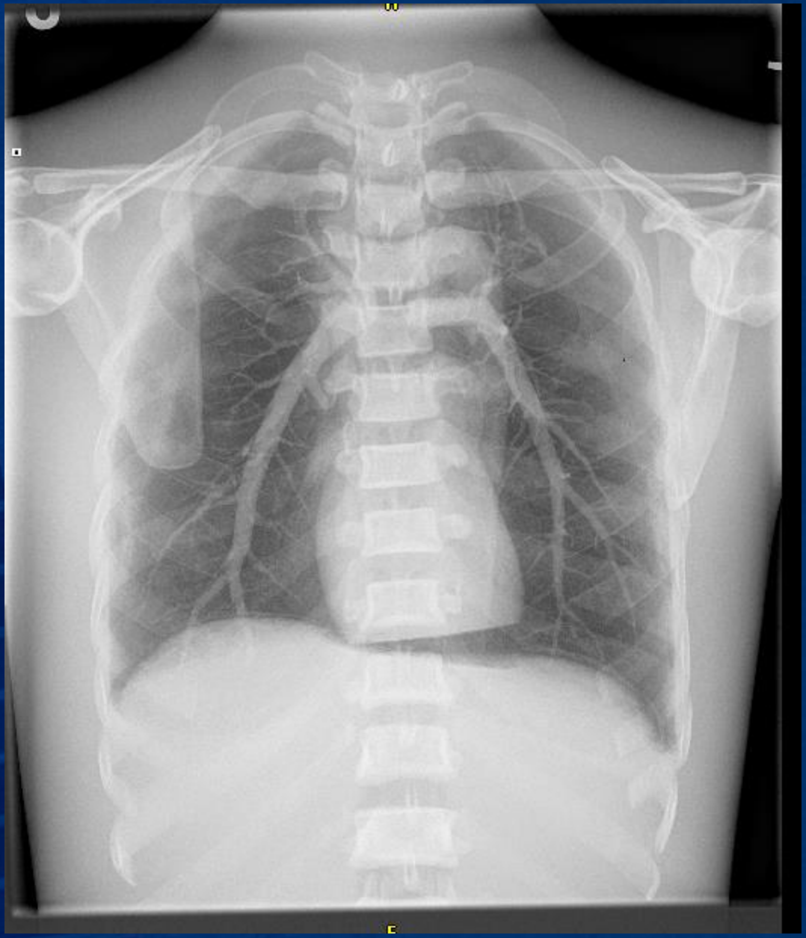
92 kV @ 20 mAs = 15% Rule with mAs compensation

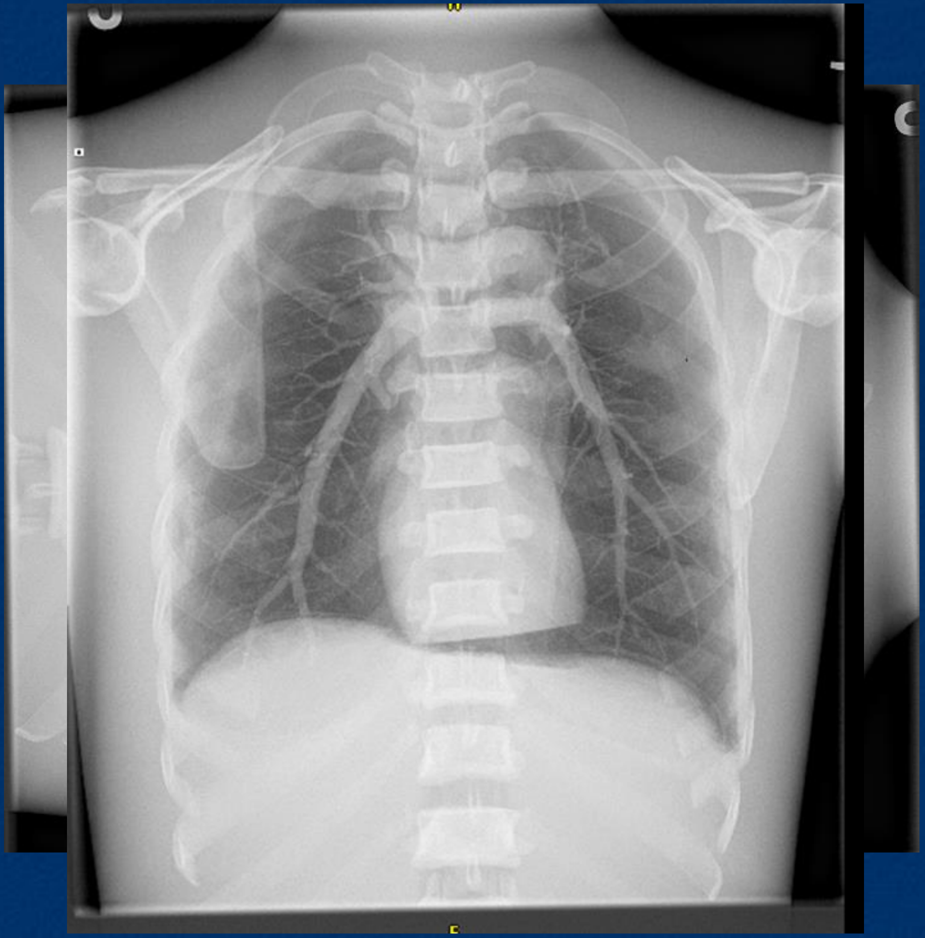
# Digital Image Manipulation

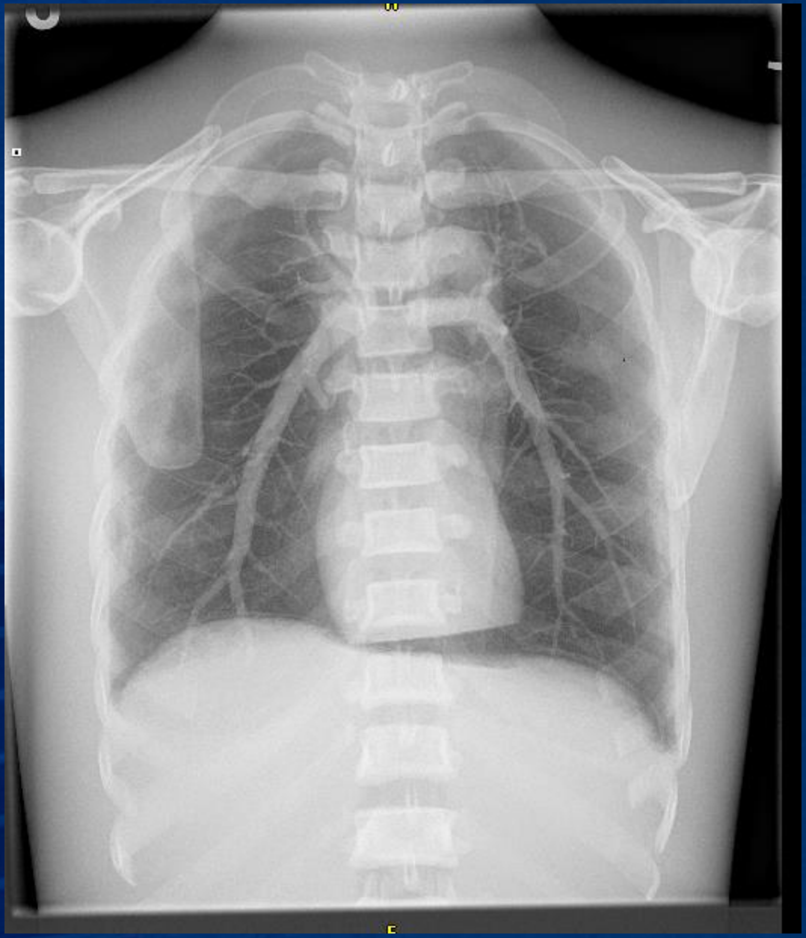
By Prof. Stelmark

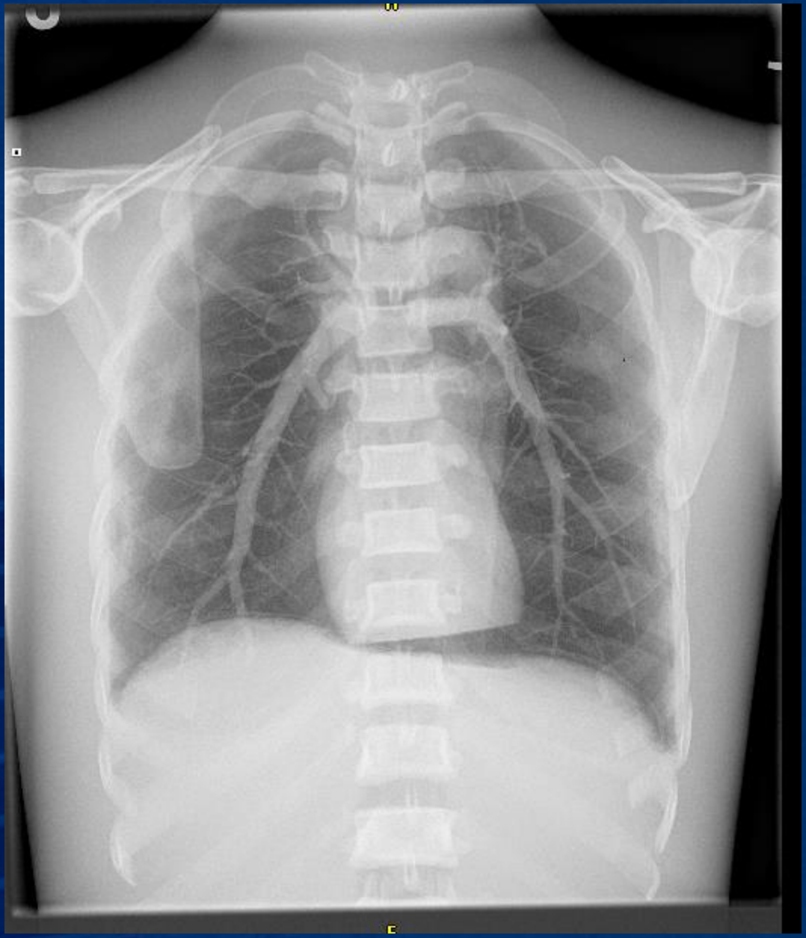


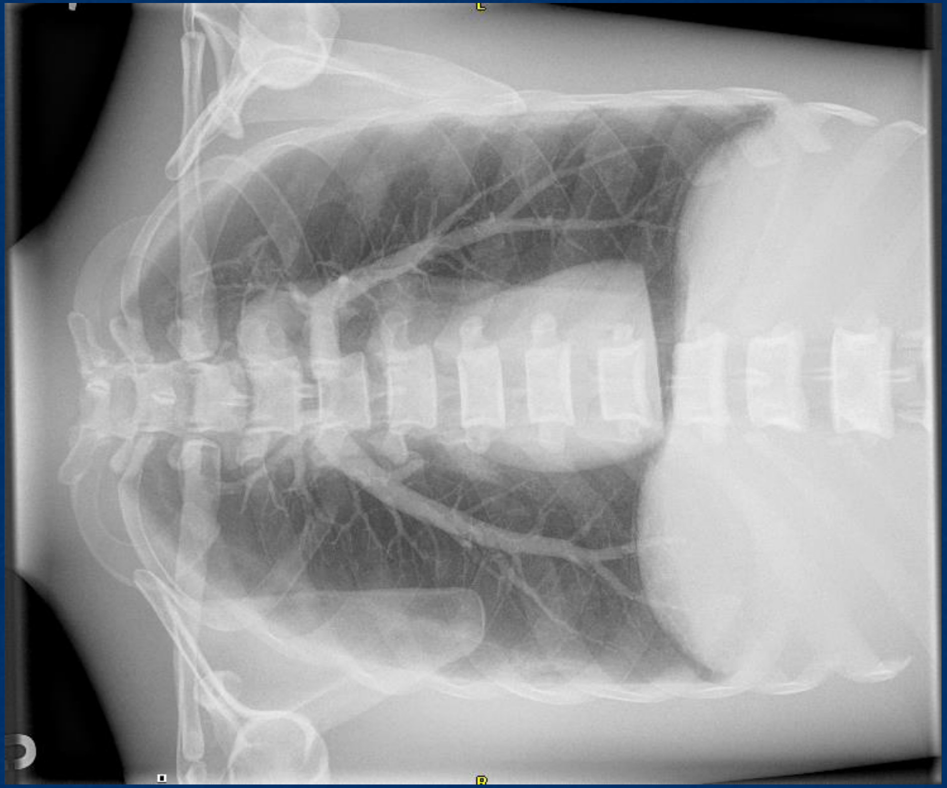


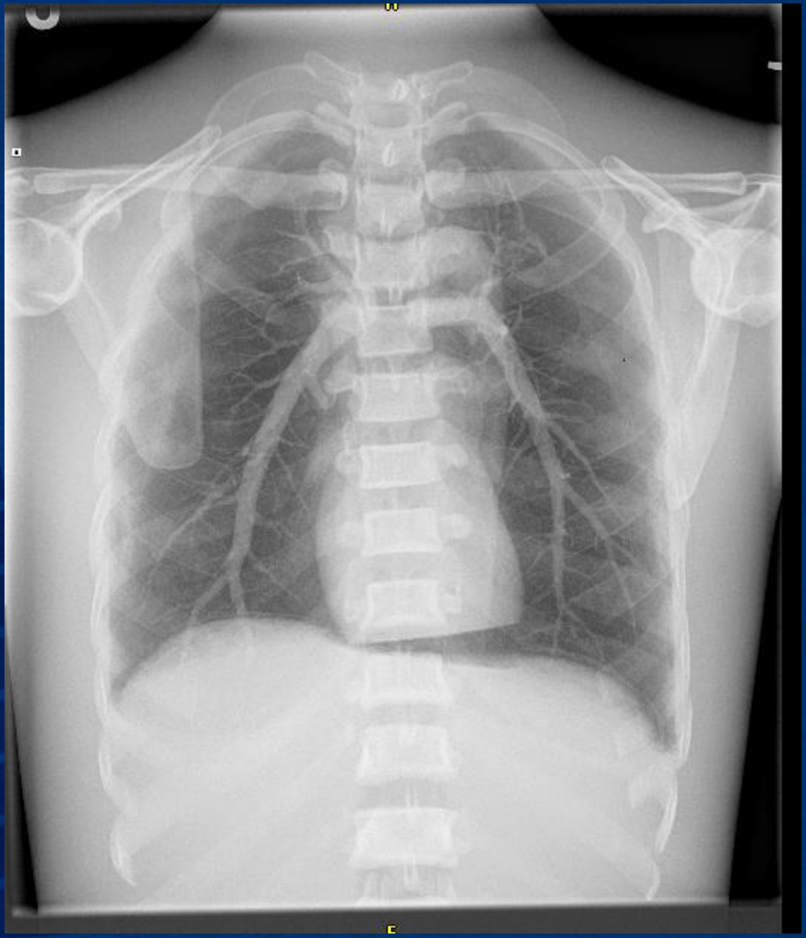


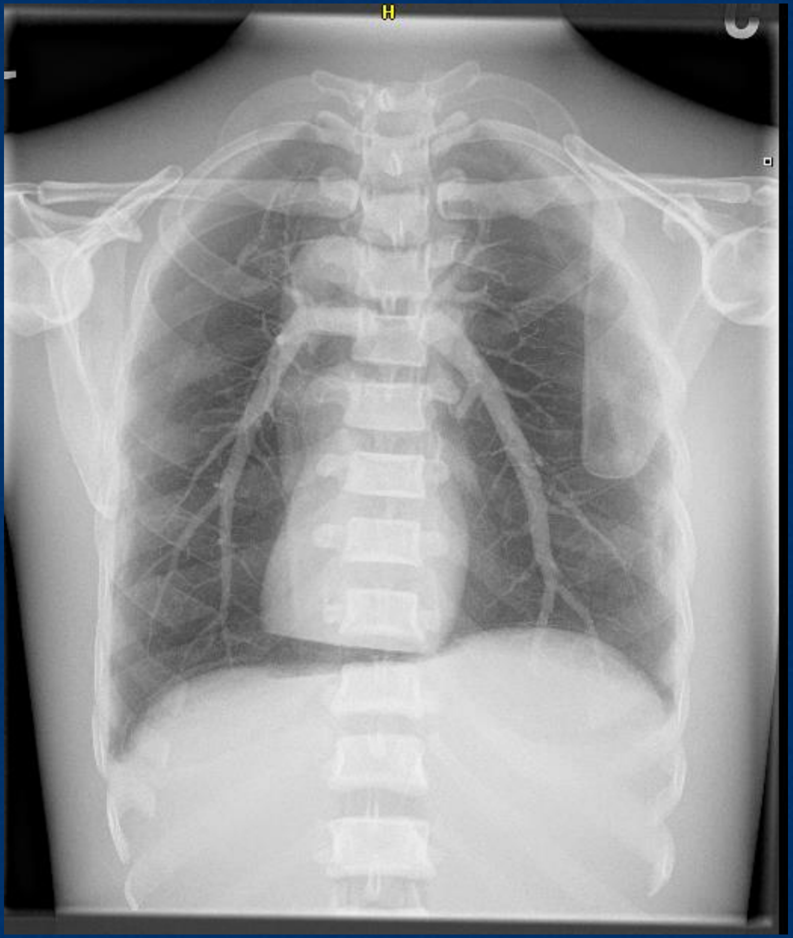




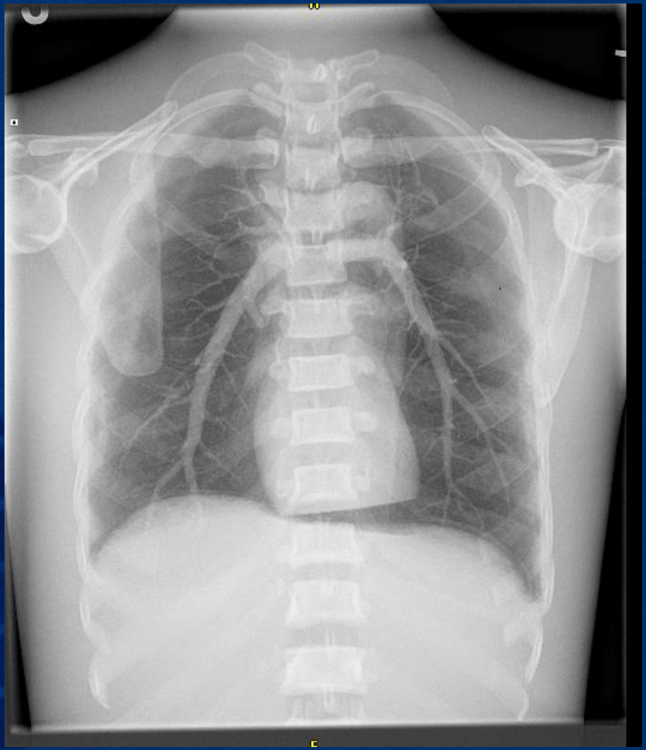


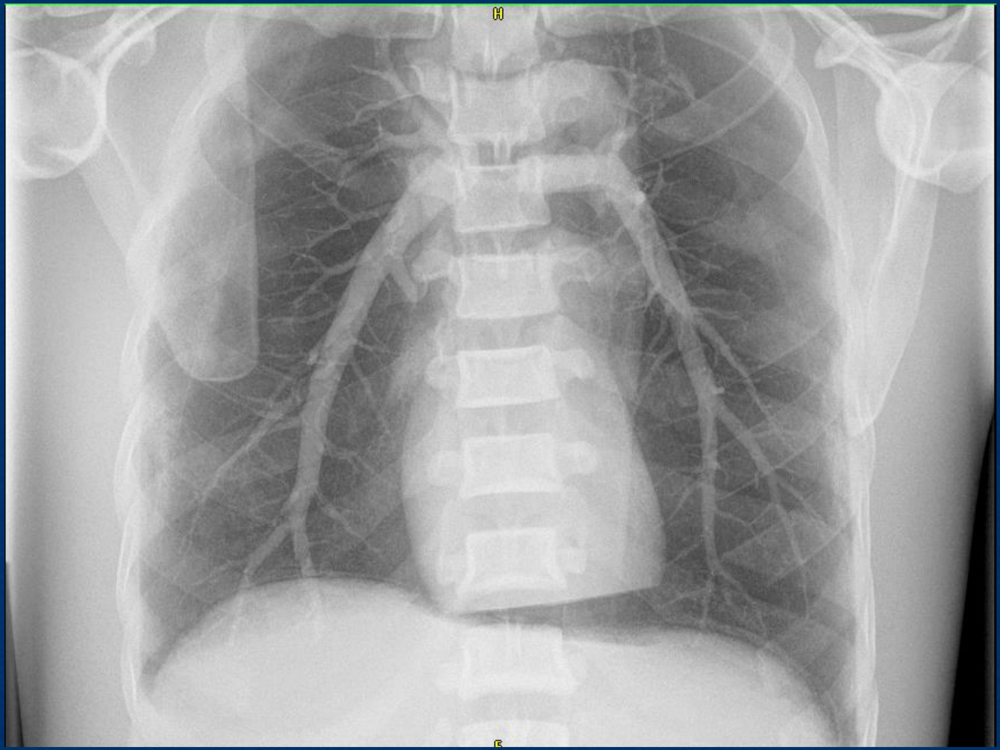


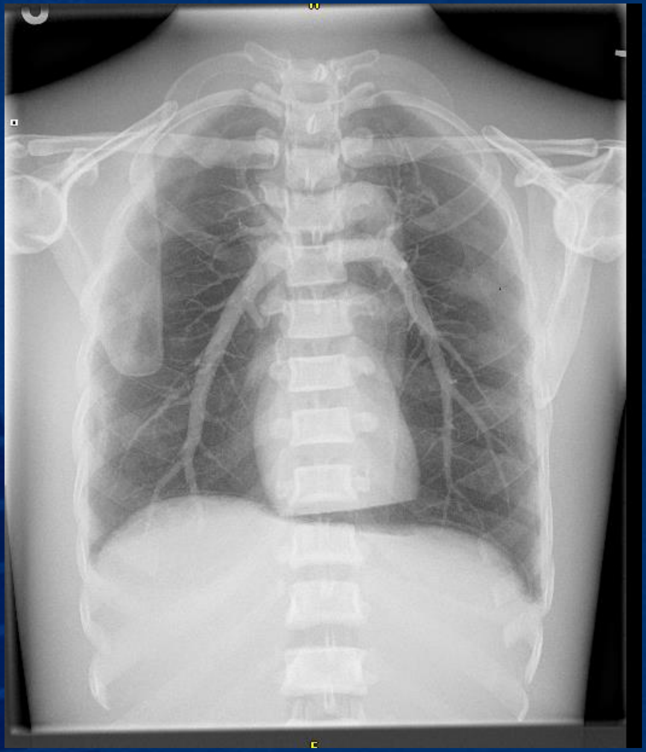


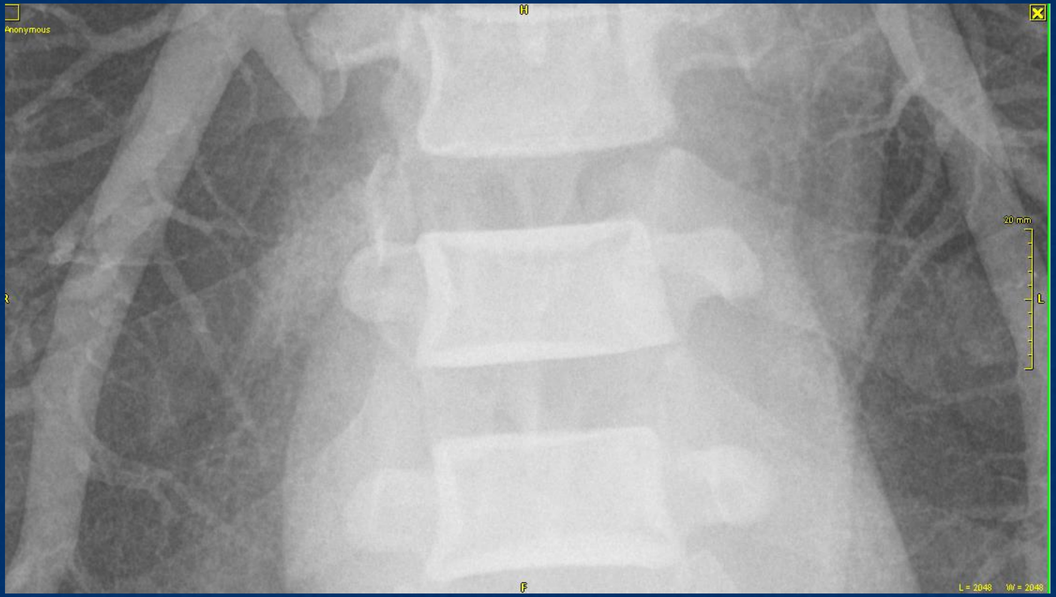

H

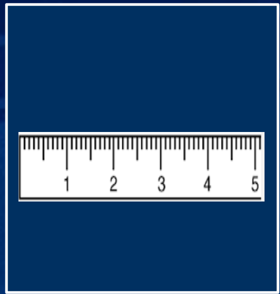

H

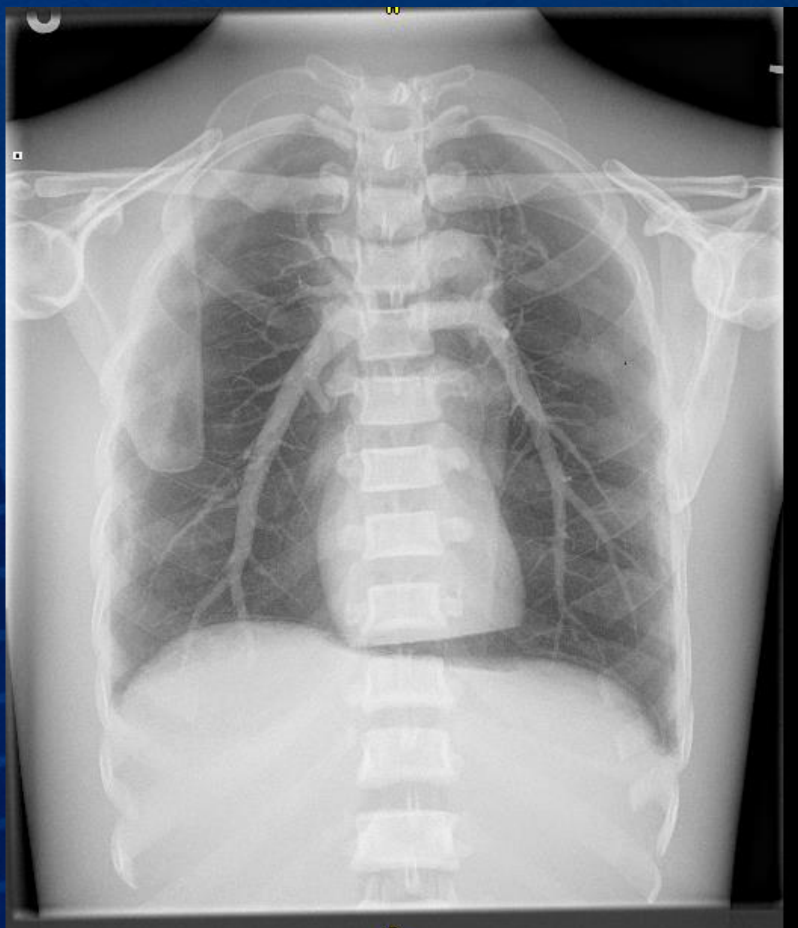


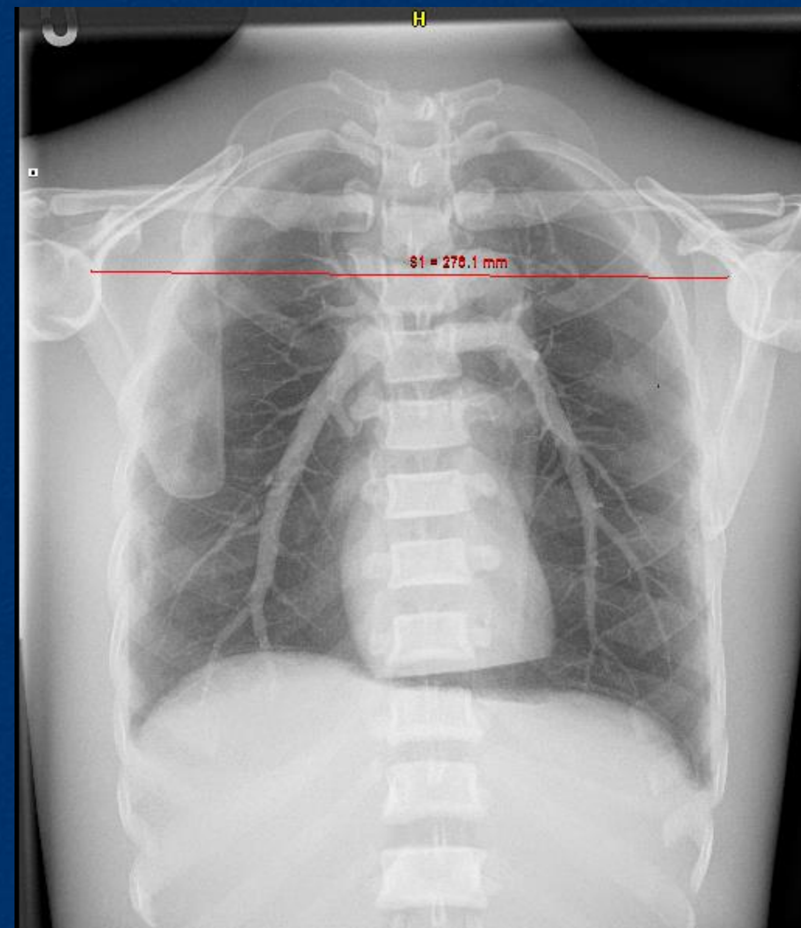

H

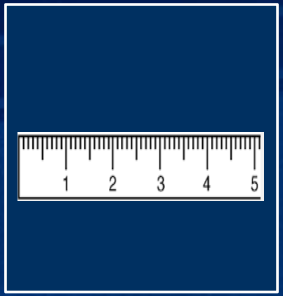

H
F

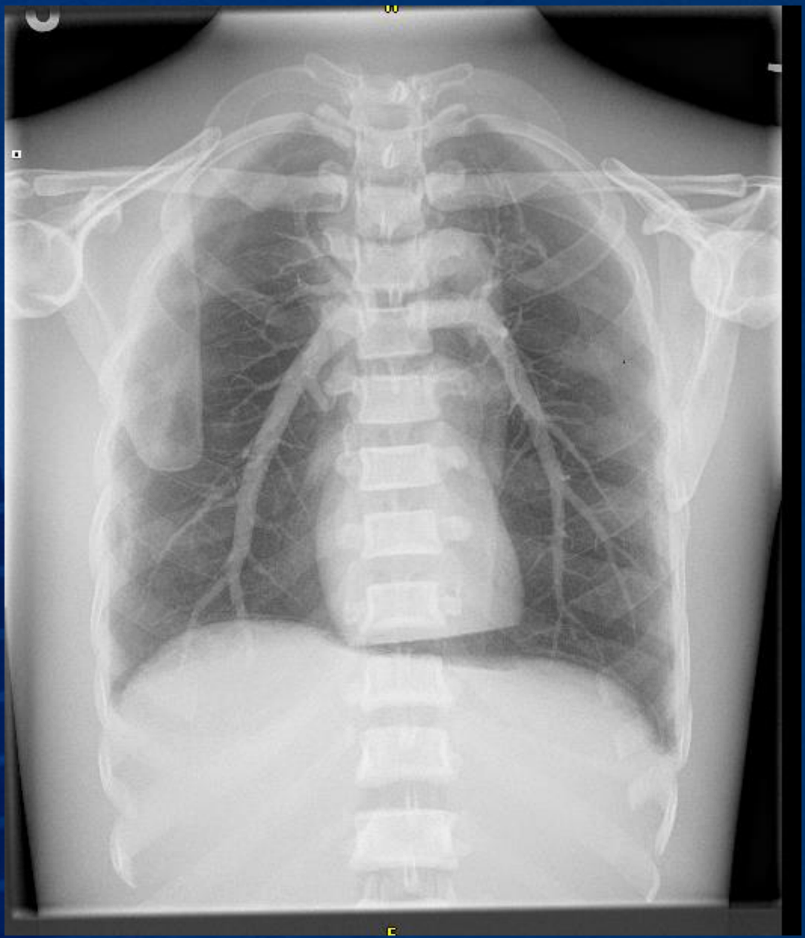

H
Anonymous
R
20 mm
L
F
L = 2048 W = 2048

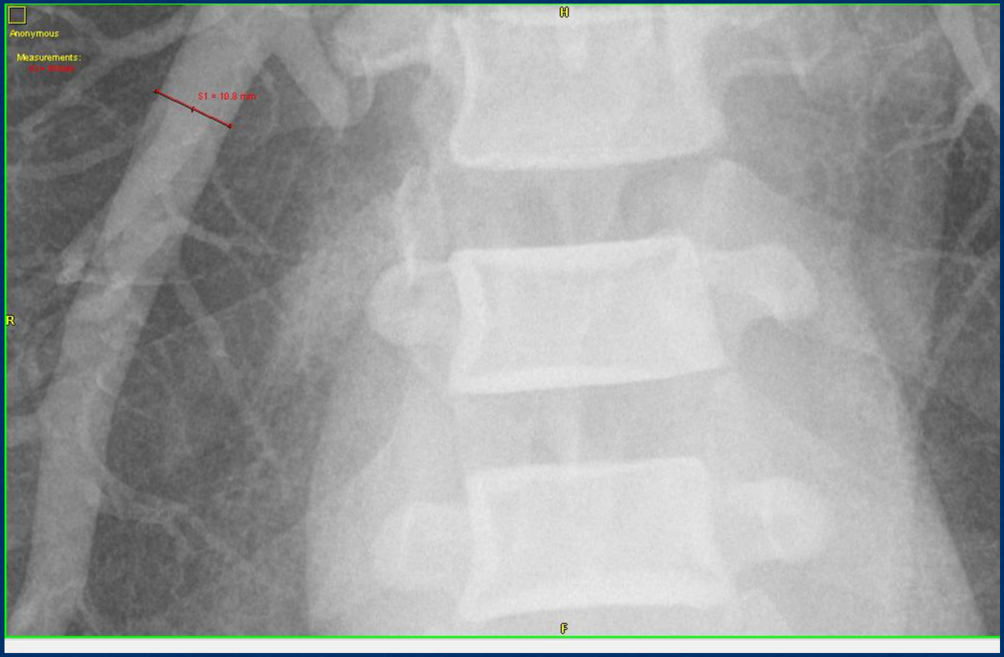

1 2 3 4 5

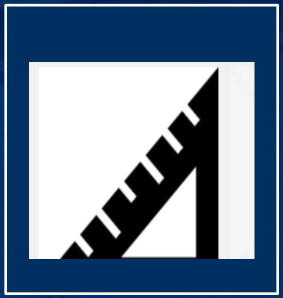


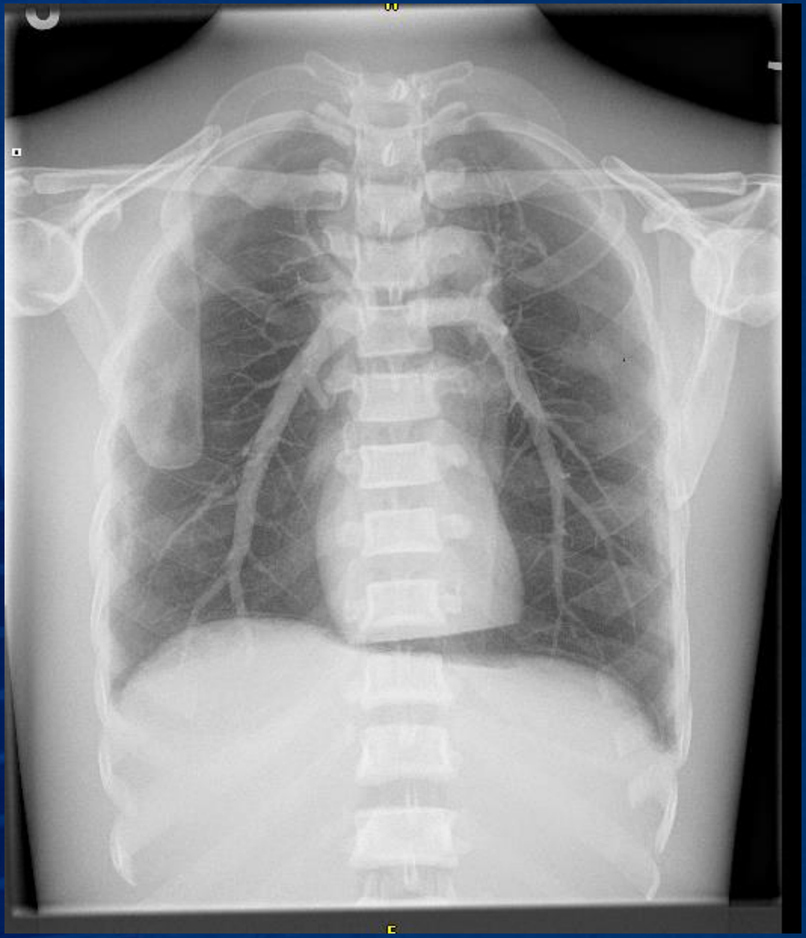

H
S1 = 276.1 mm

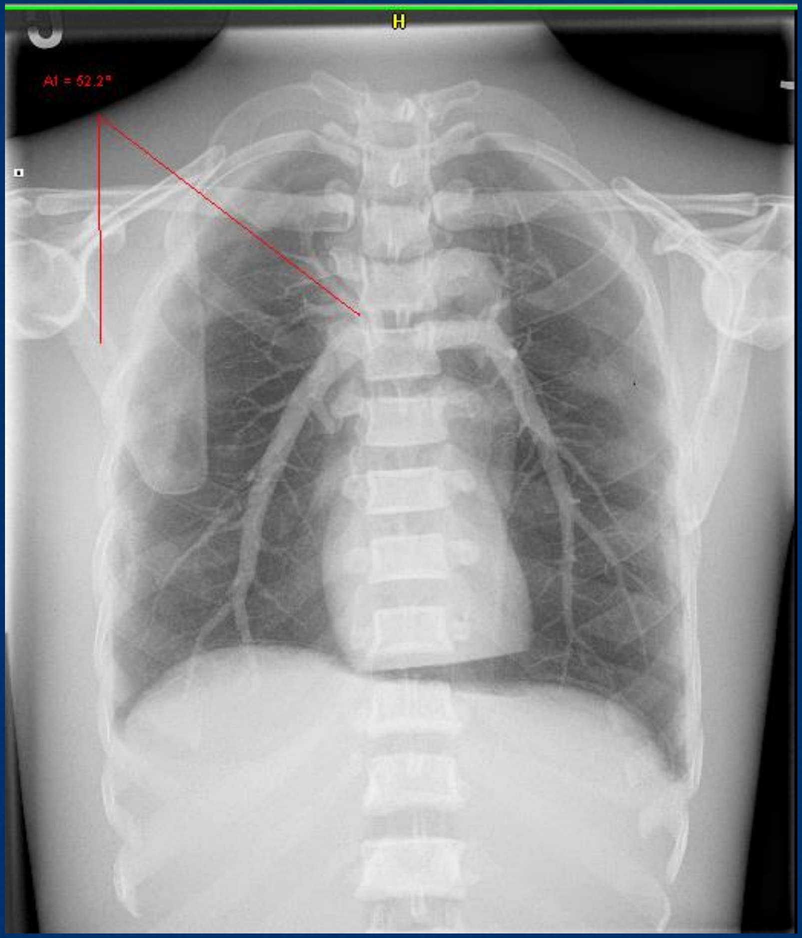

1 2 3 4 5

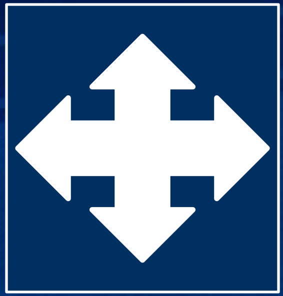


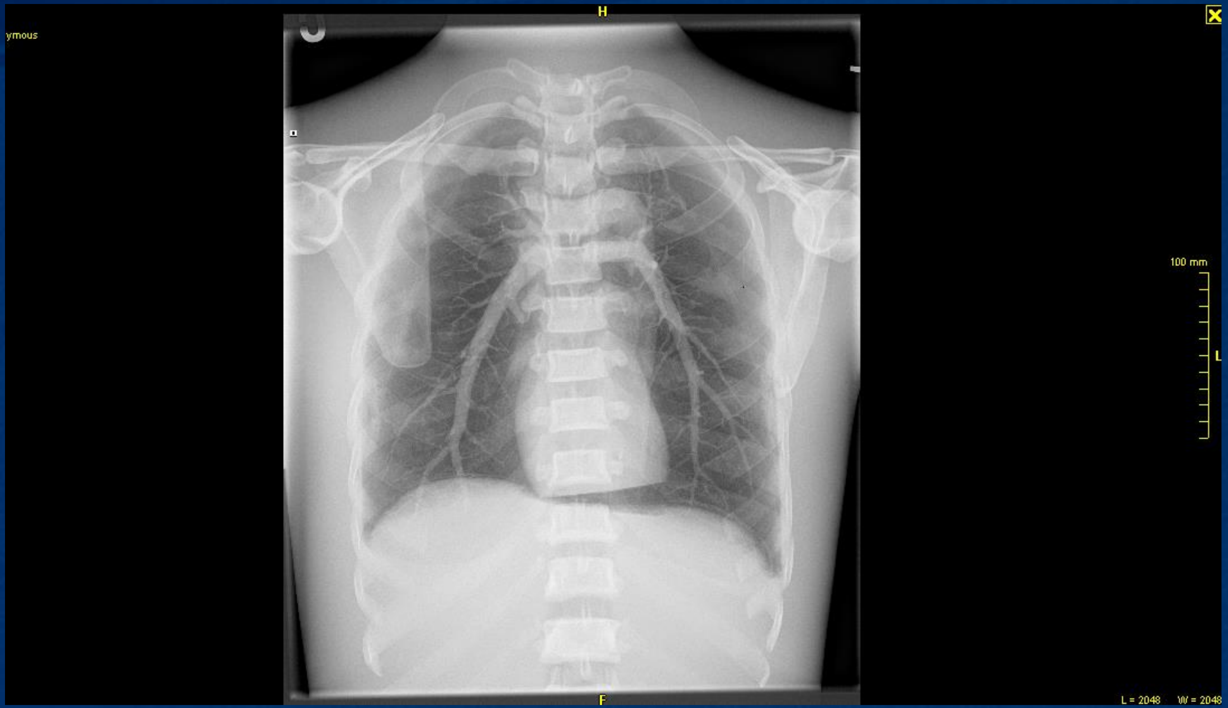

H
Anonymous
Measurements:
S1 = 10.8 mm
R
F

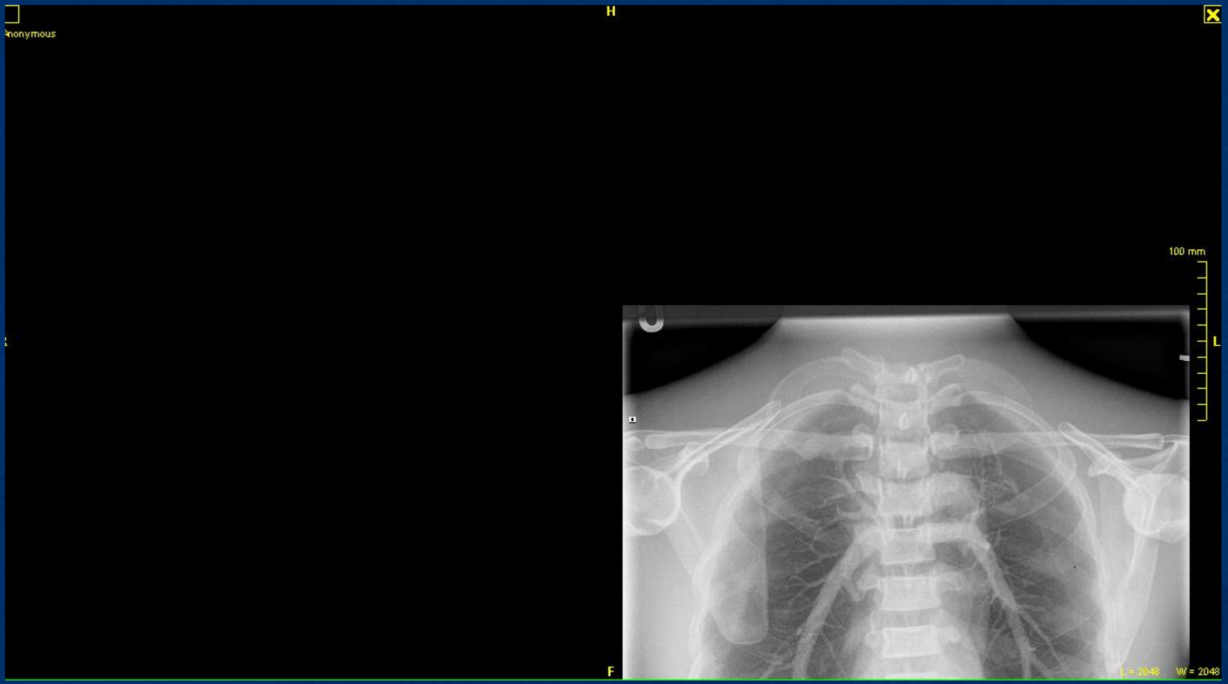


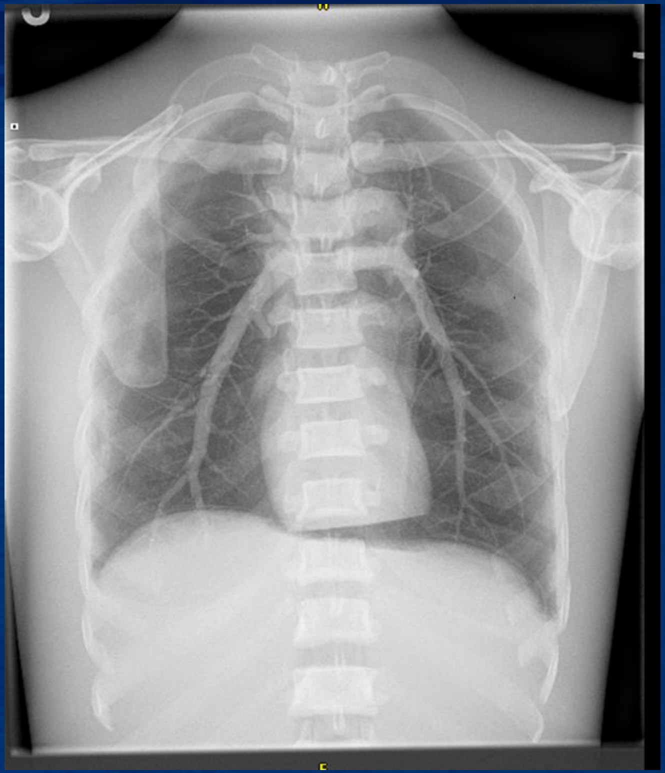



H
A1 = 52.2°



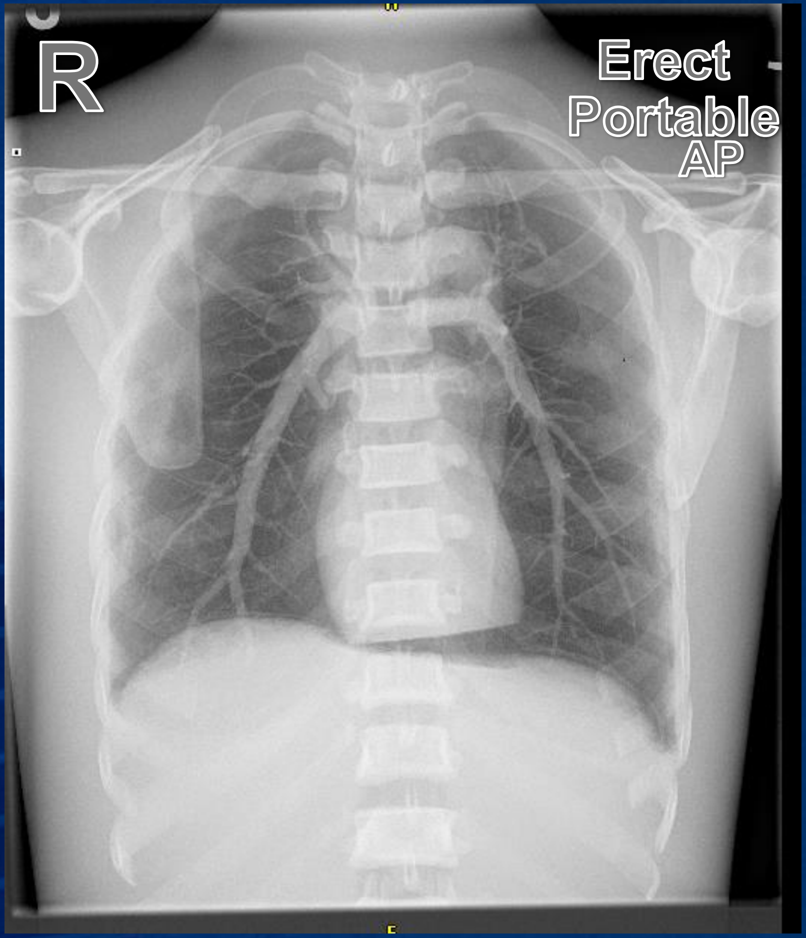

ymous
H
100 mm
L
F
L = 2048
W = 2048

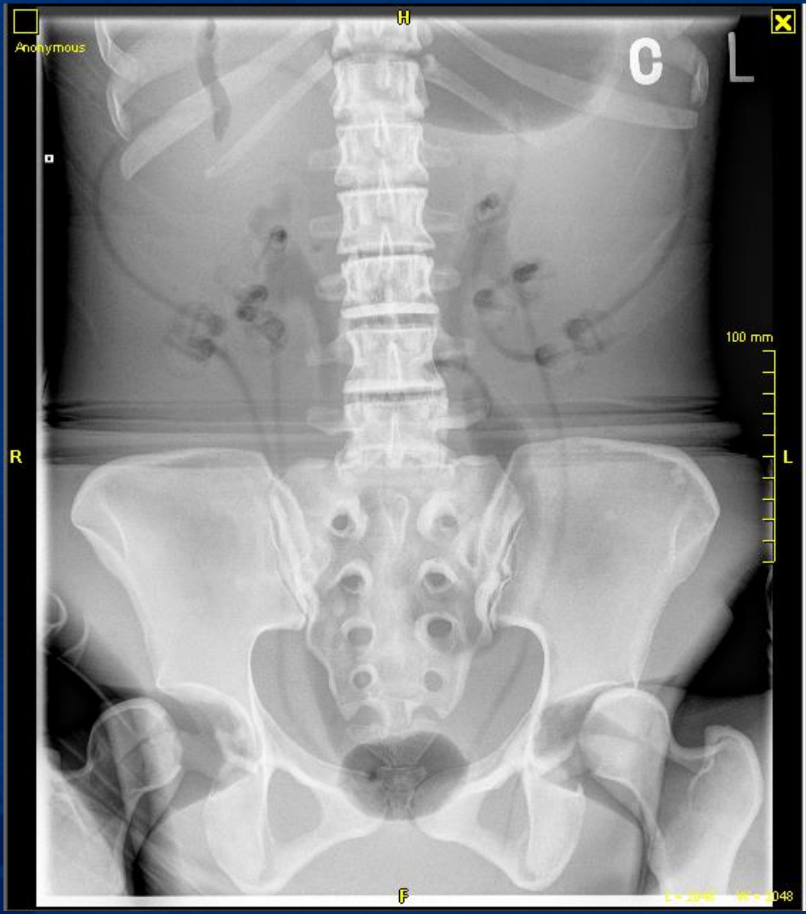

H
100 mm
L
F
L = 2048
W = 2048



R

L




H
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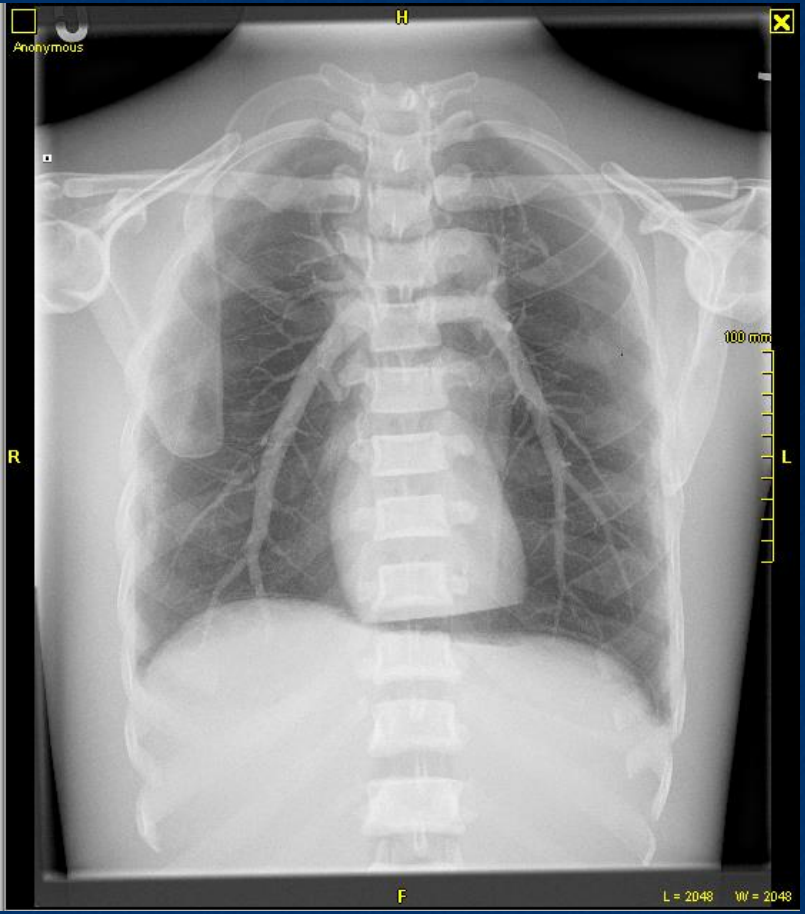
C
L
100 mm
R
L
F


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


H
C
L
100 mm
L
F


H
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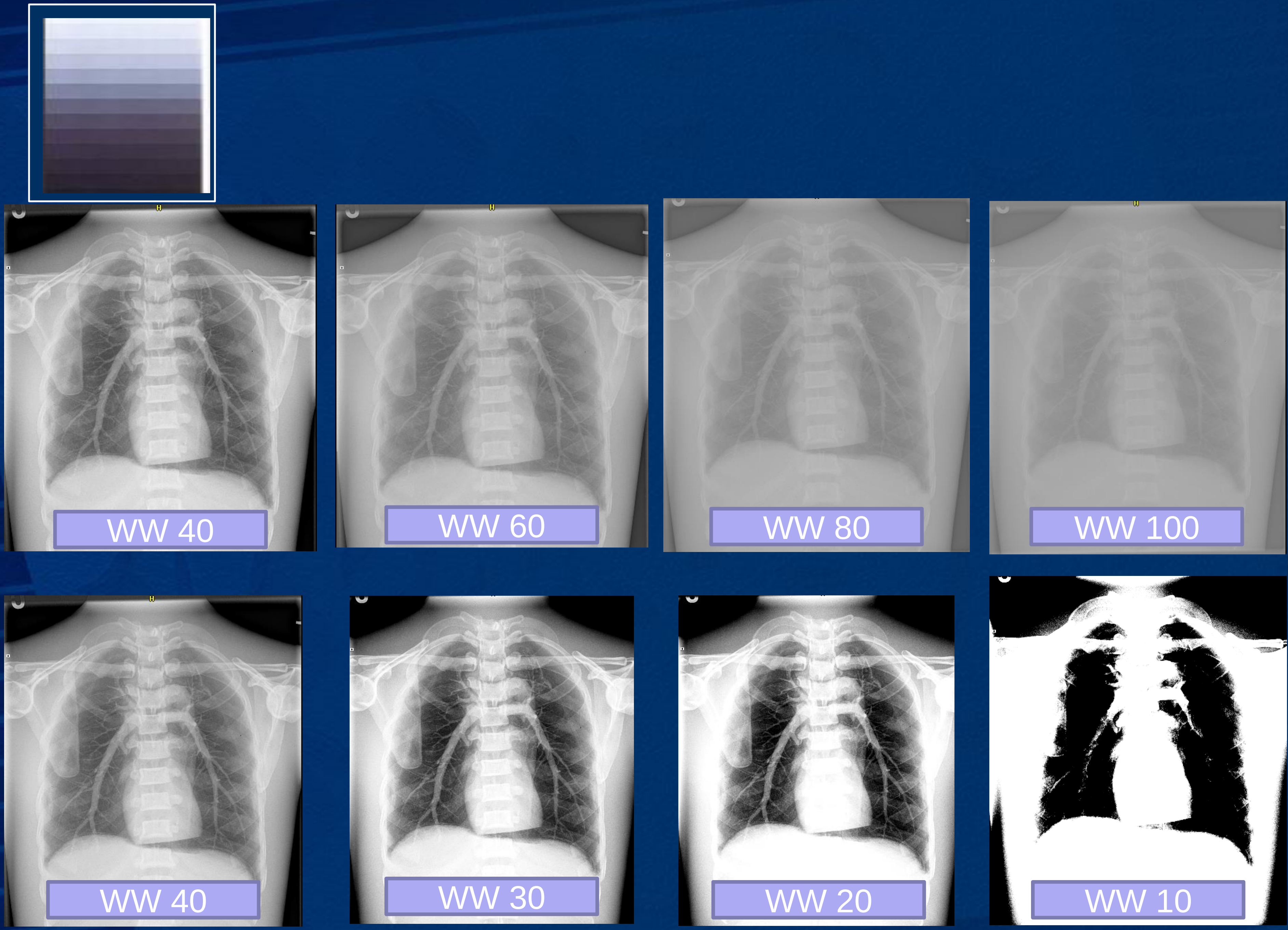
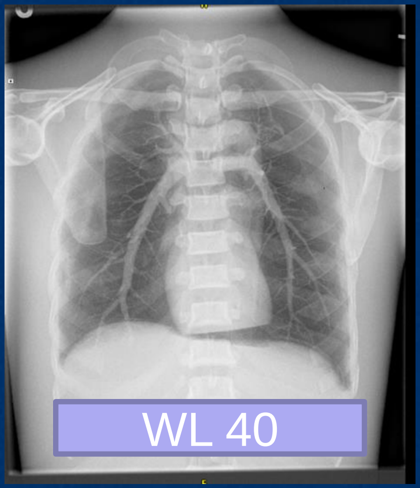
F
L = 2048
W = 2048


WW 40
WW 60
WW 80
WW 100
WW 40
WW 30
WW 20
WW 10

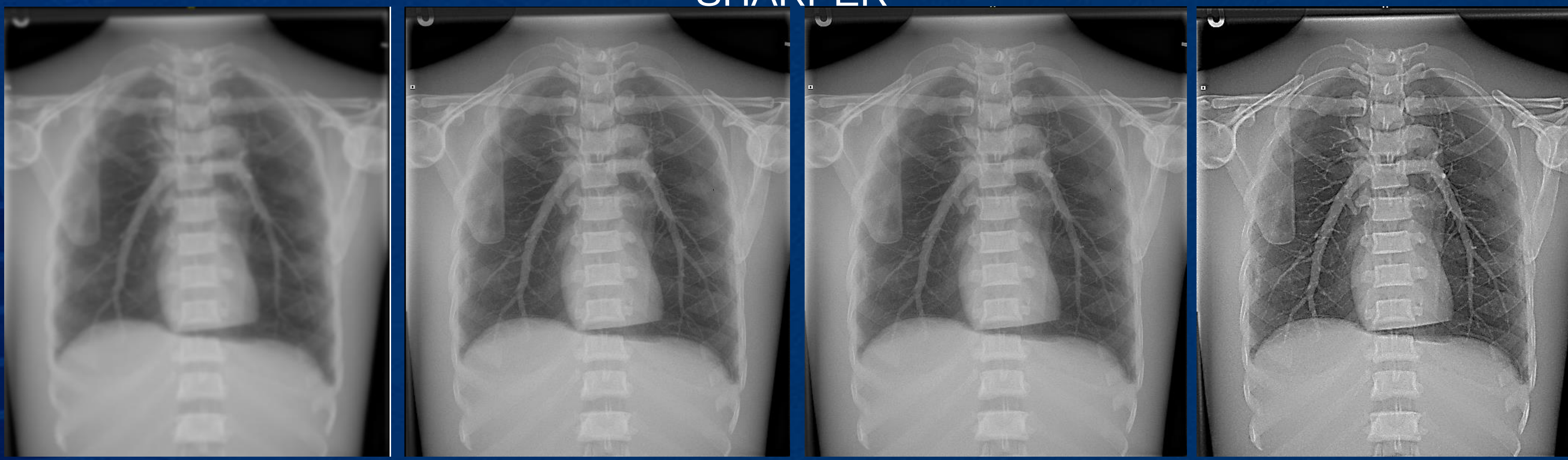

WL 10

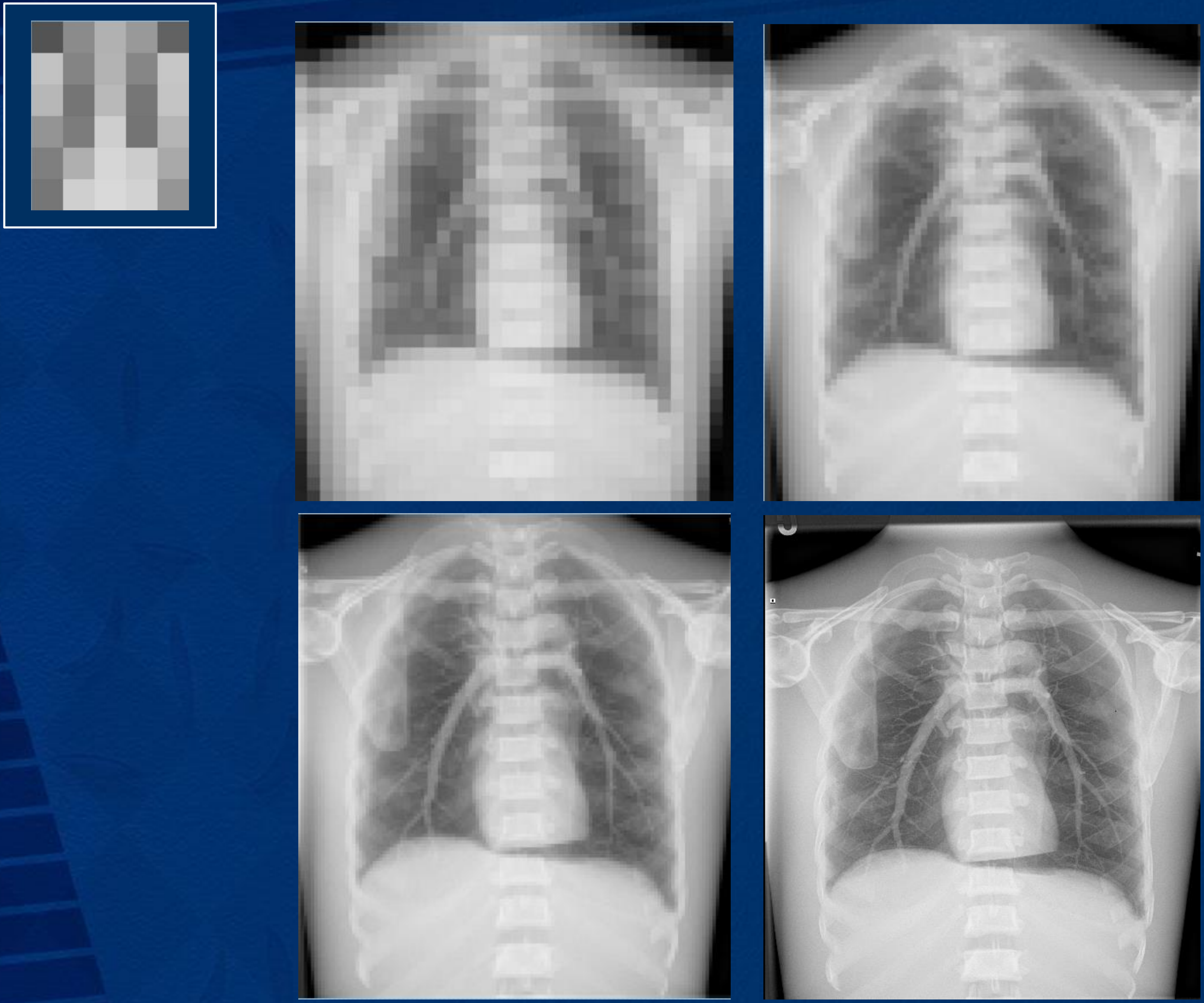

WL 20

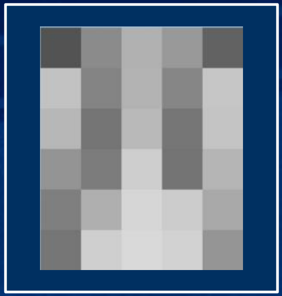

WL 40


WL 60

SMOOTHER
SHARPER

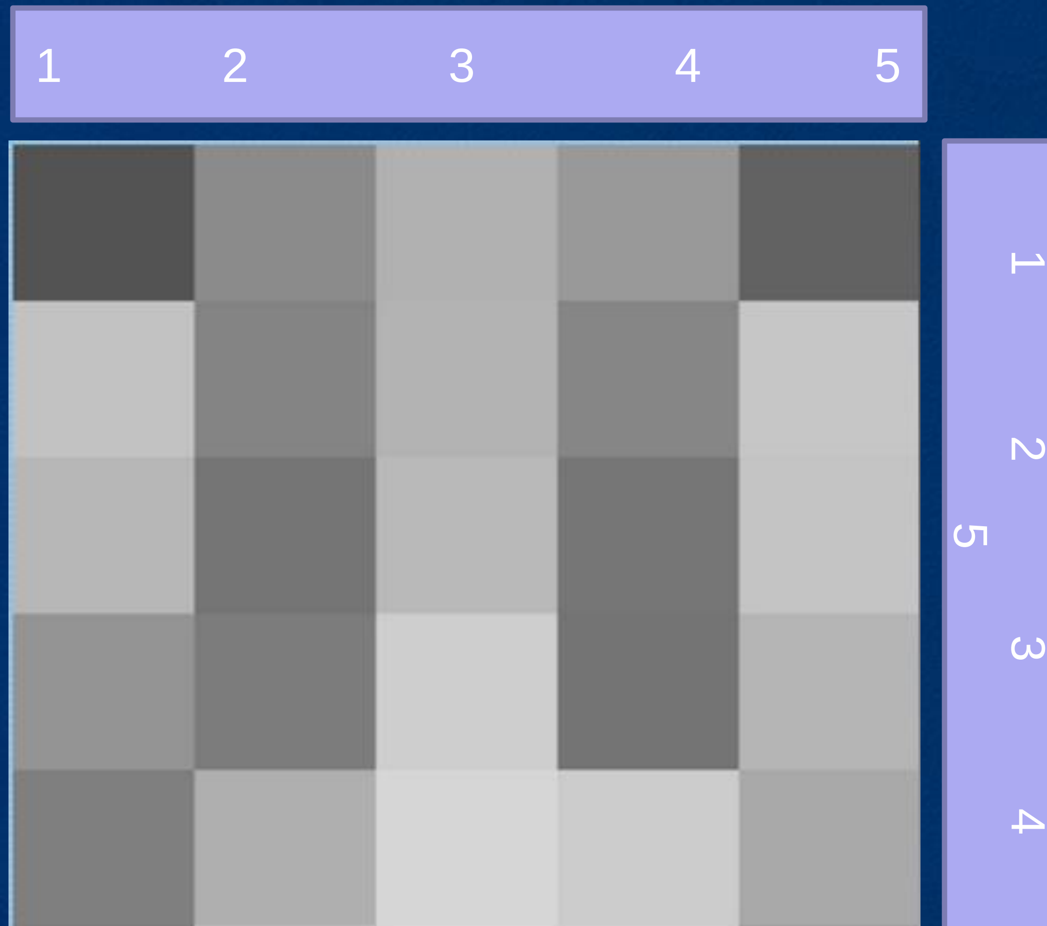


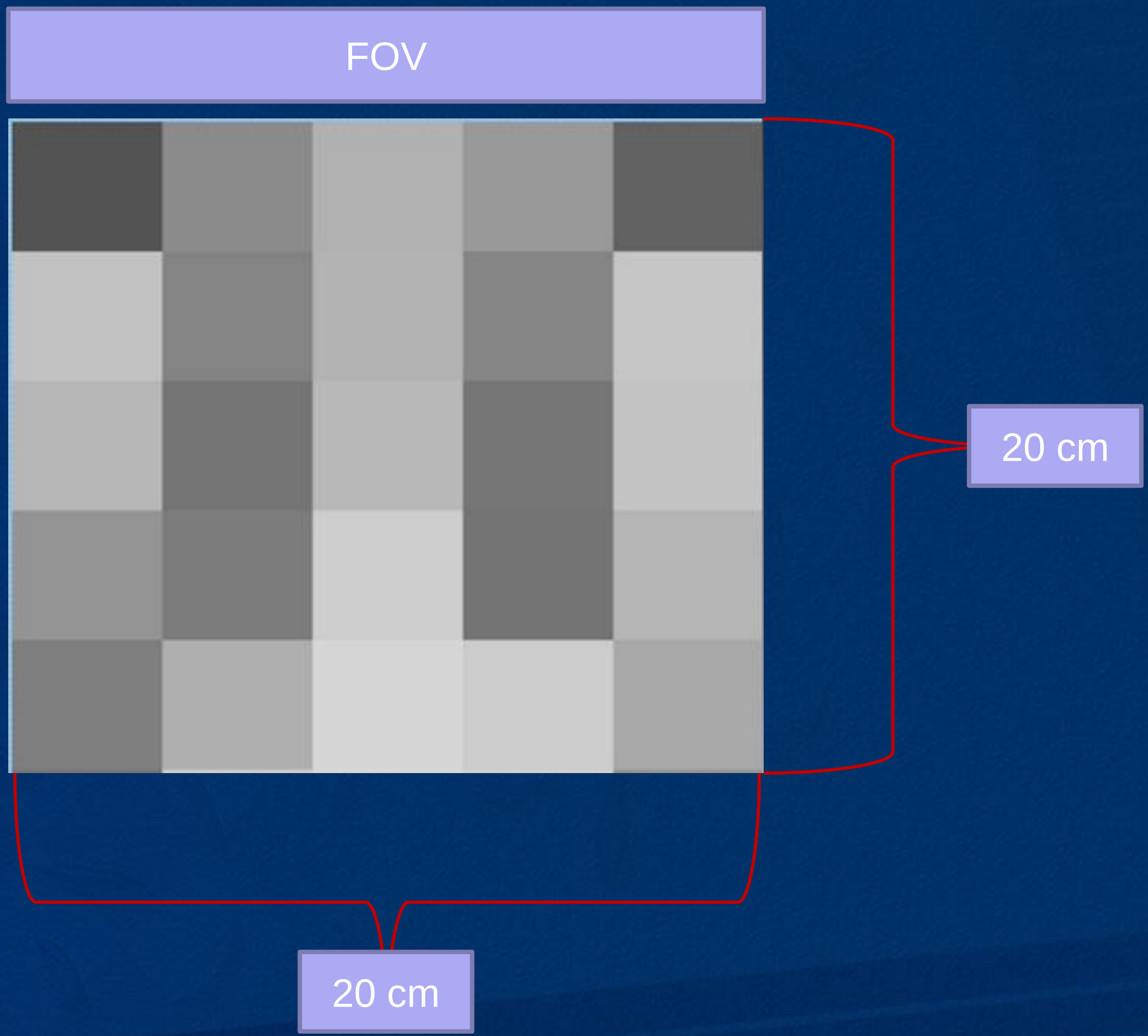




$$\text{Pixel Size} = \frac{FOV}{Matrix}$$

# Matrix 5 x 5

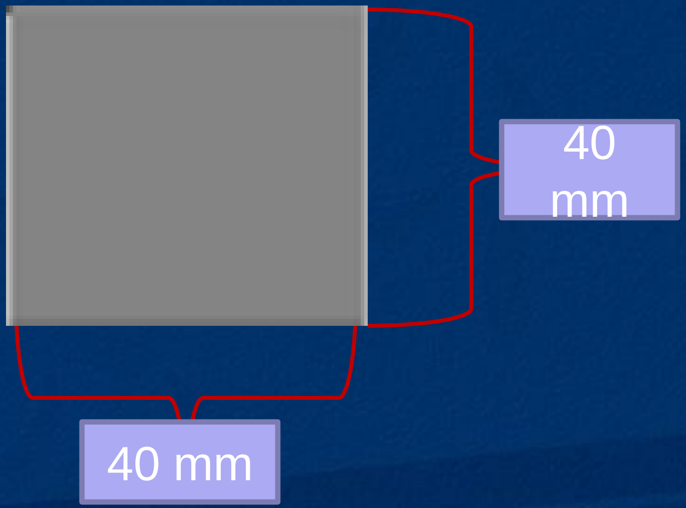



FOV
20 cm
20 cm

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

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

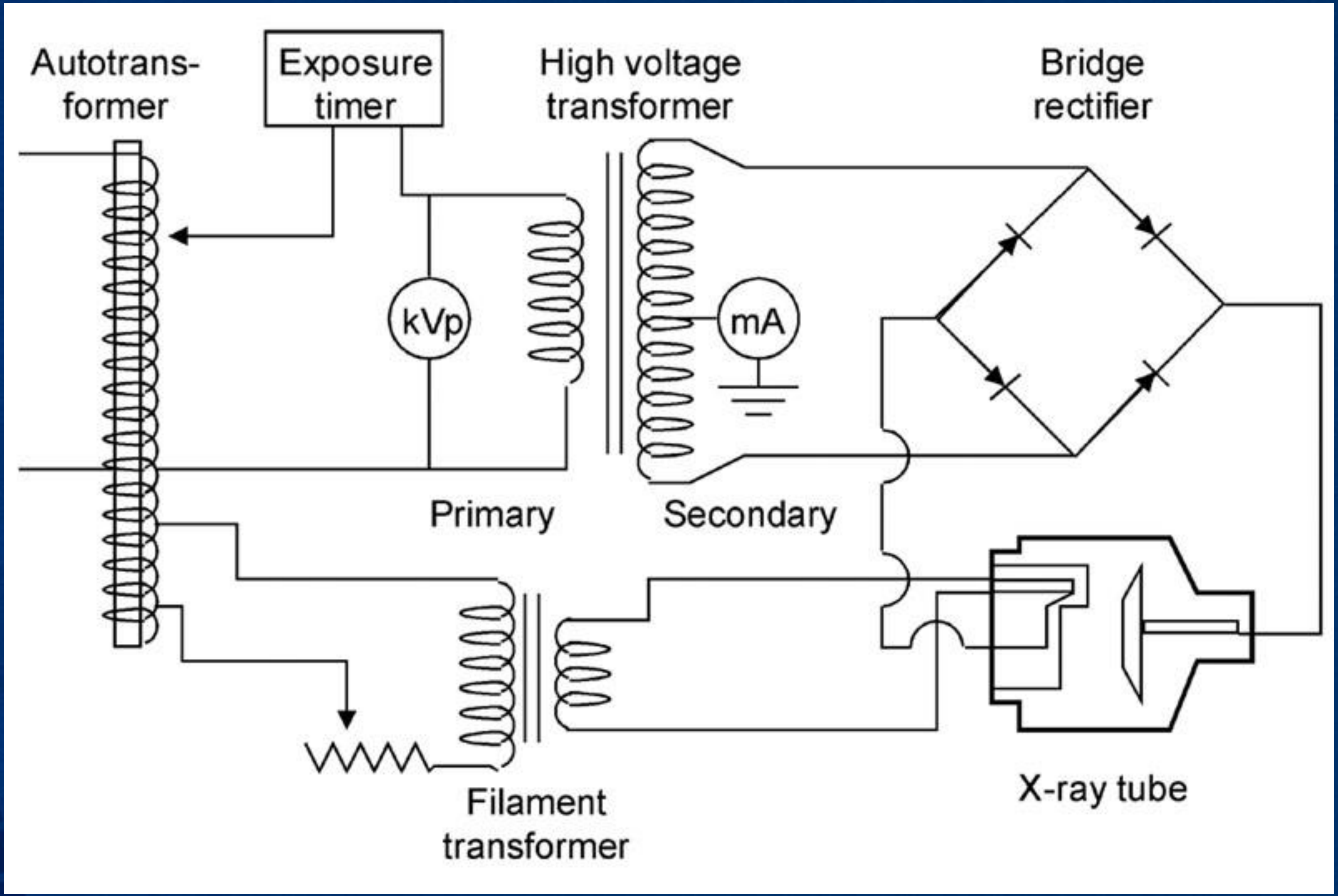
Pixel Size = $40\ mm$



# AEC and Grids

By Prof. Stelmark

# Exposure Timers


Autotrans-
former
Exposure
timer
High voltage
transformer
Bridge
rectifier
kVp
mA
Primary
Secondary
Filament
transformer
X-ray tube

## EXPOSURE TIMERS

For any given radiographic examination, the number of x-rays that reach the image receptor is directly related to both the x-ray tube current and the time that the tube is energized. X-ray operating consoles provide a wide selection of x-ray beam-on times and, when used in conjunction with the appropriate mA station, provide an even wider selection of values for mAs.

Paramount in the design of all timing circuits is that the radiographer starts the exposure and the timer stops it. If at any time during the exposure, the radiographer releases the exposure switch or the fluoroscopic foot switch, the exposure is terminated immediately.

As an additional safety feature, another timing circuit is activated on every radiographic exposure. This timer, called a guard timer, will terminate an exposure after a prescribed time, usually approximately 6 s. Thus, it is not possible for any timing circuit to continuously irradiate a patient for an extensive period.

There are four types of timing circuits. Three are controlled by the radiologic technologist and one is automatic.

- Electronic
- mAs
- AEC Automatic Exposure Control

## Electronic Timers

Electronic timers are the most sophisticated, most complicated, and most accurate of the x-ray exposure timers. Electronic timers consist of rather complex circuitry based on the time required to charge a capacitor through a variable resistance.

Electronic timers allow a wide range of time intervals to be selected and are accurate to intervals as small as 1 ms. Because they can be used for rapid serial exposures, they are particularly suitable for angio-interventional procedures.

## mAs Timers

Most x-ray apparatus is designed for accurate control of tube current and exposure time. However, the product of mA and time—mAs—determines the number of x-rays emitted and, therefore, the exposure of the image receptor. A special kind of electronic timer, called an ***mAs timer***, monitors the product of mA and exposure time and terminates exposure when the desired mAs value is attained.

## Automatic Exposure Control

The automatic exposure control (AEC) requires a special understanding on the part of the radiologic technologist. The AEC is a device that measures the quantity of radiation that reaches the image receptor. It automatically terminates the exposure when the image receptor has received the required radiation intensity

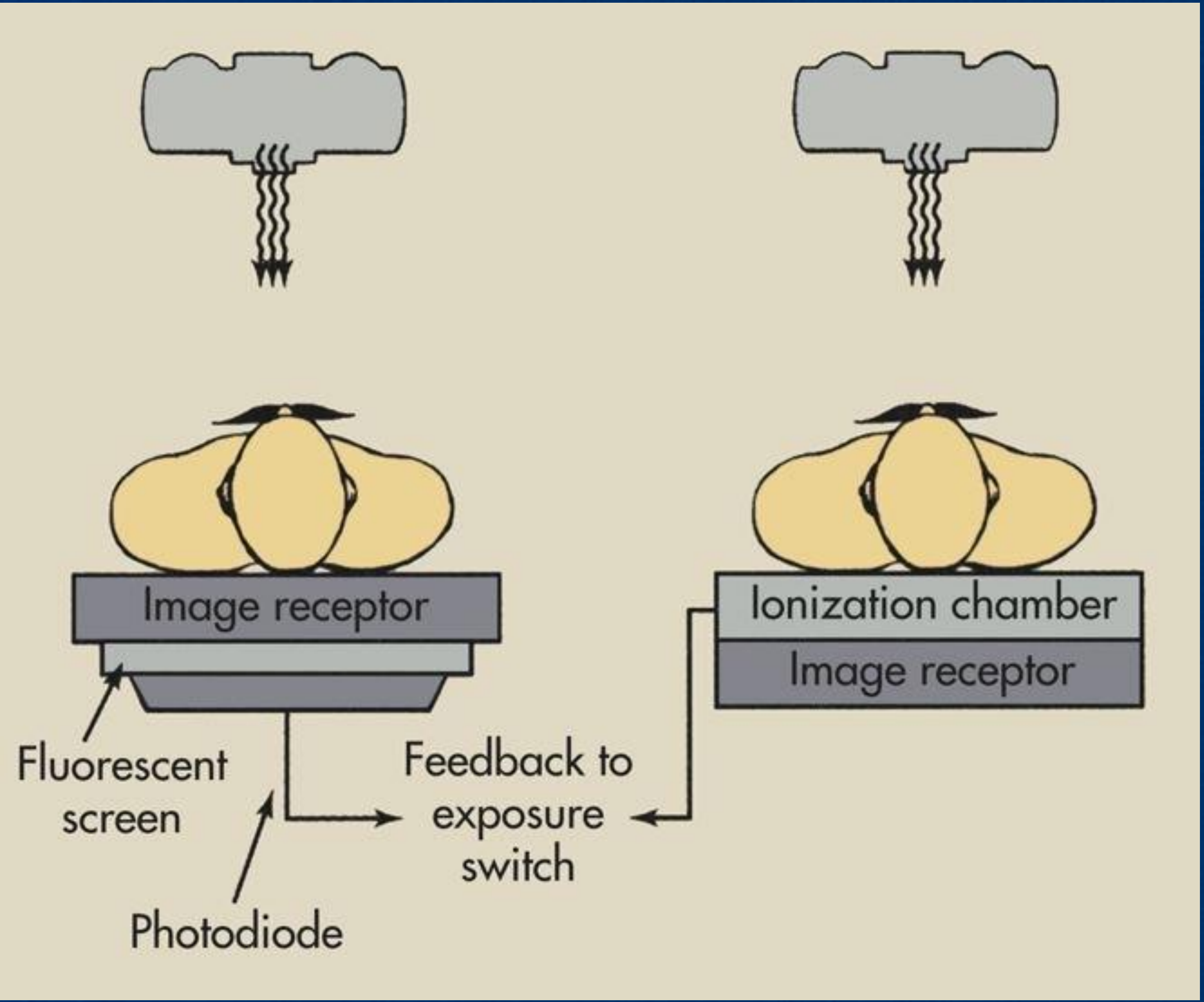


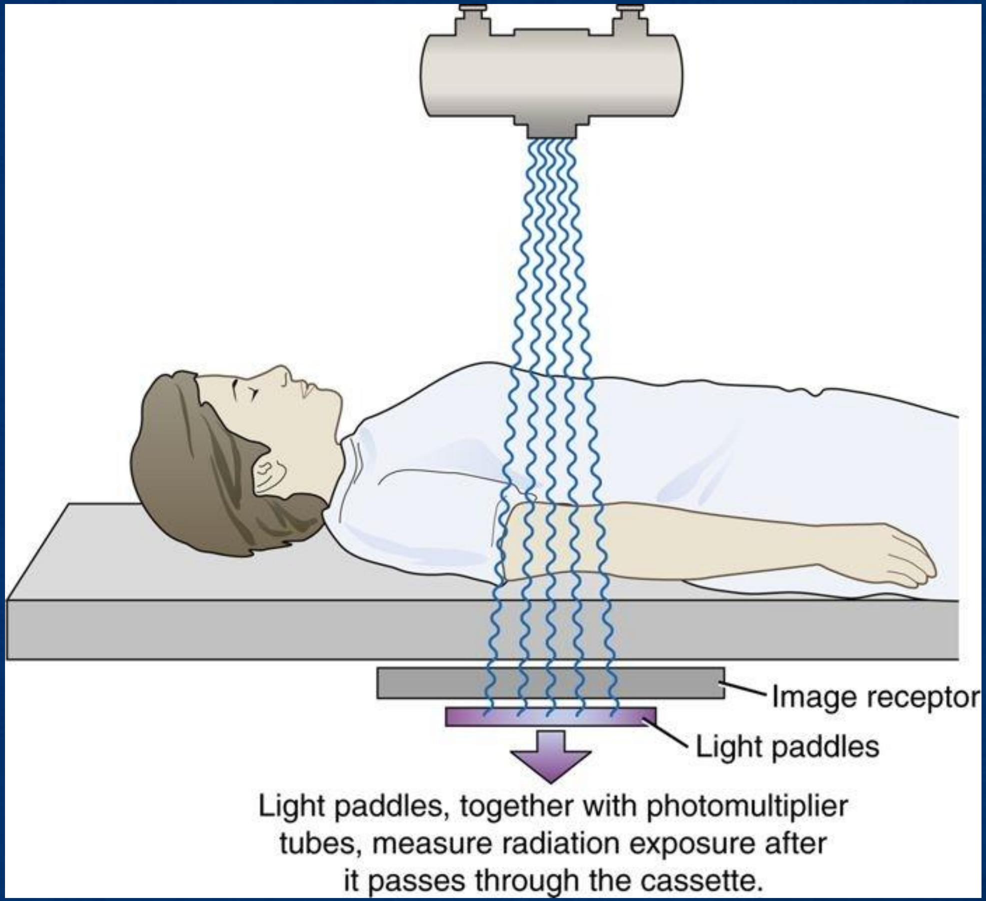
Image receptor
Fluorescent screen
Photodiode
Feedback to exposure switch
Ionization chamber
Image receptor

## PHOTOTIMERS

**Phototimers** use a fluorescent (light-producing) screen and a device that converts the light to electricity. A **photomultiplier (PM) tube** is an electronic device that converts visible light energy into electrical energy. A photodiode is a solid-state device that performs the same function. Phototimer AEC devices are considered exit-type devices because the detectors are positioned behind the image receptor so that radiation must exit the image receptor before it is measured by the detectors.

Phototimers have largely been replaced with ionization chamber systems.

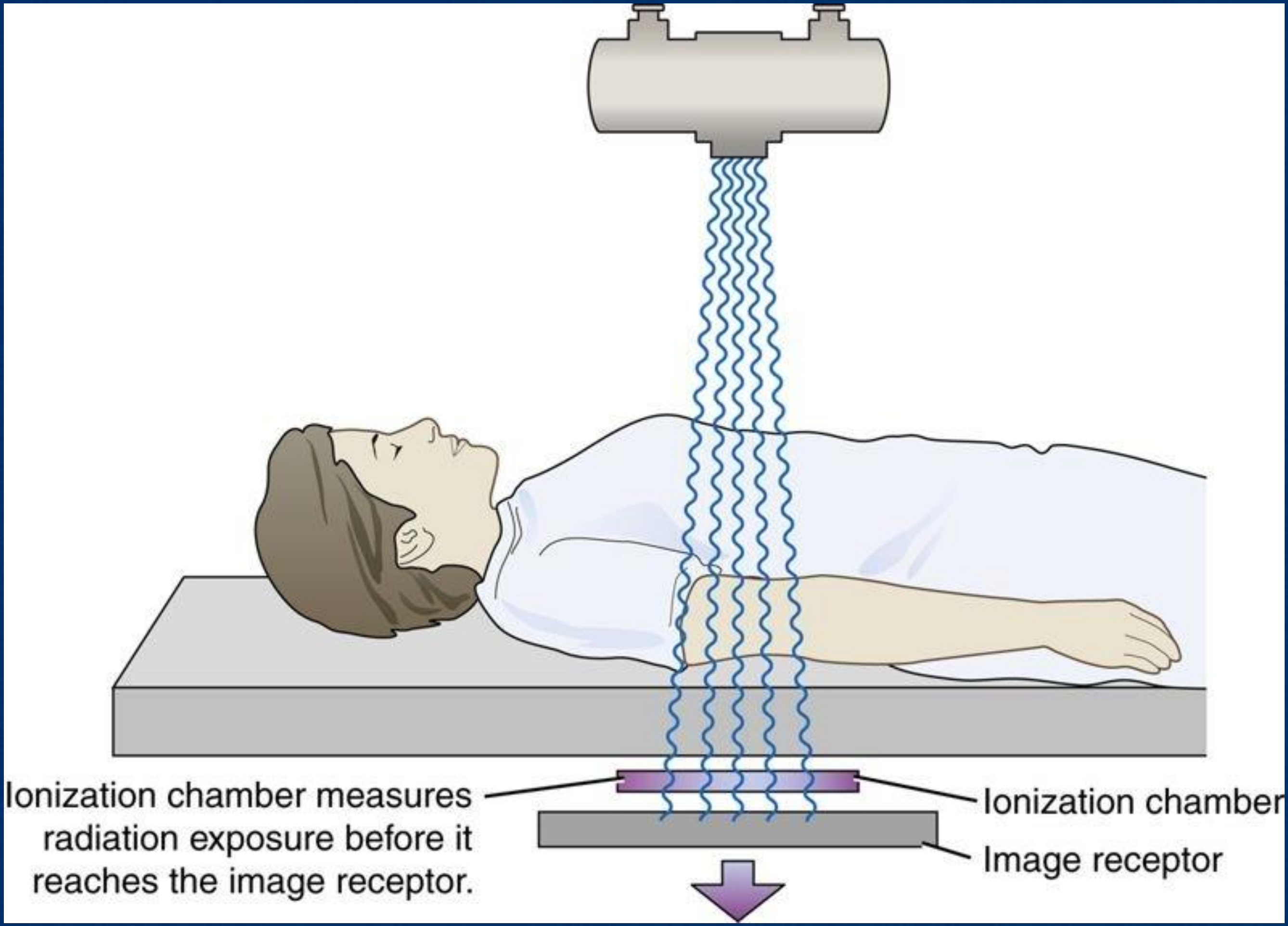
Light paddles, coated with a fluorescent material, serve as the detectors, and the radiation interacts with the paddles, producing visible light. This light is transmitted to remote PM tubes or photodiodes that convert this light into electricity. The timer is tripped and the radiographic exposure is terminated when a sufficiently large charge has been received. This electrical charge is in proportion to the radiation to which the light paddles have been exposed.



## IONIZATION CHAMBER SYSTEMS

An **ionization chamber**, or **ion chamber**, is a hollow cell that contains air and is connected to the timer circuit via an electrical wire. Ionization chamber AEC devices are considered entrance-type devices because the detectors are positioned in front of the image receptor so that radiation interacts with the detectors just before interacting with the image receptor. When the ionization chamber is exposed to radiation from a radiographic exposure, the air inside the chamber becomes ionized, creating an electrical charge. This charge travels along the wire to the timer circuit.

The timer is tripped and the radiographic exposure is terminated when a sufficiently large charge has been received. This electrical charge is in proportion to the radiation to which the ionization chamber has been exposed


Ionization chamber measures
radiation exposure before it
reaches the image receptor.
Ionization chamber
Image receptor


www.xray2000.co.uk

Compared with phototimers, ion chambers are less sophisticated and less accurate, but they are less prone to failure. Most of today's AEC systems use ionization chambers.

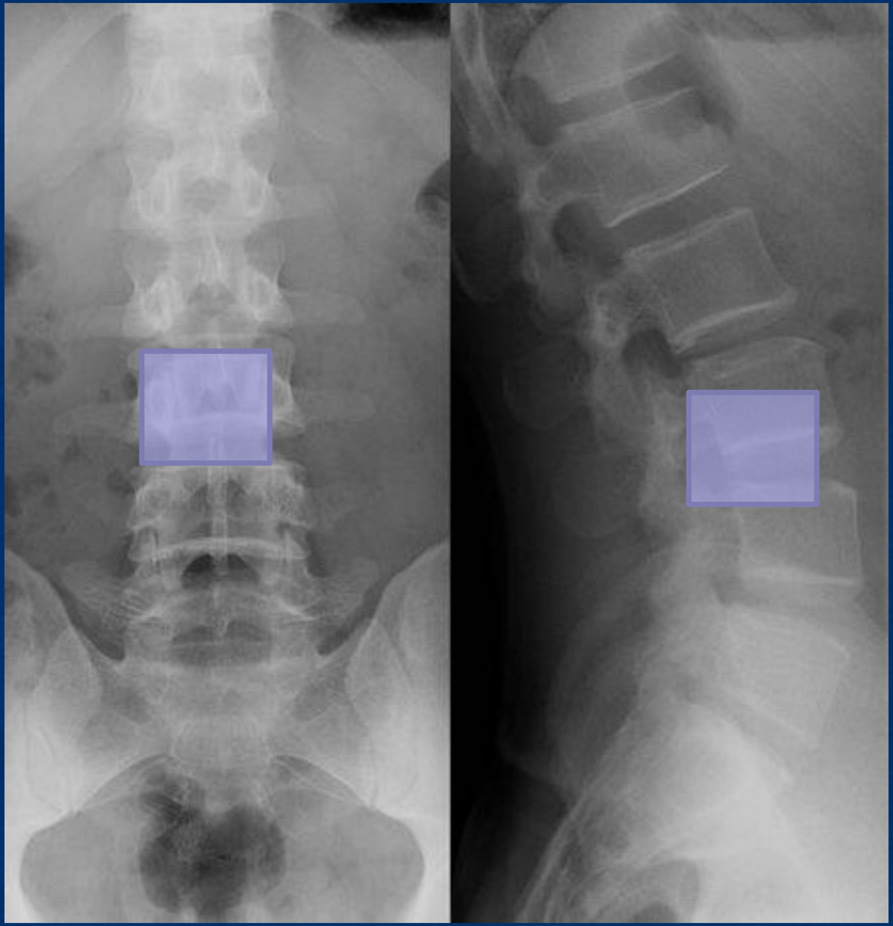
# Factors Affecting the AEC Response

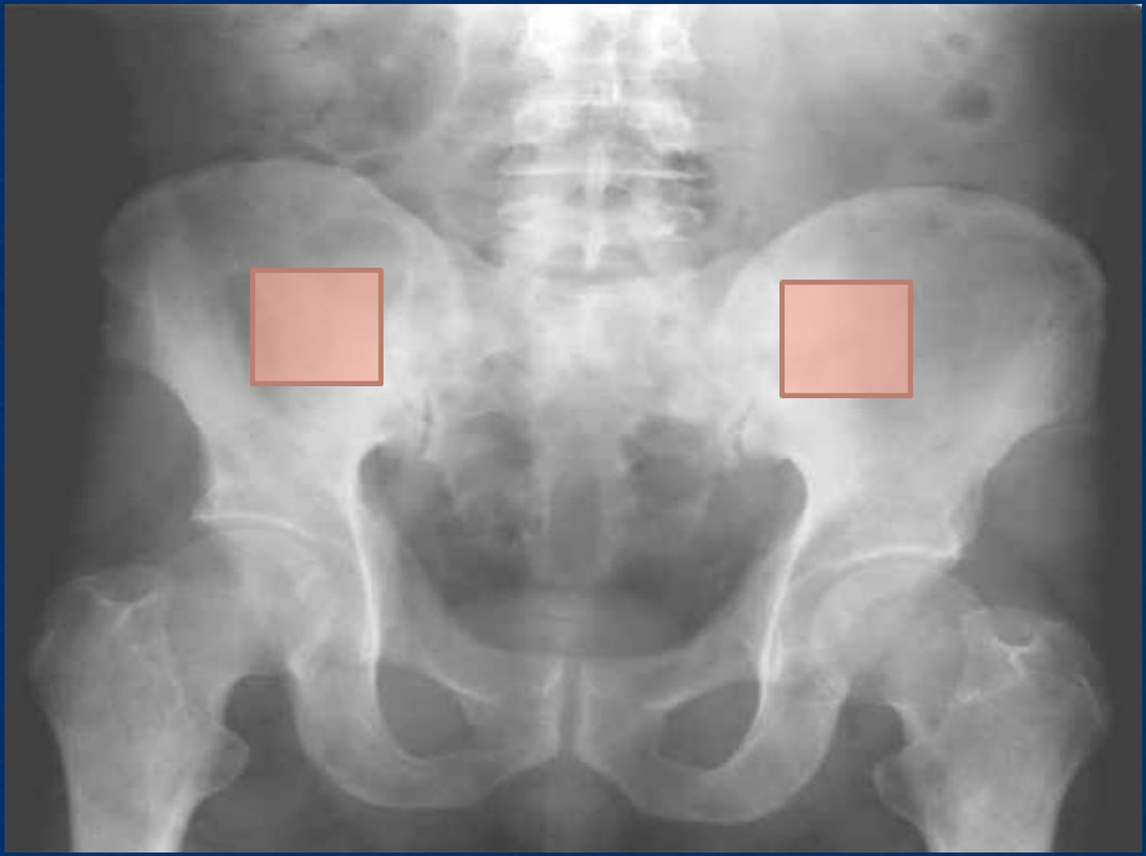
- Detector Selection
- Backup Time
- Minimum Response Time
- kVp
- mA
- Patient Thickness
- Density Setting
- Collimation
- Type of Image Receptor

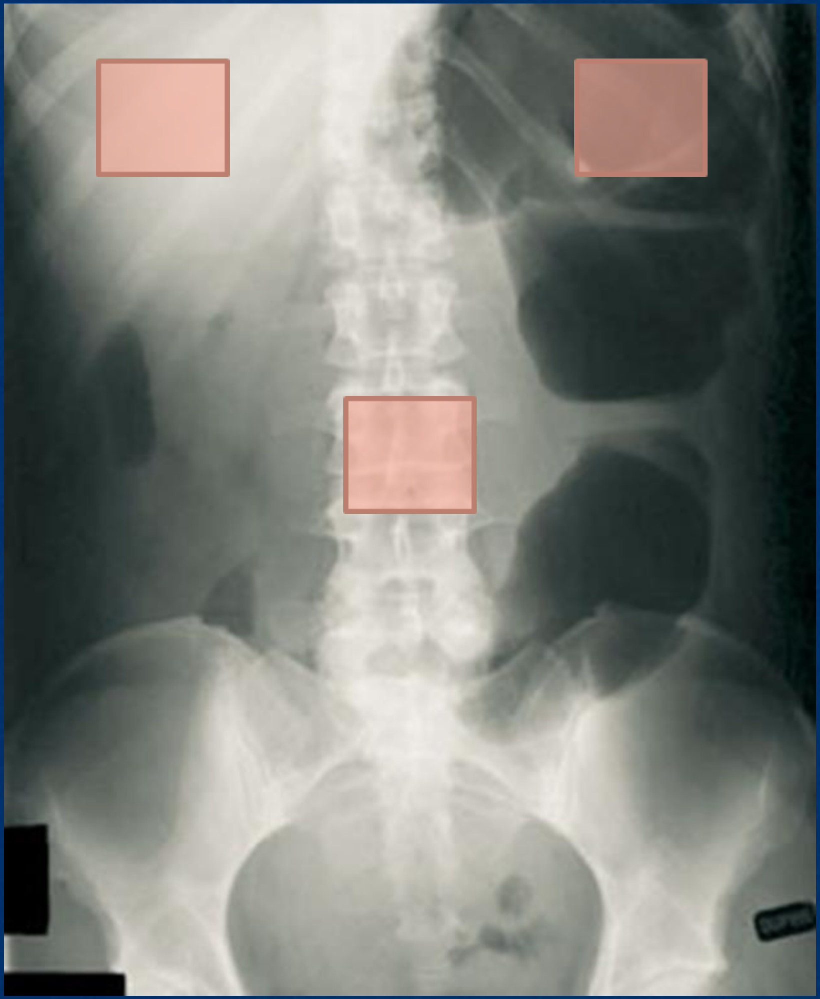
## Detector Selection

Selection of the detector or detectors to be used for a particular examination is critical when using an AEC system. AEC systems with multiple detectors typically allow the radiographer to select any combination of one, two, or all three detectors.

The selected detectors actively measure radiation during exposure and the electrical signals are averaged. Typically, the detector that receives the greatest amount of exposure has a greater effect on the total exposure.







## Milliamperage/Second Readout

When a radiographic study is performed using an AEC device, the total amount of radiation (milliamperage/second [mAs]) required to produce the appropriate exposure to the image receptor is determined by the system. Many radiographic units include a **mAs readout** display, on which the actual amount of mAs used for that image is displayed immediately after the exposure, sometimes for only a few seconds.

## Backup Time

**Backup time** refers to the maximum length of time the x-ray exposure continues when using an AEC system. The backup time may be set by the radiographer or may be controlled automatically by the radiographic unit. It may be set as backup exposure time or as backup mAs (the product of mA and exposure time).

The role of the backup time is to act as a safety mechanism when an AEC system fails or the equipment is not used properly. In either case, the backup time protects the patient from receiving unnecessary exposure and protects the x-ray tube from reaching or exceeding its heat-loading capacity. If the backup time is controlled automatically, it should terminate at a maximum of 600 mAs.

## Setting Backup Time

Backup time should be set at 150% to 200% of the expected exposure time. This allows the properly used AEC system to appropriately terminate the exposure, but protects the patient and tube from excessive exposure if a problem occurs.

To minimize patient exposure, the backup time should be neither too long nor too short. A backup time that is too short results in the exposure being stopped prematurely and the image may need to be repeated because of poor image quality. A backup time that is too long results in the patient receiving unnecessary radiation if a problem occurs and the exposure does not end until the backup time is reached. In addition, the image may have to be repeated because of poor image quality.

## Minimum Response Time

The term **minimum response time** refers to the shortest exposure time that the system can produce. Minimum response time (1 ms with modern AEC systems) usually is longer with AEC systems than with other types of radiographic timers (i.e., other types of radiographic timers usually are able to produce shorter exposure times than AEC devices).

This can be a problem with some segments of the patient population, such as pediatric patients and uncooperative patients. Typically, the radiographer increases the mA so the time of exposure terminates more quickly. If the minimum response time is longer than the amount of time needed to terminate the preset exposure, an increased amount of radiation reaches the image receptor. With pediatric patients and others who cannot or will not cooperate with the radiographer by holding still or holding their breath during the exposure, AEC devices may not be the technology of choice.

## Kilovoltage Peak and Automatic Exposure Control Response

The radiographer must be sure to set the kVp value as needed to ensure adequate penetration and to produce the appropriate scale of contrast. The kVp selected determines the length of exposure time when using AEC. A low kVp requires more exposure time to reach the predetermined amount of exposure. A high kVp decreases the exposure time to reach the predetermined amount of exposure and reduces the overall radiation exposure to the patient.

## Milliamperage and Automatic Exposure Control Response

If the radiographer can set the mA when using AEC, it affects the time of exposure for a given procedure. Increasing the mA decreases the exposure time to reach the predetermined amount of exposure. Decreasing the mA increases exposure time to reach the predetermined amount of exposure.

## Density Adjustment

AEC devices are equipped with **density controls** that allow the radiographer to adjust the amount of preset radiation detection values. These generally are in the form of buttons on the control panel that are numbered −2, −1, +1, and +2. The actual numbers presented on density controls vary, but each of these buttons changes exposure time by some predetermined amount or increment expressed as a percentage. A common increment is 25%, meaning that the predetermined exposure level needed to terminate the timer can be either increased or decreased from normal in one increment (+25% or −25%) or two increments (+50% or −50%). Manufacturers usually provide information on how these density controls should be used. Common sense and practical experience should also serve as guidelines for the radiographer. Routinely using plus or minus density settings to produce an acceptable radiograph indicates that a problem exists, possibly a problem with the AEC device.

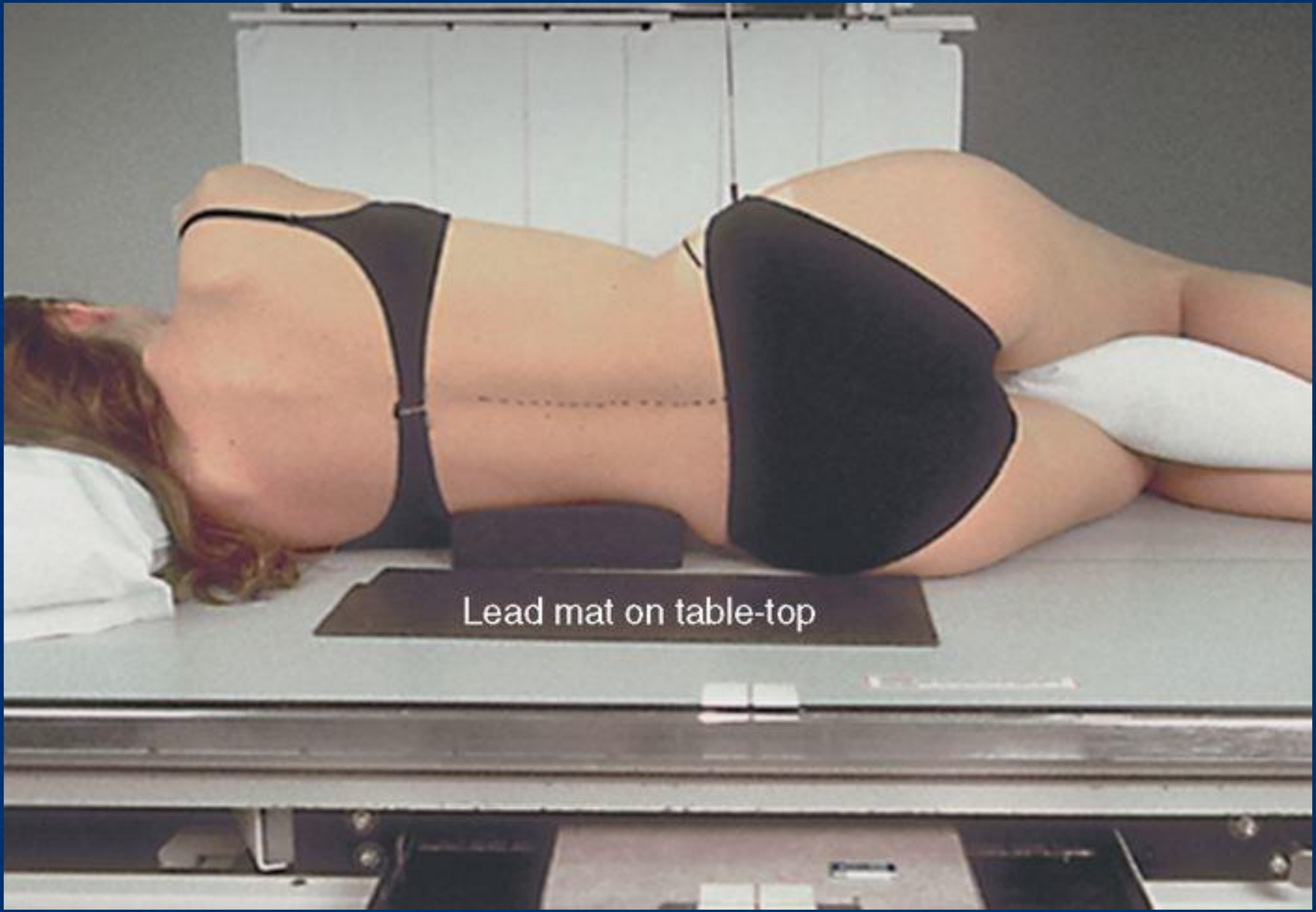
# DENSITY SETTING

| D. SETTING | % OD CHANGE |
|---|---|
| +4 | +100 |
| +3 | +75 |
| +2 | +50 |
| +1 | +25 |
| 0 | 0 |
| -1 | -25 |
| -2 | -50 |
| -3 | -75 |
| -4 | -100 |

## Collimation

The size of the x-ray field is a factor when AEC systems are used because the additional scatter radiation produced by failure to accurately restrict the beam may cause the detector to terminate the exposure prematurely. The detector is unable to distinguish transmitted radiation from scattered radiation and, as always, ends the exposure when a preset amount of exposure has been reached. Because the detector is measuring both types of radiation exiting the patient, the timer is turned off too soon when scatter is excessive, which results in underexposure of the area of interest.

Additionally, if the x-ray field size is collimated too closely, the detector does not receive sufficient exposure initially and may prolong the exposure time, which could result in overexposure. The radiographer should open the collimator to the extent that the part being radiographed is imaged appropriately, but not so much as to cause the AEC device to terminate the exposure before the area being imaged is properly exposed.

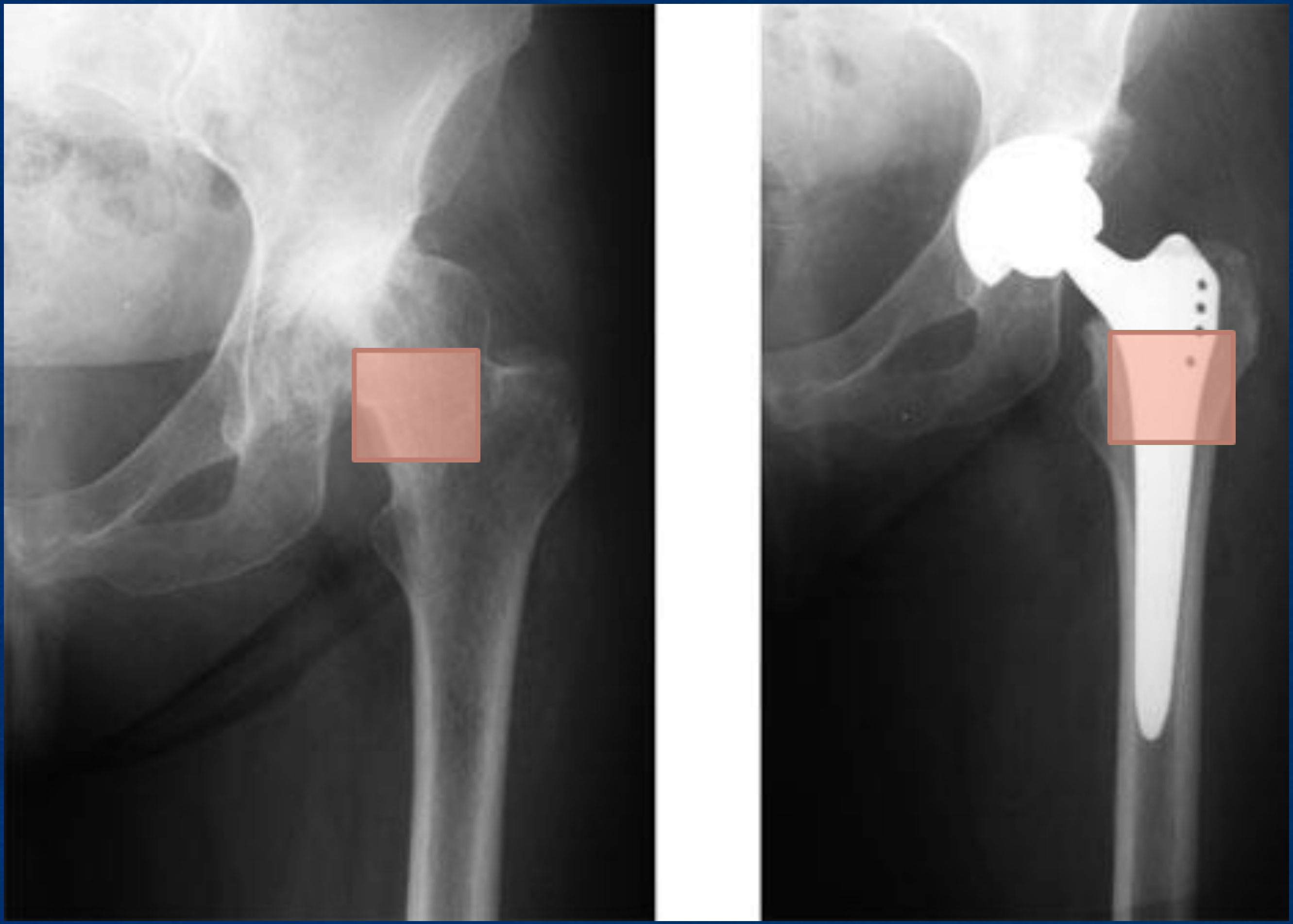

Lead mat on table-top

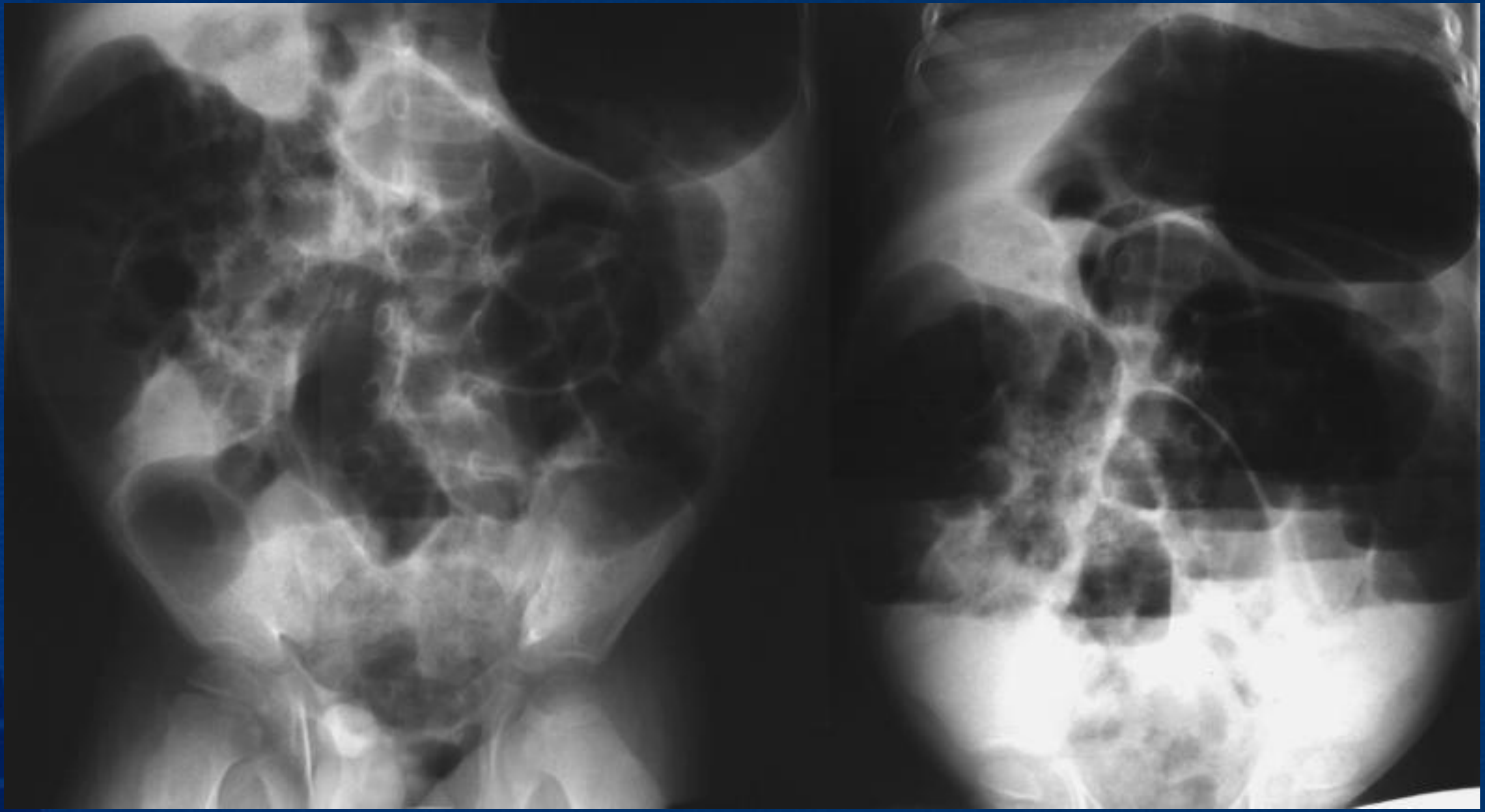
## Type of Image Receptor and Automatic Exposure Control Response

The AEC system is calibrated to the type and speed class of the image receptor used. If an image receptor of a different type or speed is used, the detectors will not sense the difference, the exposure time will terminate at the preset value, and image quality may be jeopardized.

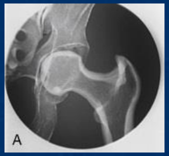
## Patient Consideration

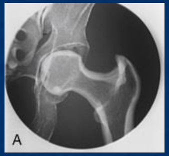
Patient factors affect the time the exposure takes to reach the image receptor and ultimately affect image quality. Variations in patient thickness result in changes in the time of exposure accordingly if the AEC system is functioning properly. Pathologic conditions, contrast media, foreign objects, or pockets of gas are patient variations that may affect the proper exposure to the image receptor and ultimately image quality.

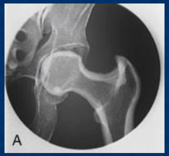


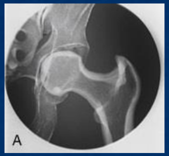


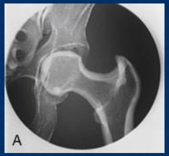
| Factor Increased | Effect on Exposure Time |
|---|---|
| kVp | decrease |
| mA | decrease |
| Patient thickness | increase |
| SID | increase |
| OID | increase |
| Image receptor Speed | No effect |
| Scatter | decrease |

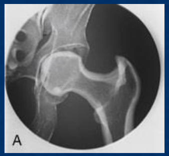


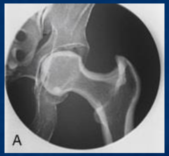








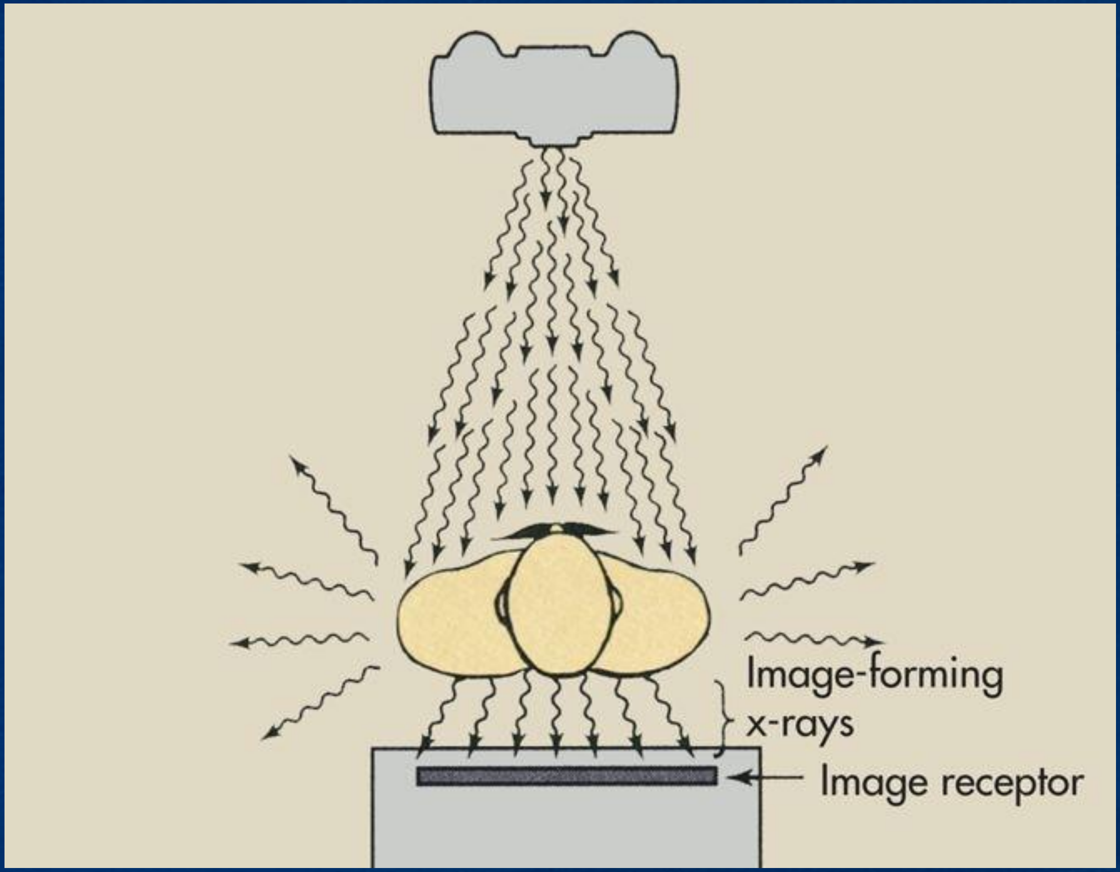




# Radiographic Grids I

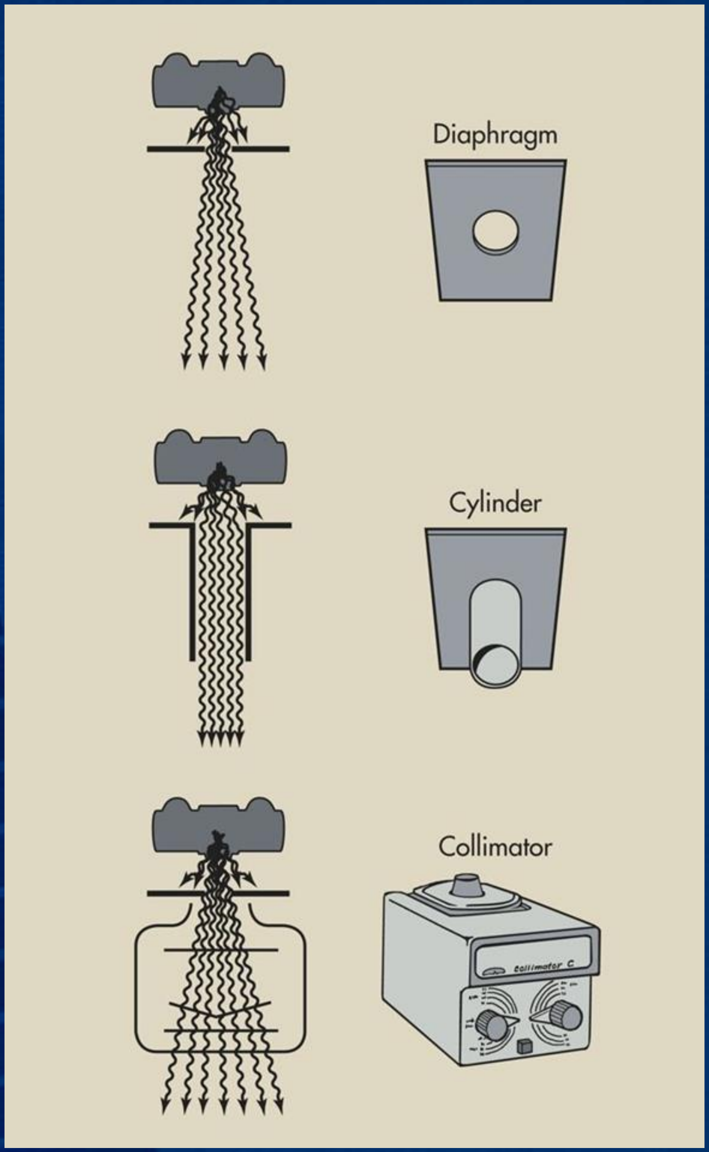
Even under the most favorable conditions, most remnant x-rays are scattered.

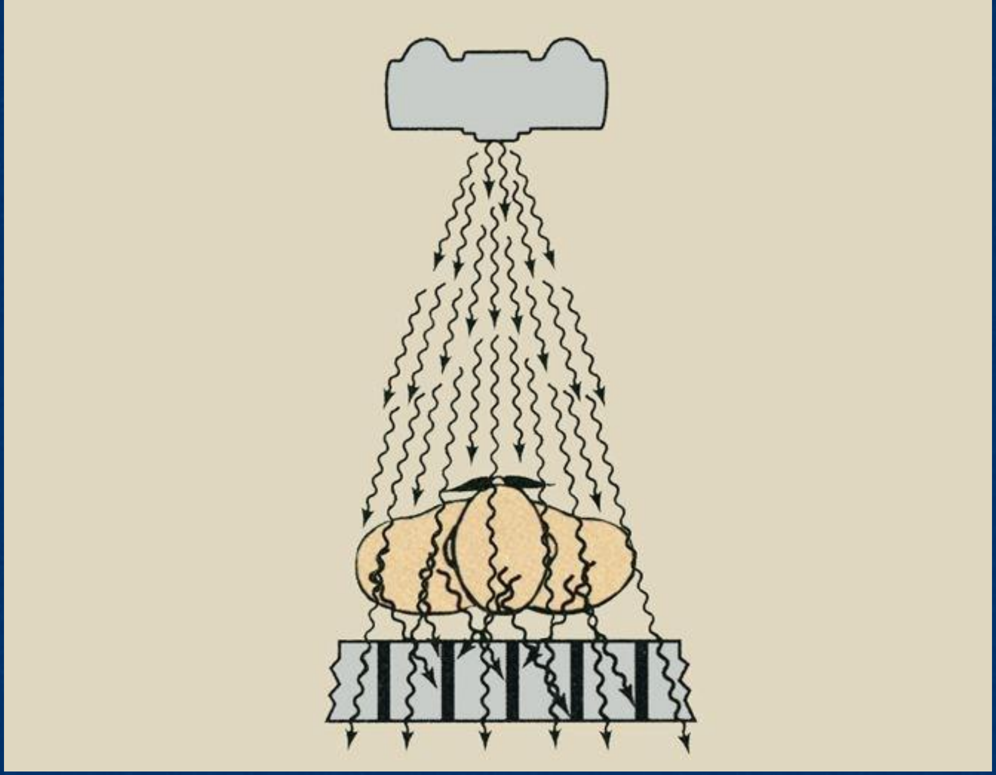
If the radiograph were taken with only scatter radiation and no transmitted x-rays reached the image receptor, the image would be dull gray. The radiographic contrast would be very low.



In the normal situation, however, x-rays arriving at the image receptor consist of both transmitted and scattered x-rays.  This image would have moderate contrast. The loss of contrast results from the presence of scattered x-rays.

Two types of devices reduce the amount of scatter radiation that reaches the image receptor: **beam restrictors** and **grids.**



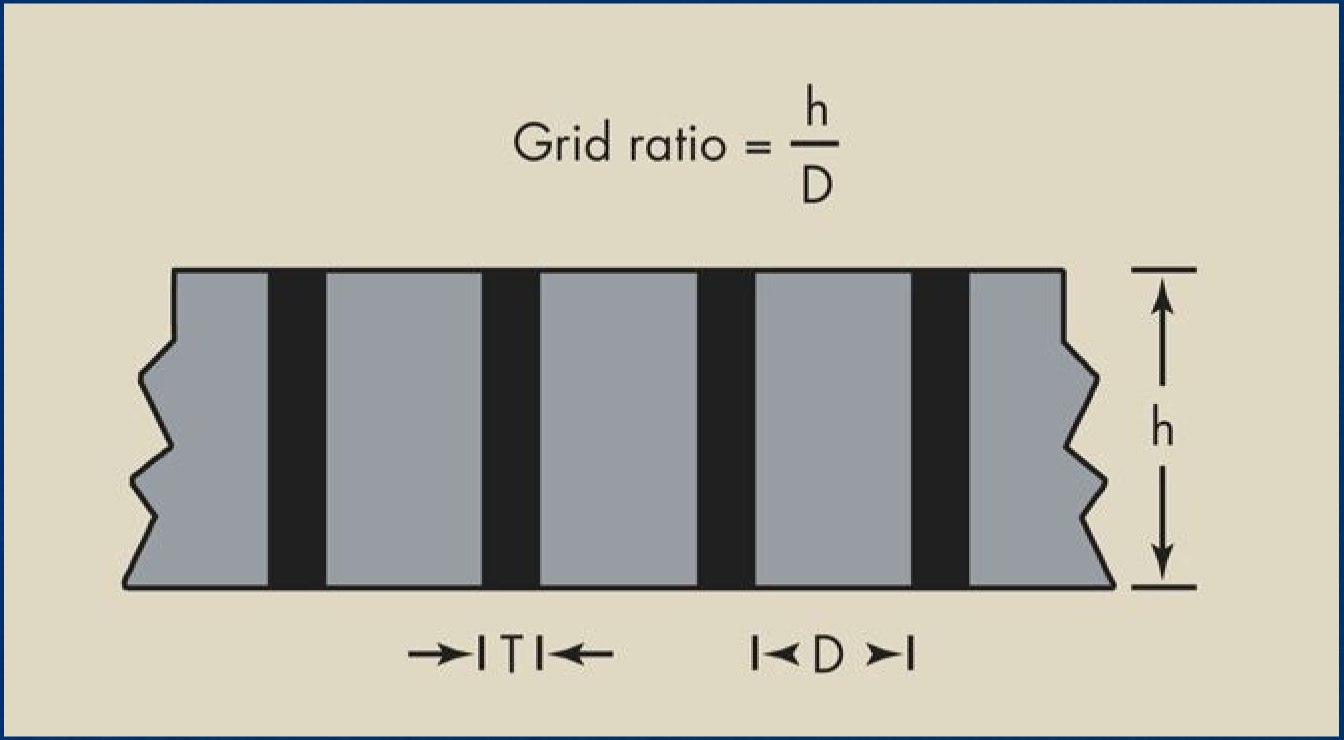



# Grids

Scattered x-rays that reach the image receptor are part of the image-forming process; indeed, the x-rays that are scattered forward do contribute to the image. An extremely effective device for reducing the level of scatter radiation that reaches the image receptor is the grid, a carefully fabricated series of sections of radiopaque material (grid strips) alternating with sections of radiolucent material (interspace material). The grid is positioned between the patient and the image receptor.

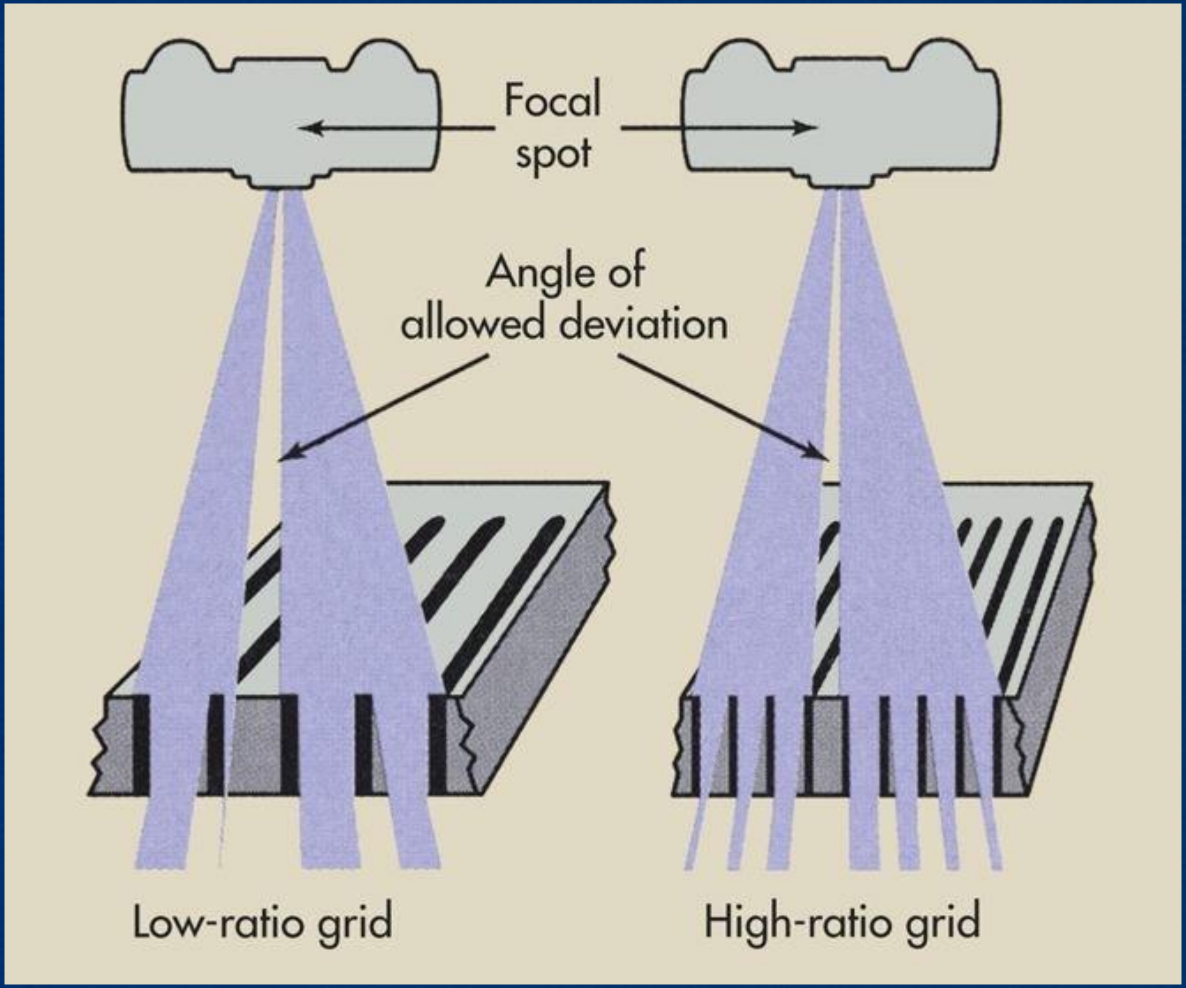
# Grid Ratio

A grid consists of three important dimensions: the thickness of the grid strip (T), the width of the interspace material (D), and the height of the grid (h). The grid ratio is the height of the grid divided by the interspace width



If the angle of a scattered x-ray is great enough to cause it to intersect a lead grid strip, it will be absorbed. If the angle is slight, the scattered x-ray will be transmitted similarly to a primary x-ray. Laboratory measurements show that high-quality grids can attenuate 80% to 90% of the scatter radiation. Such a grid is said to exhibit good “cleanup.”

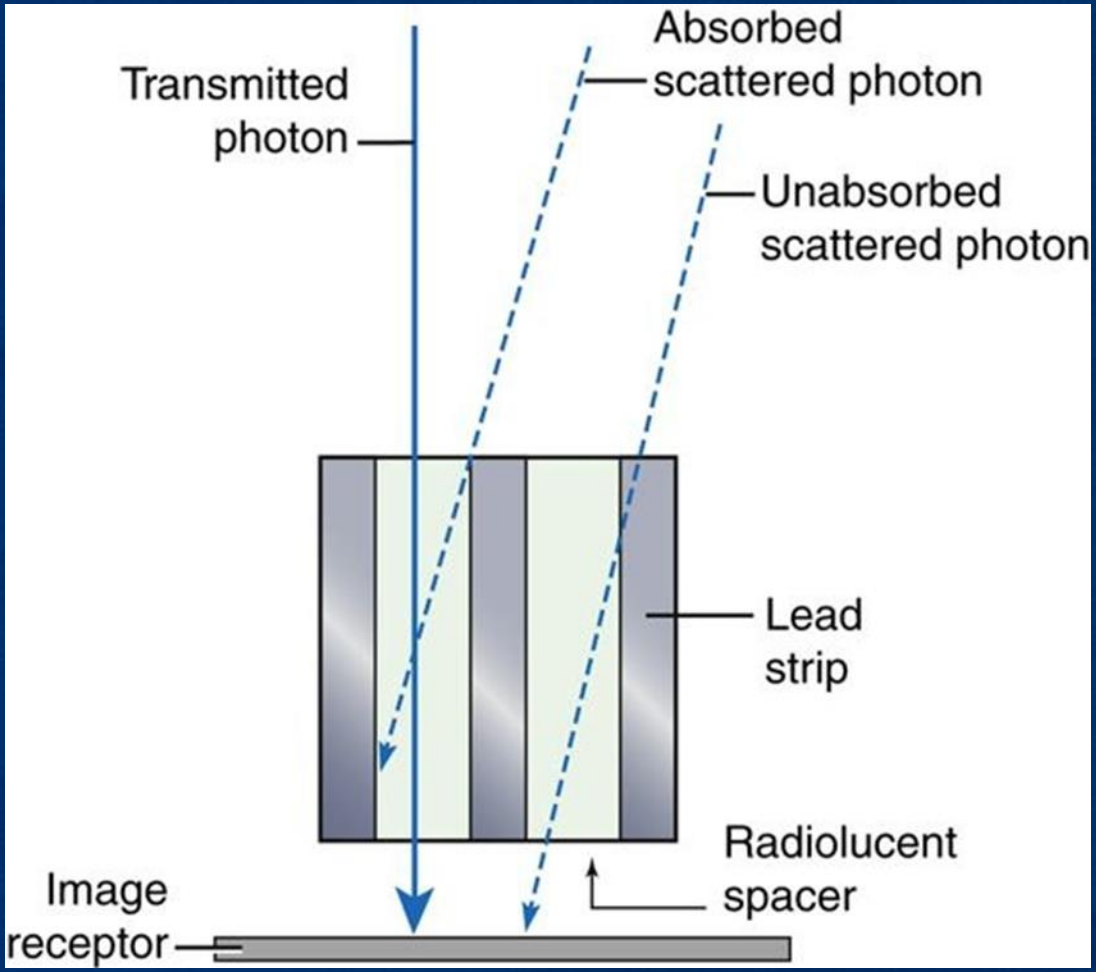
High-ratio grids are more effective in cleaning up scatter radiation than are low-ratio grids. This is because the angle of scatter allowed by high-ratio grids is less than that permitted by low-ratio grids.




High-ratio grids increase patient radiation dose.

# Grid Interspace Material

The purpose of the interspace material is to maintain a precise separation between the delicate lead strips of the grid. The interspace material of most grids consists of aluminum or plastic fiber; reports are conflicting as to which is better.



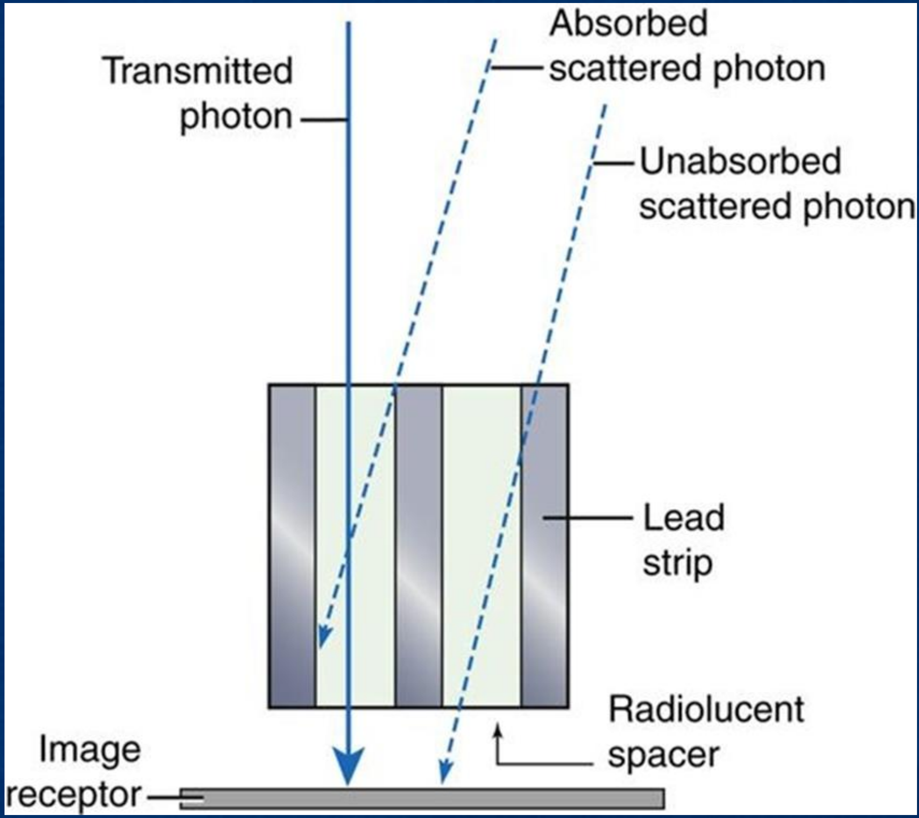
Aluminum has a higher atomic number than plastic and therefore may provide some selective filtration of scattered x-rays not absorbed in the grid strip. Aluminum also has the advantage of producing less visible grid lines on the radiograph.

On the other hand, use of aluminum as interspace material increases the absorption of primary x-rays in the interspace, especially at low kVp. The result is higher mAs and higher patient dose. Above 100 kVp, this property is unimportant, but at low kVp, the patient dose may be increased by approximately 20%. For this reason, fiber interspace grids usually are preferred to aluminum interspace grids.

Still, aluminum has two additional advantages over fiber. It is **nonhygroscopic**, that is, it does not absorb moisture as plastic fiber does. Fiber interspace grids can become warped if they absorb moisture. Also, aluminum interspace grids of high quality are easier to manufacture because aluminum is easier to form and roll into sheets of precise thickness.

## Grid Strip

Theoretically, the grid strip should be infinitely thin and should have high absorption properties. These strips may be formed from several possible materials. Lead is most widely used because it is easy to shape and is relatively inexpensive. Its high atomic number and high mass density make lead the material of choice in the manufacture of grids. Tungsten, platinum, gold, and uranium all have been tried, but none has the overall desirable characteristics of lead.



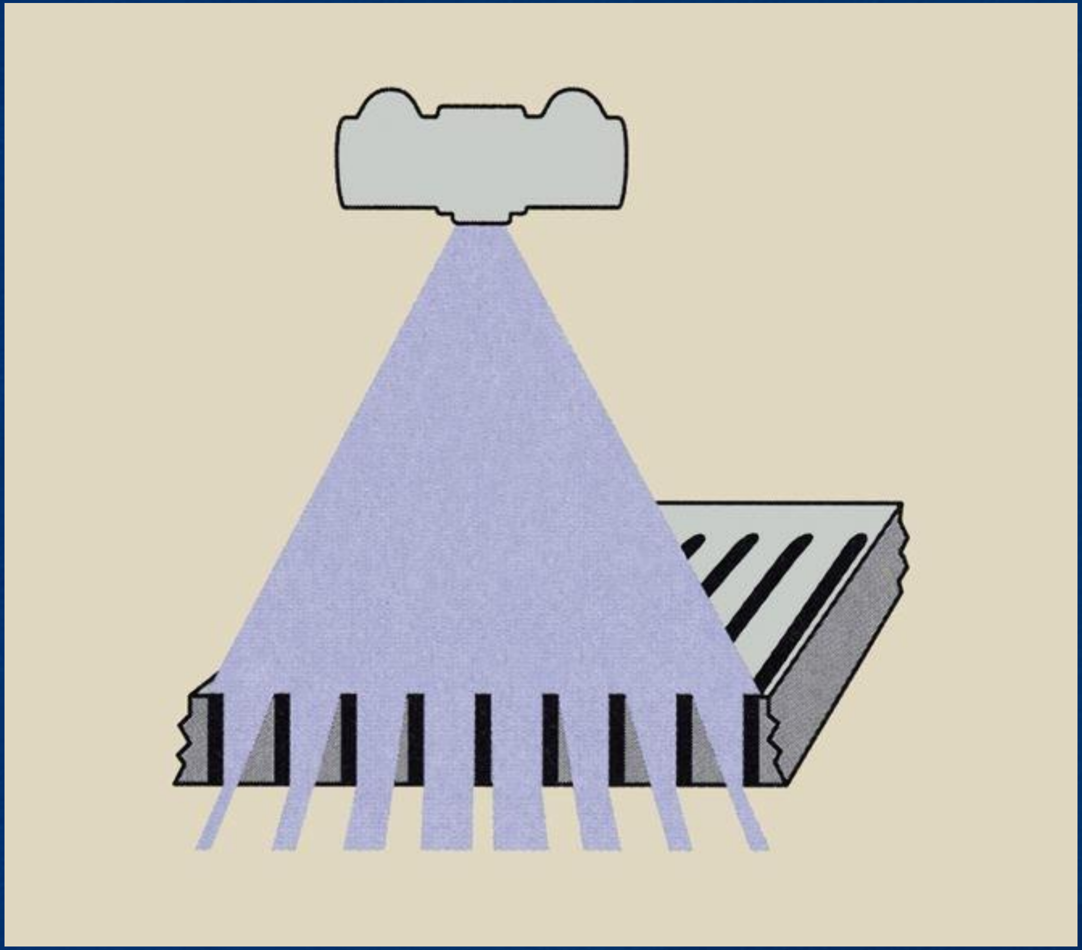
# Types of Grids

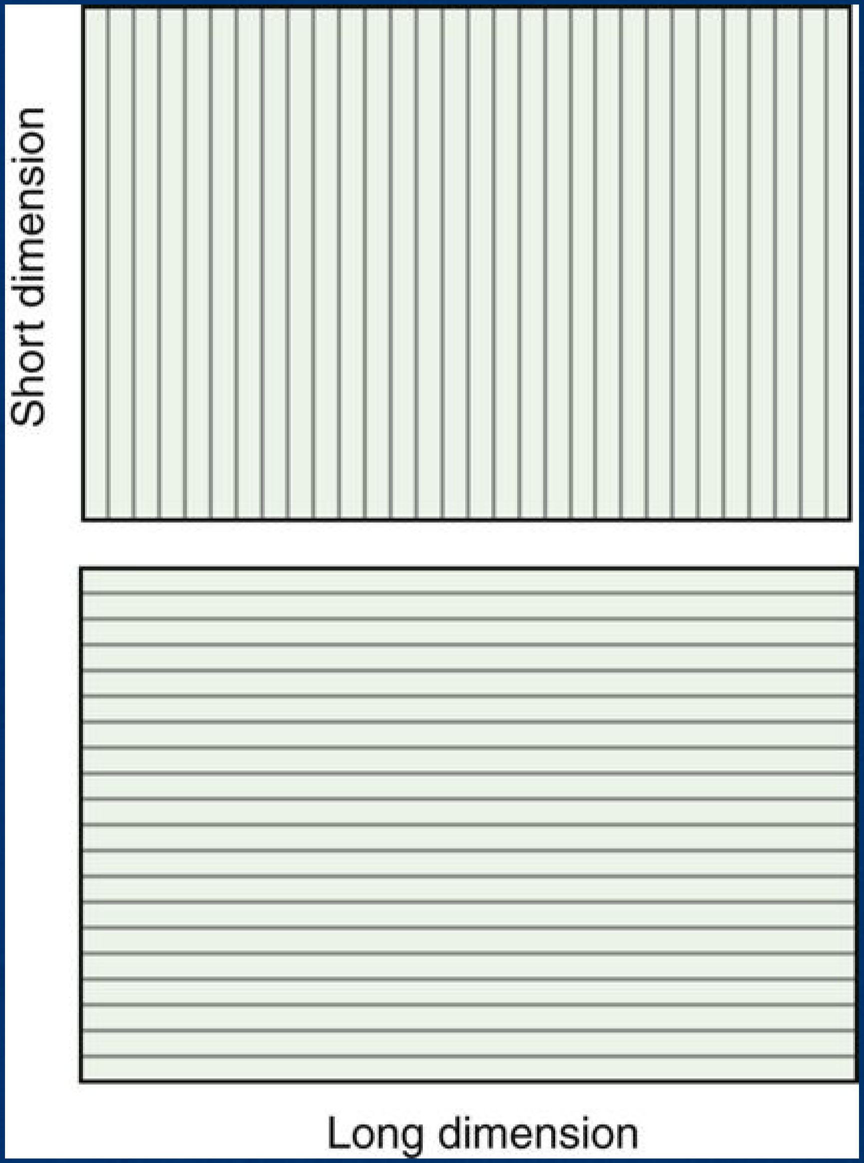
- Parallel
- Crossed
- Focused

- Air gap technique

## Parallel Grid

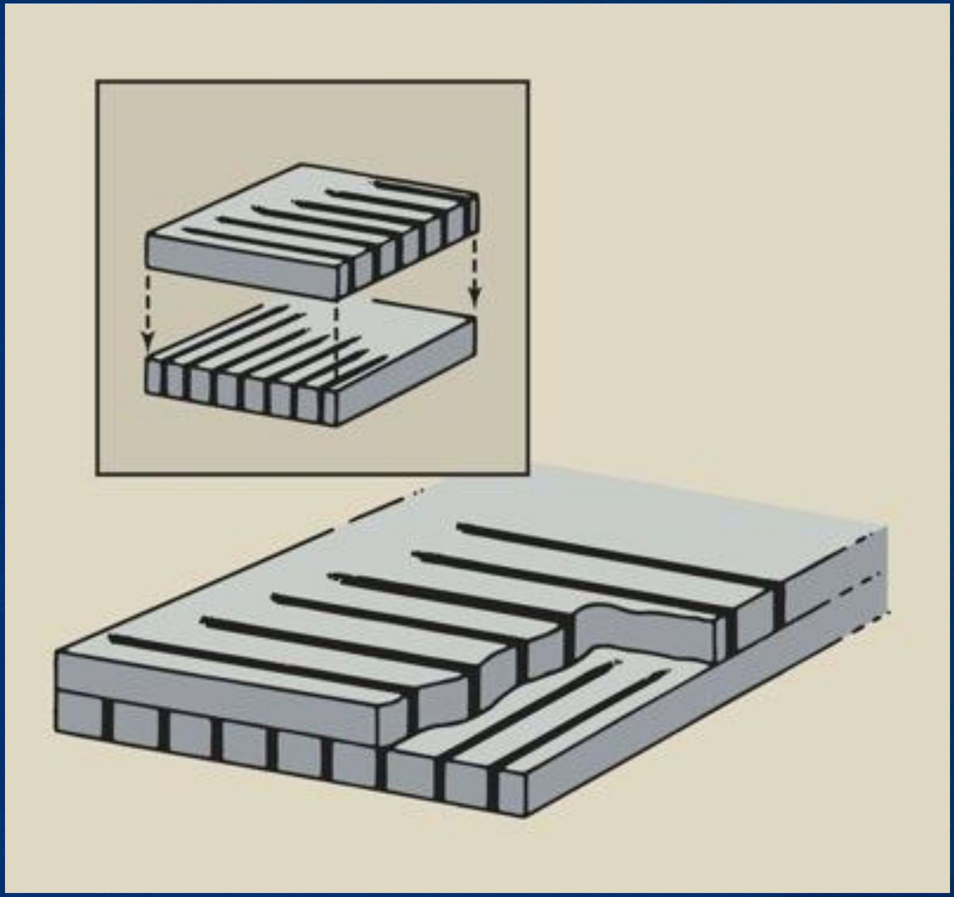
The simplest type of grid is the parallel grid. In the parallel grid, all lead grid strips are parallel. This type of grid is the easiest to manufacture, but it has some properties that are clinically undesirable, namely grid cutoff, the undesirable absorption of primary x-rays by the grid.




Short dimension
Long dimension

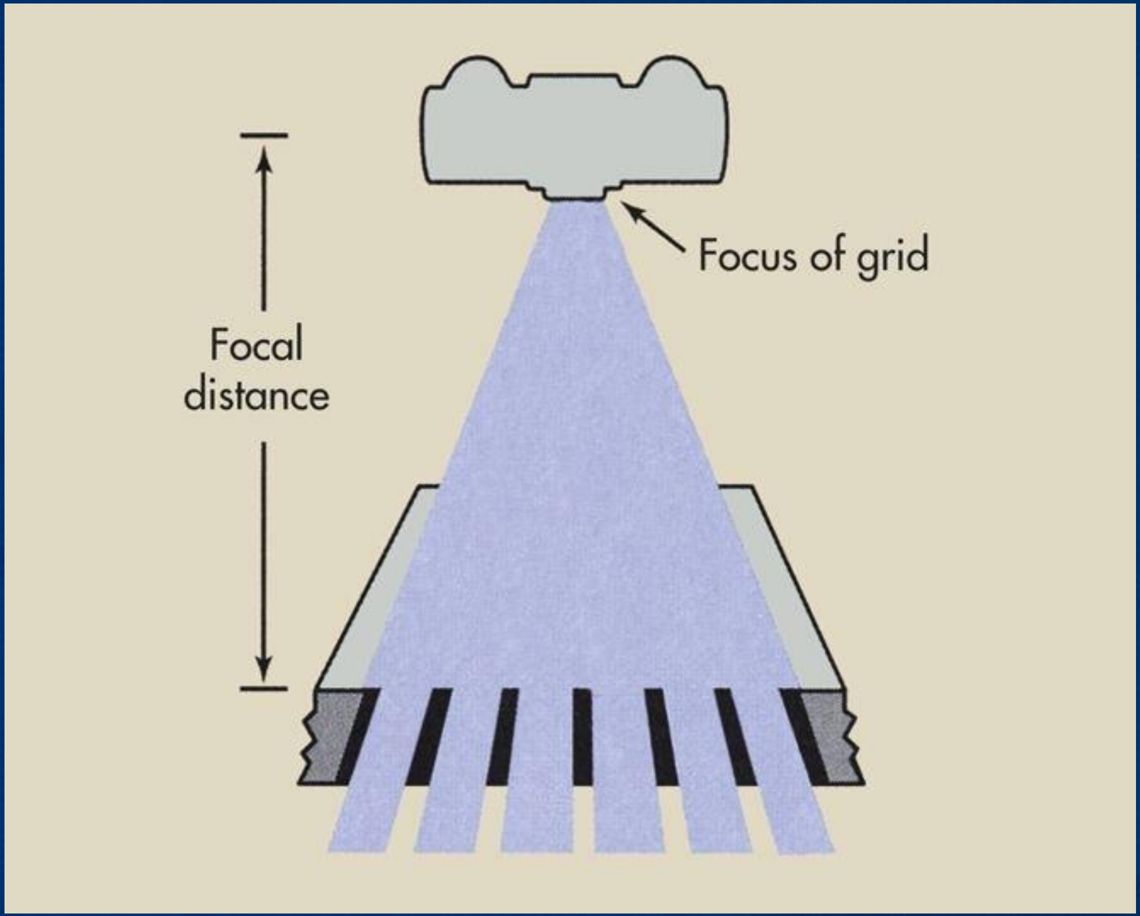
## Crossed Grid

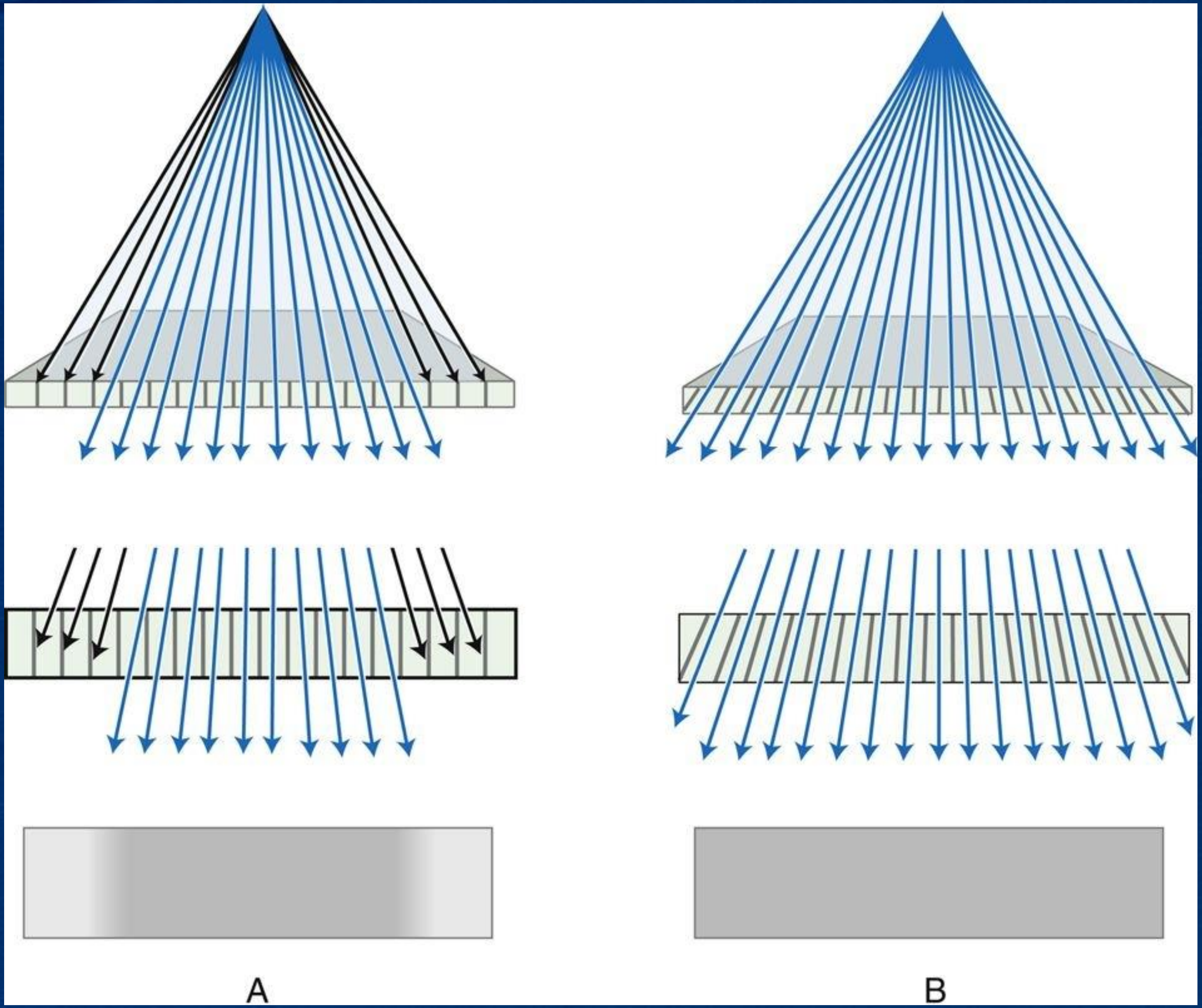
Parallel grids clean up scatter radiation in only one direction, along the axis of the grid. Crossed grids are designed to overcome this deficiency. Crossed grids have lead grid strips that run parallel to the long and short axes of the grid. They are usually fabricated by sandwiching two parallel grids together, with their grid strips perpendicular to one another.



# Focused Grid

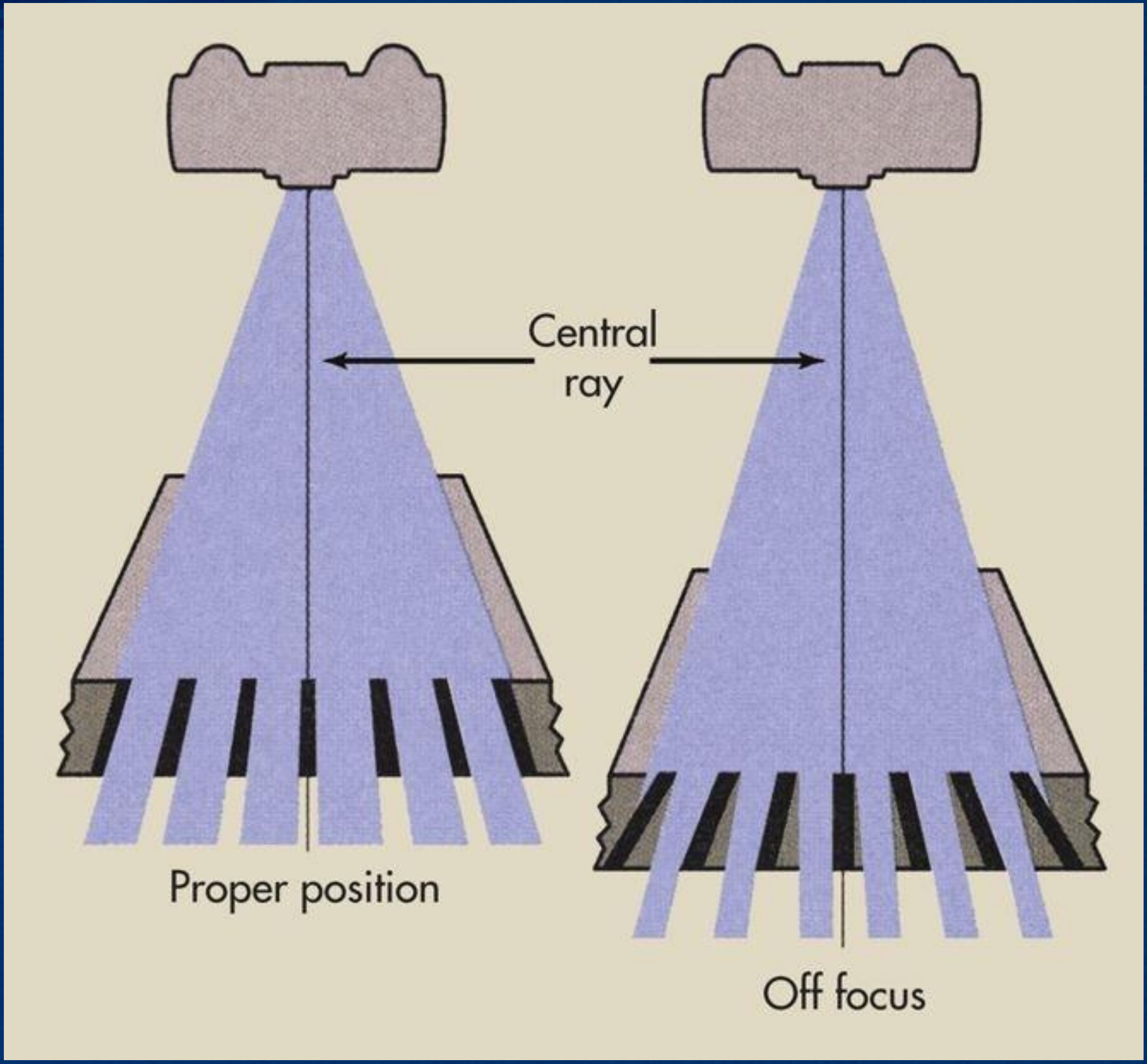
The focused grid is designed to minimize grid cutoff. The lead grid strips of a focused grid lie on the imaginary radial lines of a circle centered at the focal spot, so they coincide with the divergence of the x-ray beam. The x-ray tube target should be placed at the center of this imaginary circle when a focused grid is used

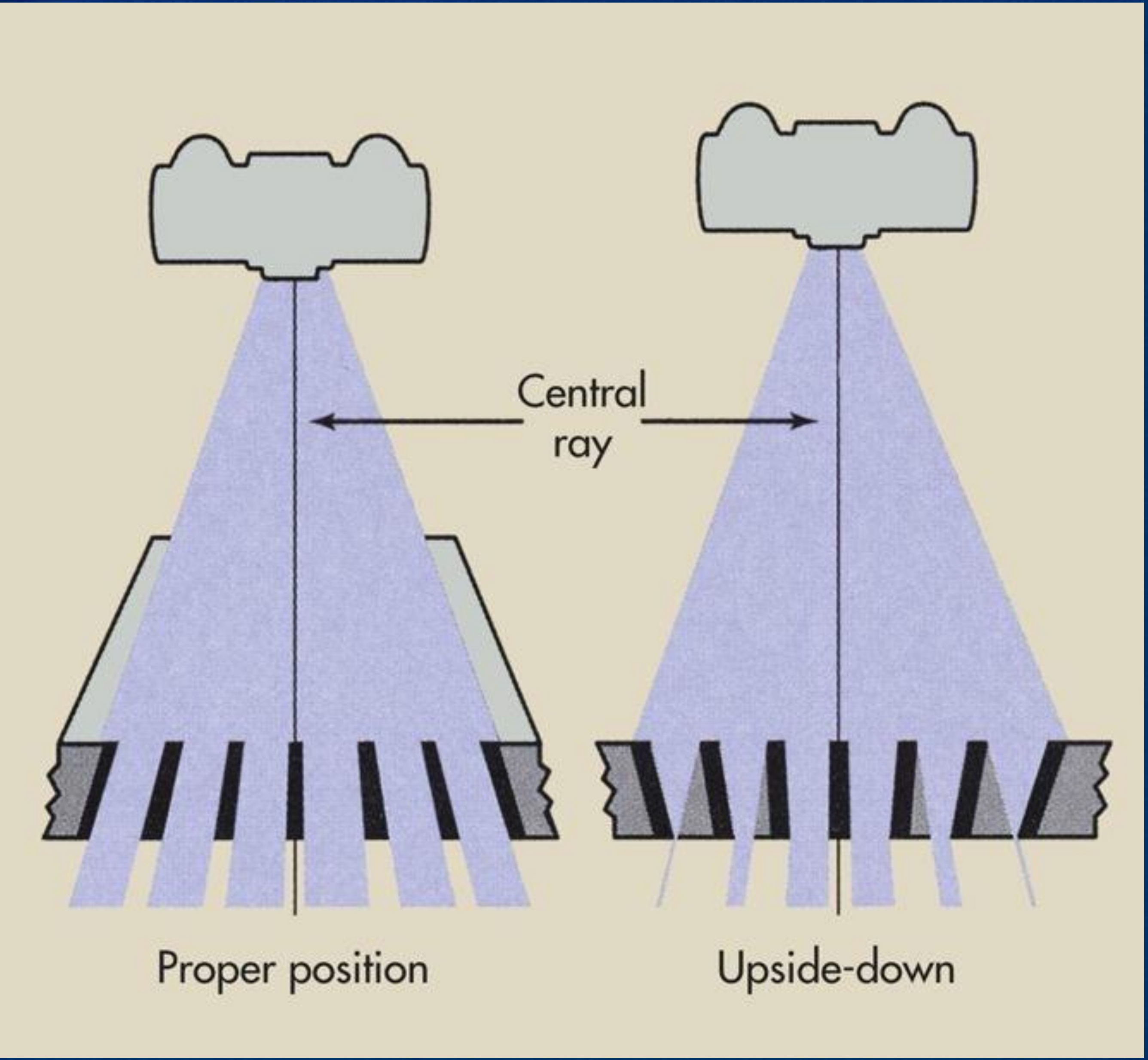



A
B

Focused grids are more difficult to manufacture than parallel grids. They are characterized by all the properties of parallel grids, except that when properly positioned, they exhibit no grid cutoff. The radiologic technologist must take care when positioning focused grids because of their geometric limitations.

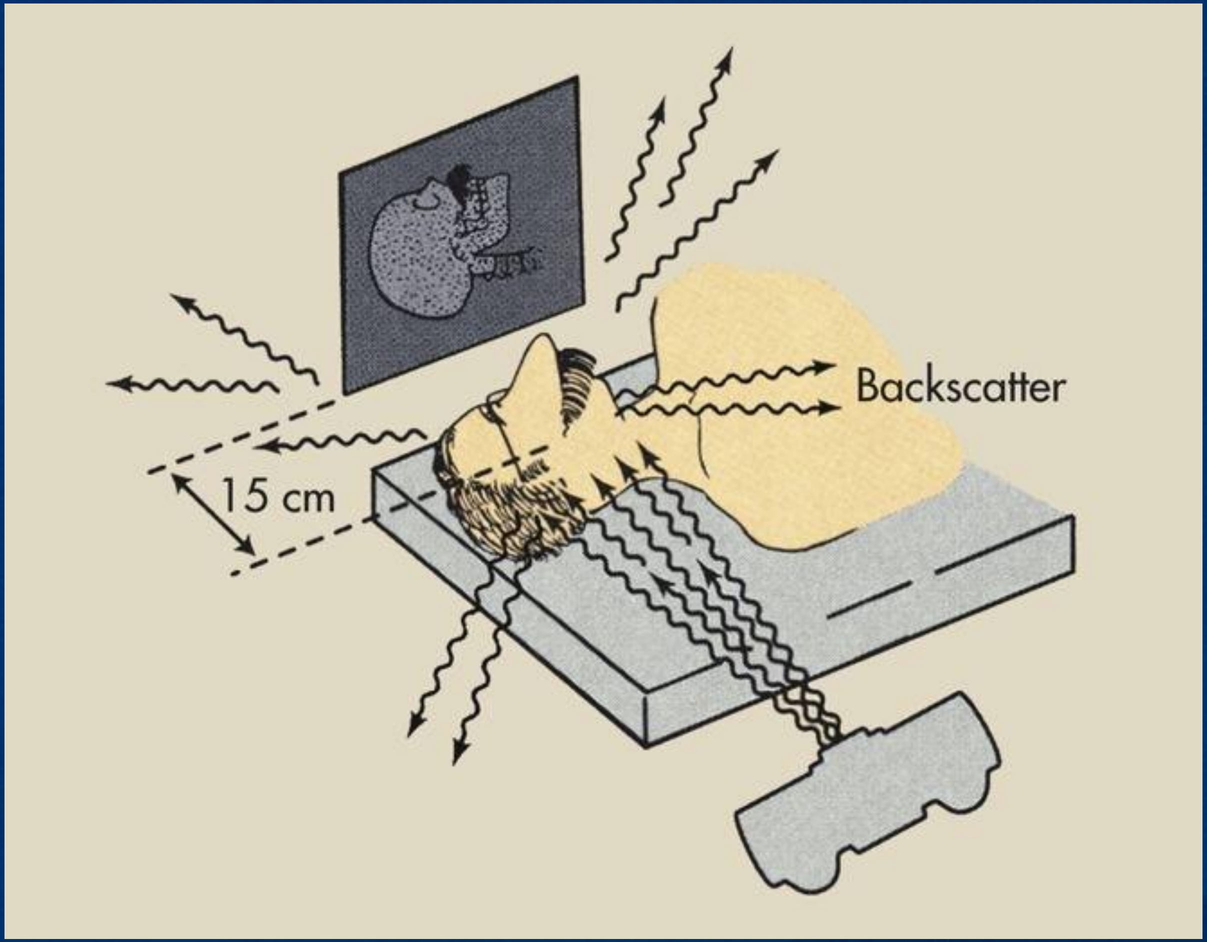
Every focused grid is marked with its intended focal distance and the side of the grid that should face the x-ray tube. If radiographs are taken at distances other than those intended, grid cutoff occurs.


Central
ray
Proper position
Off focus


Central
ray
Proper position
Upside-down

## Air-Gap Technique

A clever technique that may be used as an alternative to the use of radiographic grids is the air-gap technique. The air-gap technique is another method of reducing scatter radiation, thereby enhancing image contrast.



When the air-gap technique is used, the image receptor is moved 10 to 15 cm from the patient. A portion of the scattered x-rays generated in the patient would be scattered away from the image receptor and not be detected. Because fewer scattered x-rays interact with the image receptor, the contrast is enhanced.

Usually, when an air-gap technique is used, the mAs is increased approximately 10% for every centimeter of air gap. The technique factors usually are about the same as those for an 8:1 grid. Therefore, the patient dose is higher than that associated with the non-grid technique and is approximately equivalent to that of an intermediate grid technique.

# Grid Performance

**GRID PERFORMANCE**

Perhaps the largest single factor responsible for poor radiographic quality is scatter radiation. By removing scattered x-rays from the remnant beam, the radiographic grid removes the source of reduced contrast.

**The principal function of a grid is to improve image contrast.**

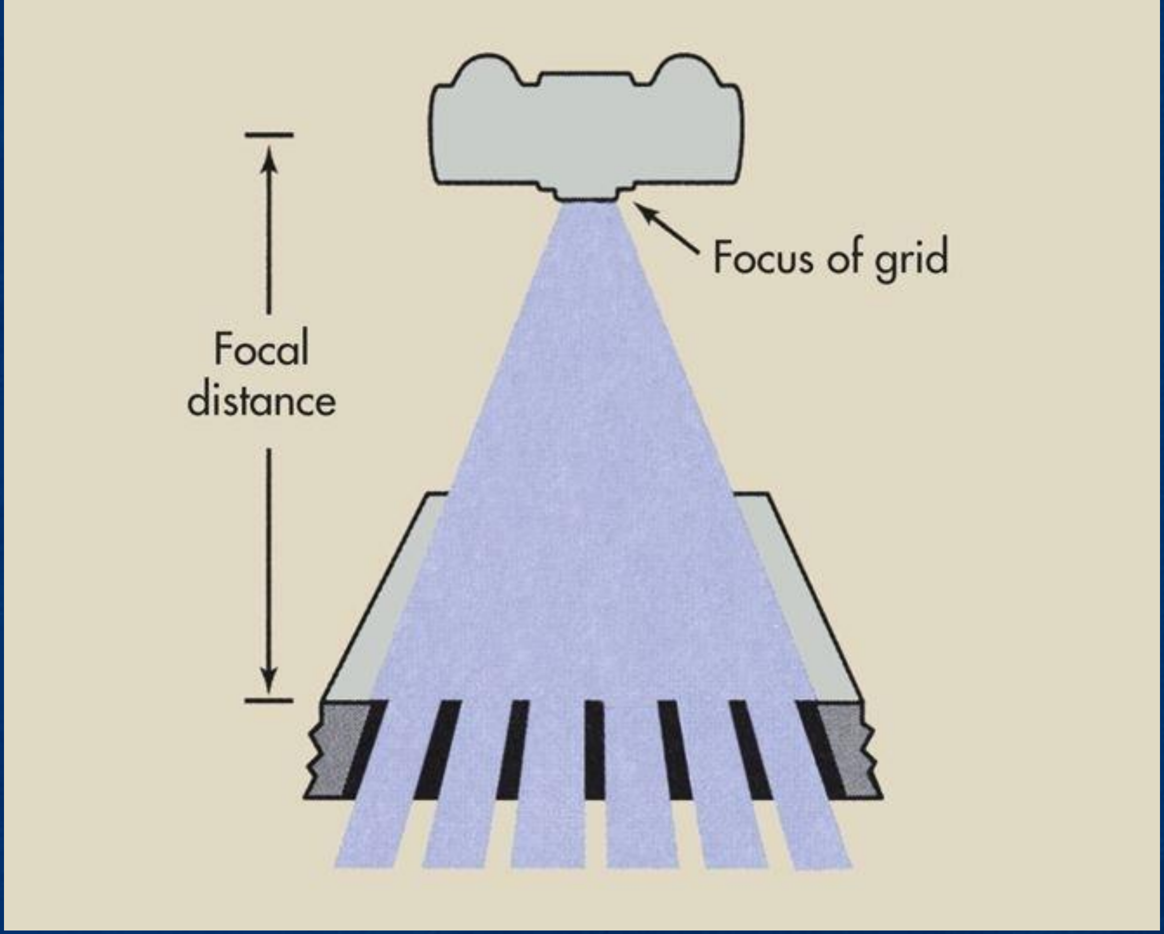
## Bucky Factor

Although the use of a grid improves contrast, a penalty is paid in the form of patient dose. The quantity of image-forming x-rays transmitted through a grid is much less than that of image-forming x-rays incident on the grid. Therefore, when a grid is used, the radiographic technique must be increased to produce the same exposure. The amount of this increase is given by the Bucky factor (B), often called the grid factor.

**The higher the grid ratio, the higher is the Bucky factor**

## Focused Grid

The focused grid is designed to minimize grid cutoff. The lead grid strips of a focused grid lie on the imaginary radial lines of a circle centered at the focal spot, so they coincide with the divergence of the x-ray beam. The x-ray tube target should be placed at the center of this imaginary circle when a focused grid is use



Focused grids are more difficult to manufacture than parallel grids. They are characterized by all the properties of parallel grids, except that when properly positioned, they exhibit no grid cutoff. The radiologic technologist must take care when positioning focused grids because of their geometric limitations.

# The Grid Conversion factor

| Grid Ratio | mAs Compensation |
|---|---|
| •Non –grid | |
| •5:1 | •2 ( 2 x non-grid mAs) |
| •6:1 | •3 ( 3 x non-grid mAs) |
| •8:1 | •4 ( 4 x non-grid mAs) |
| •12:1 | •5 ( 5 x non-grid mAs) |
| •16:1 | •6 ( 6 x non-grid mAs) |

# Grid conversion Factor

When converting from one radiographic grid to another, the following formula should be used.

$$\frac{mAs1}{mAs2} = \frac{GCF1}{GCF2}$$

mAs1 = original mAs
mAs2 = new mAs
GCF1 = Original grid conversion factor
GCF2 = new grid conversion factor

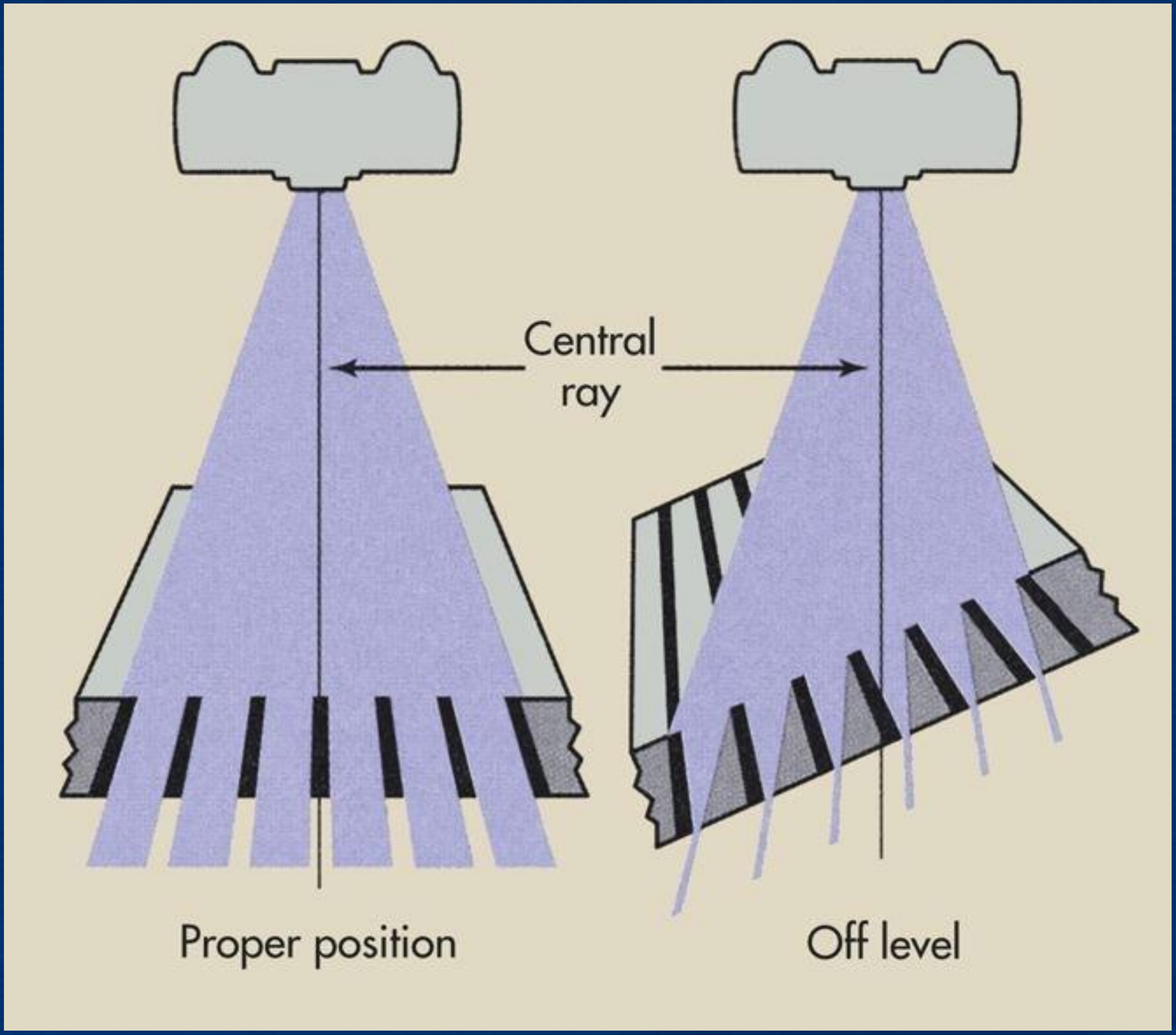
## GRID PROBLEMS

Most grids in diagnostic imaging are of the moving type. They are permanently mounted in the moving mechanism just below the tabletop or just behind the vertical chest board.

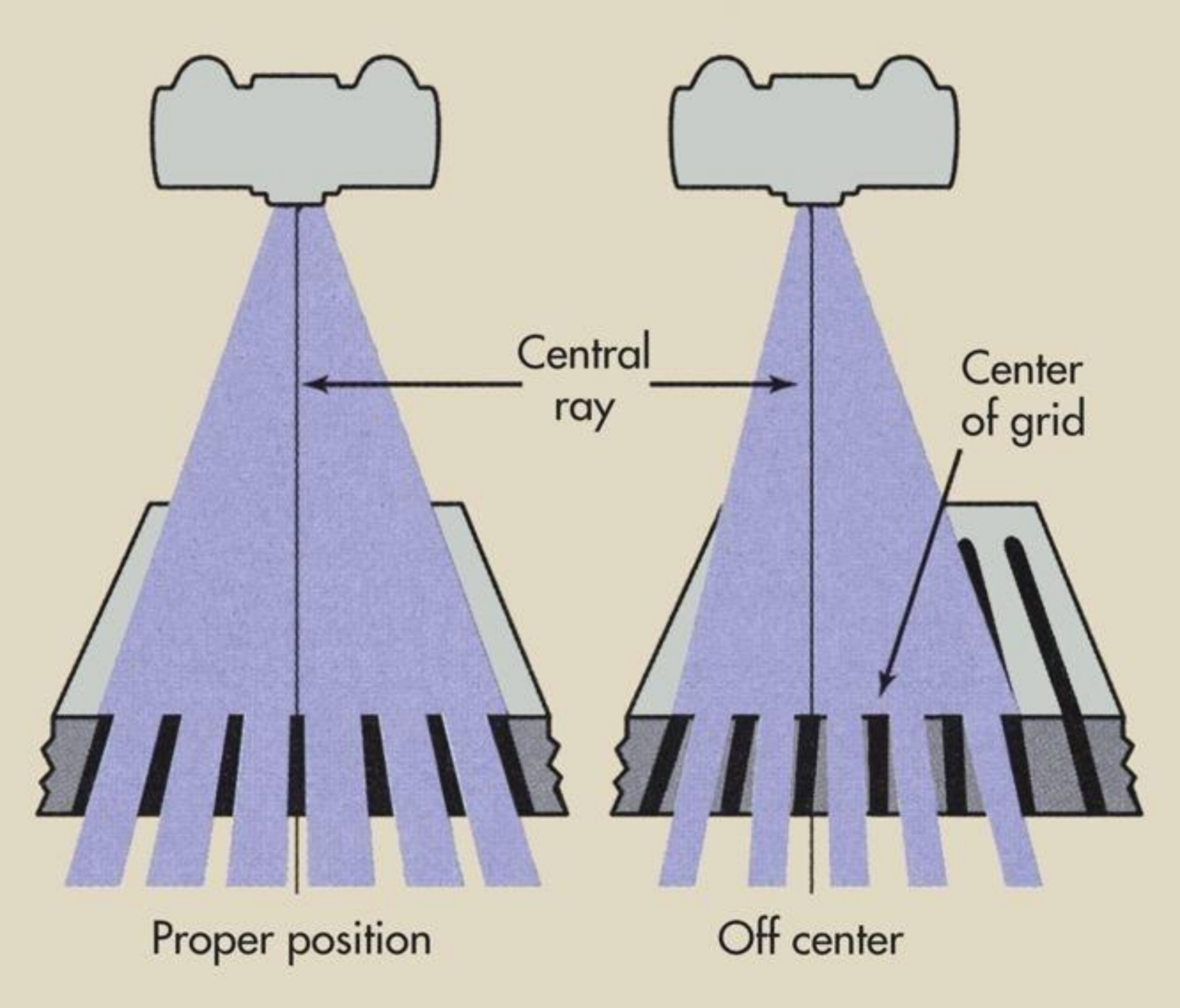
To be effective, of course, the grid must move from side to side. If the grid is installed incorrectly and moves in the same direction as the grid strips, grid lines will appear on the radiograph.

The most frequent error in the use of grids is improper positioning. For the grid to function correctly, it must be precisely positioned relative to the x-ray tube target and to the central ray of the x-ray beam.

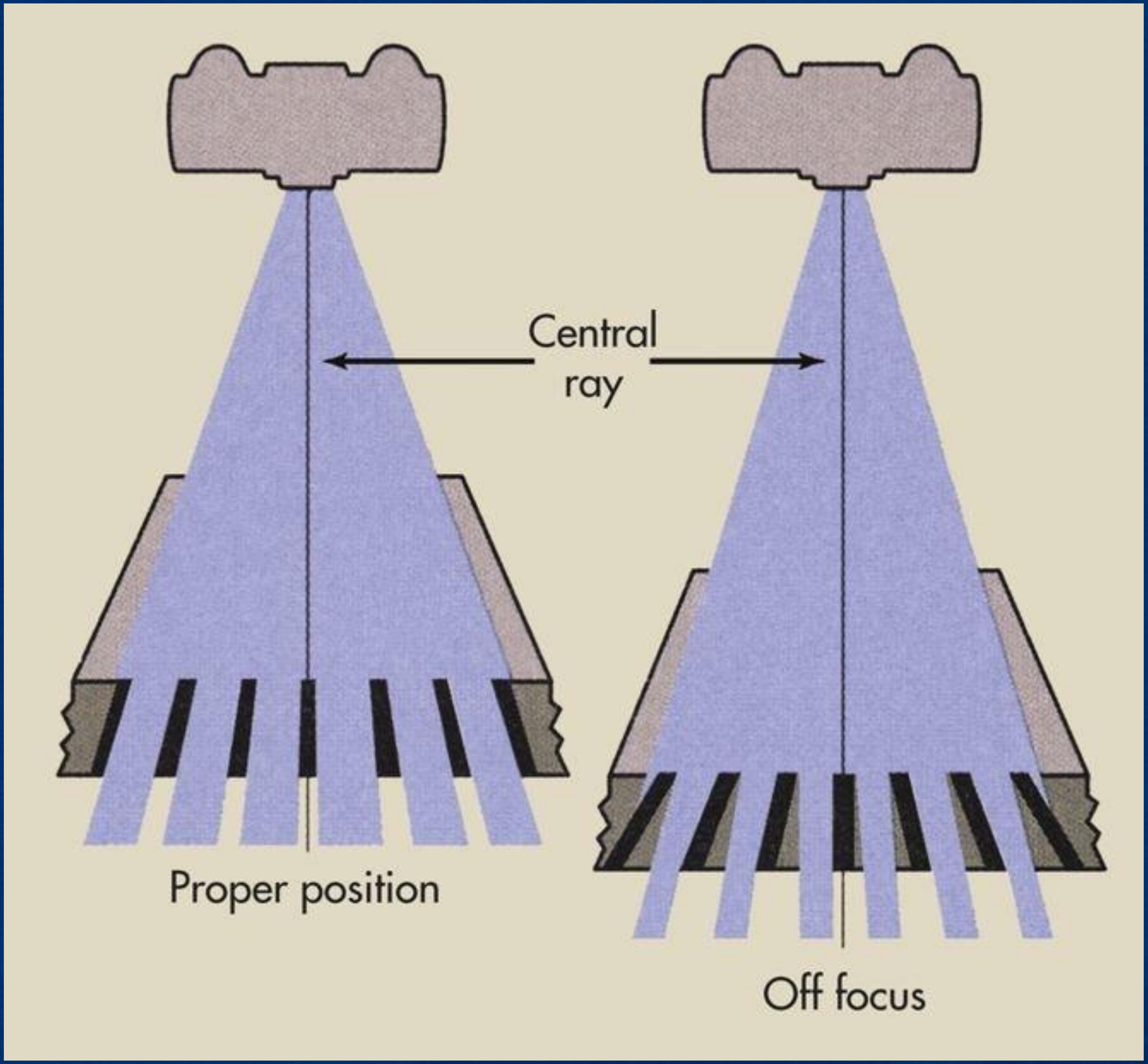
Grid cutoff across image; underexposed, light image



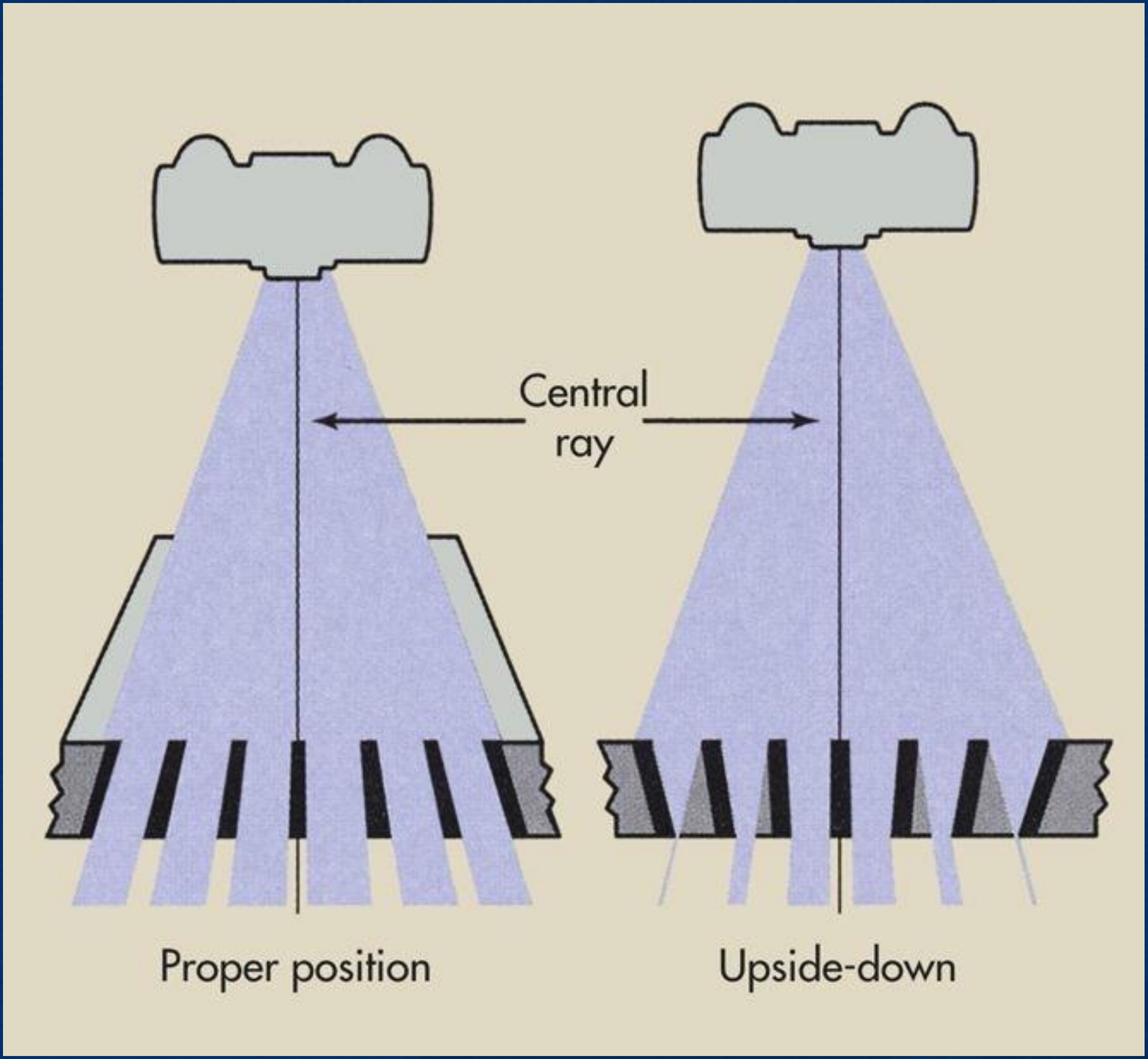
Grid cutoff across image; underexposed, light image



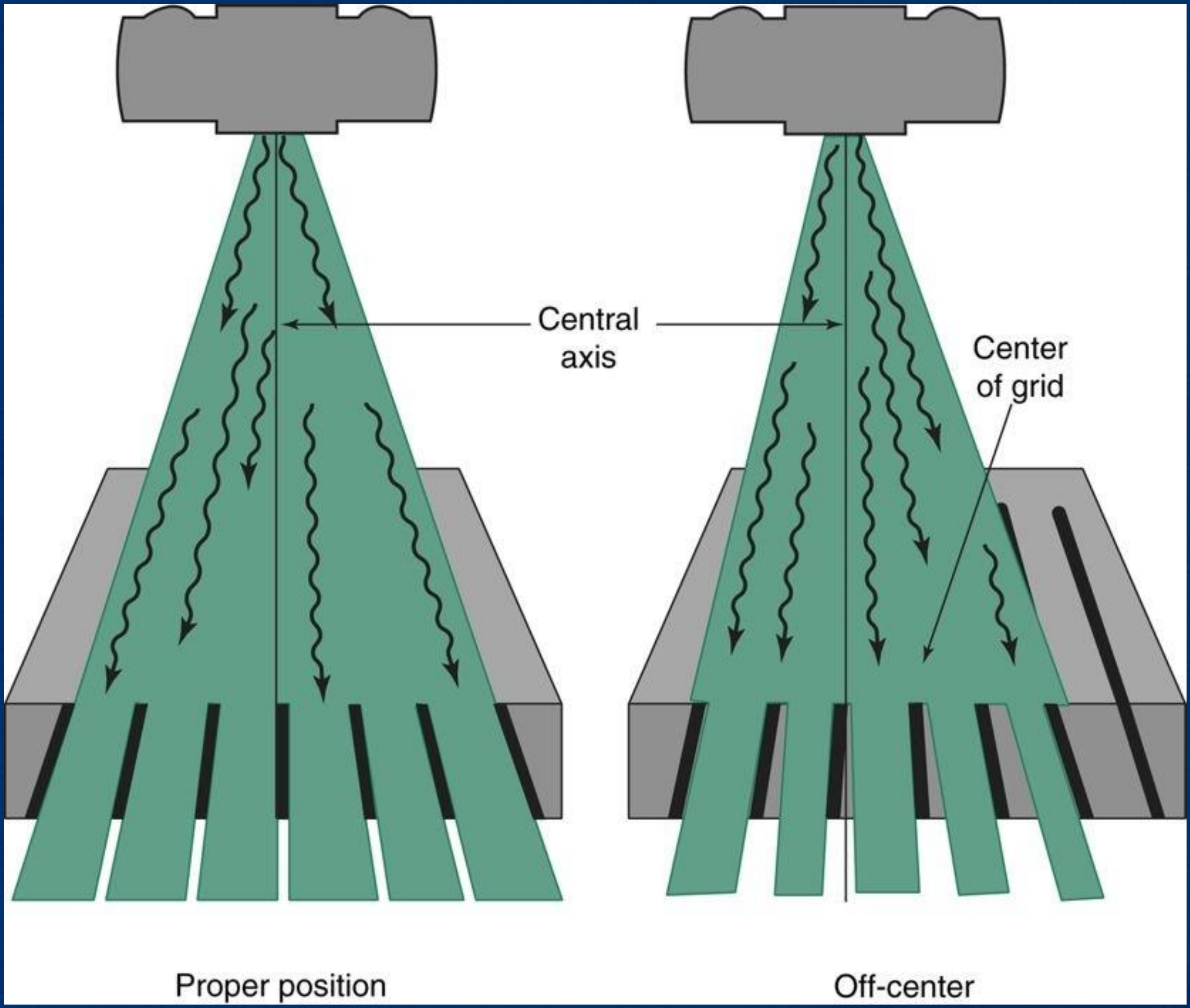
Grid cutoff toward edge of image



Severe grid cutoff toward edge of image



Grid cutoff on one side of image



# Artifacts 1

# Backscatter or ghosting

# Filtration error

# Patient on the board

# Scatter

# Double exposure

# Wet hair

# Hair extensions

# Back brace

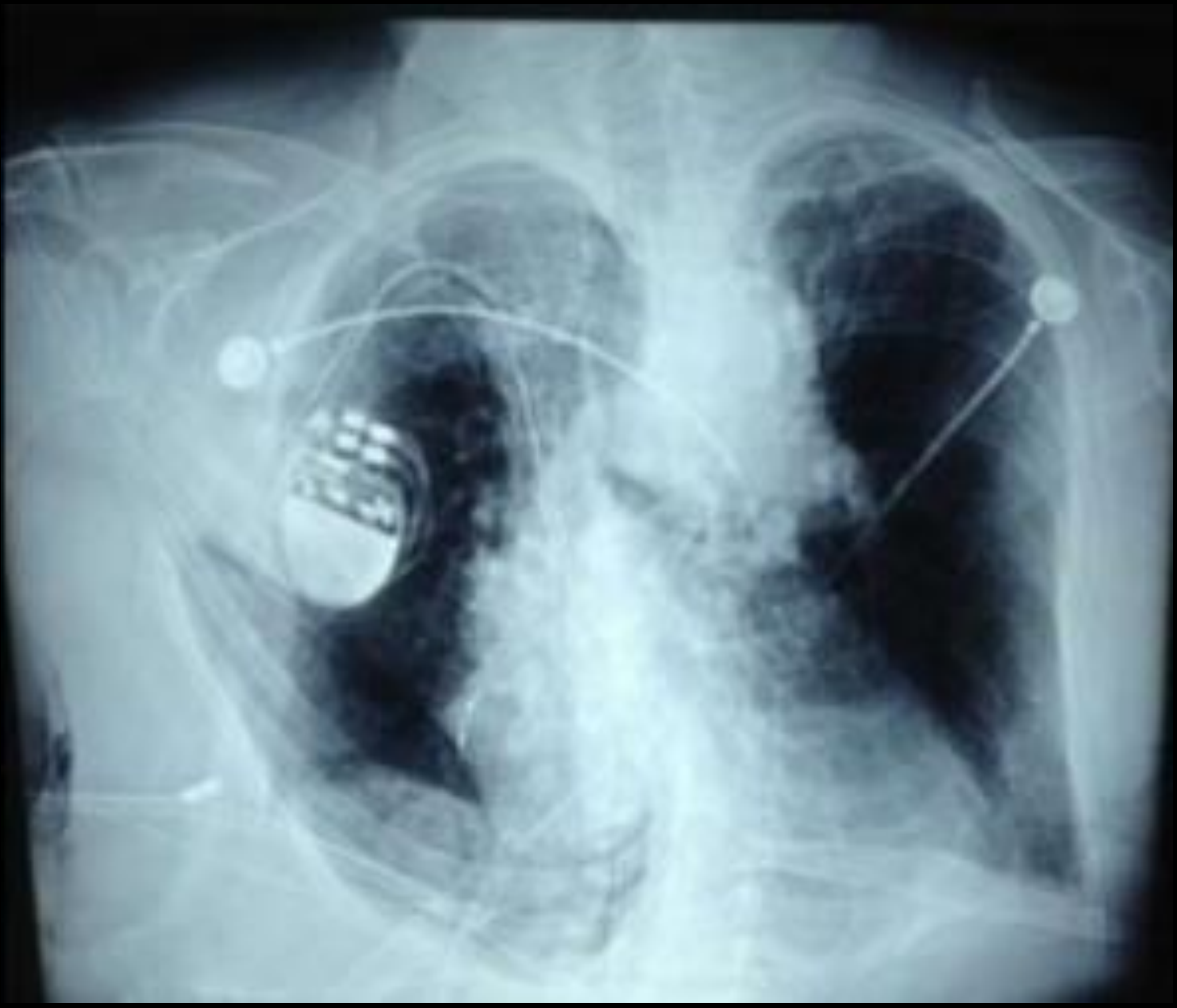
# Body piercing

# Bra

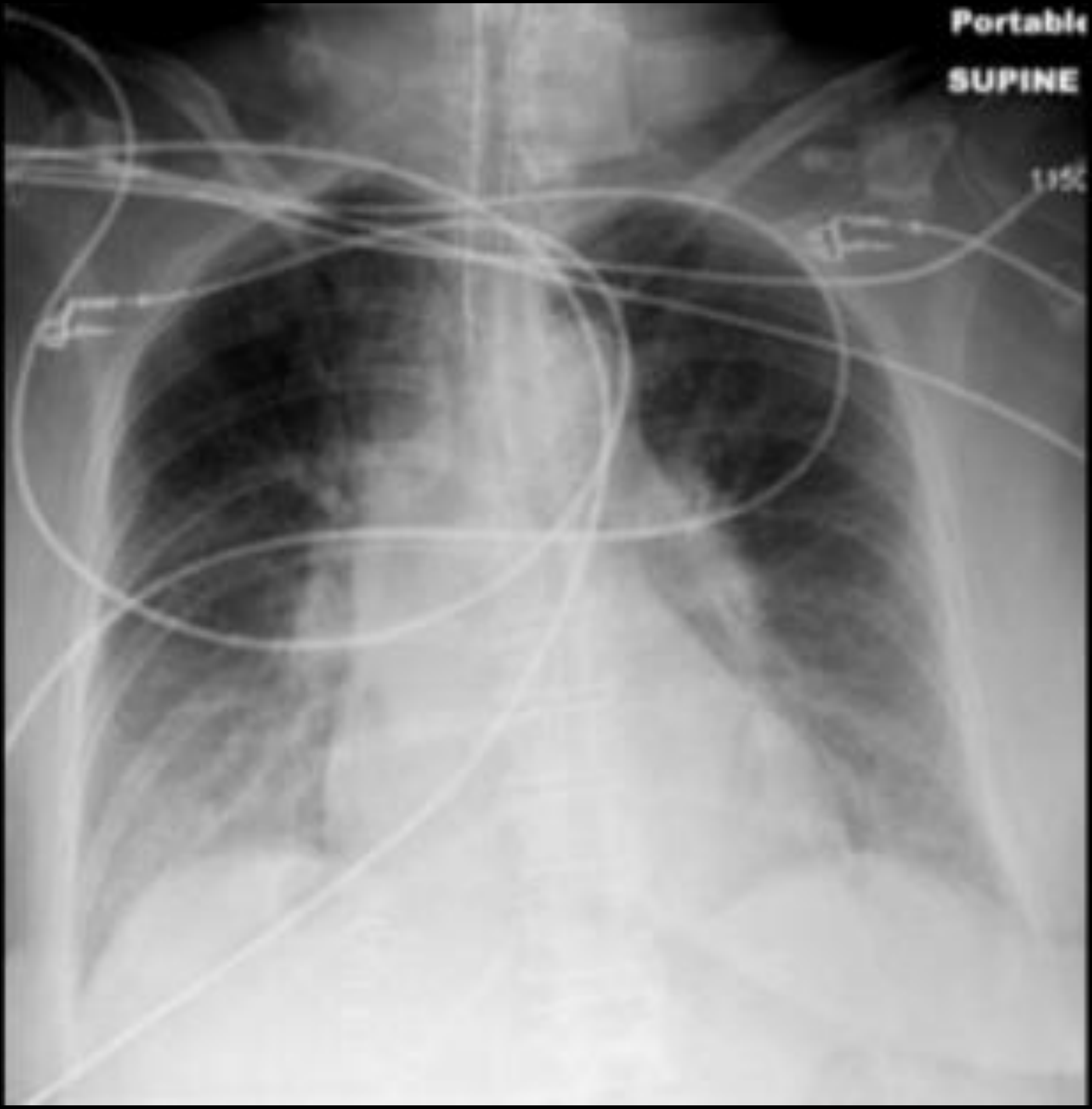
# Double exposure

# Double exposure

# Double exposure



# EKG wires



# Forceps left inside the patient

# Bullet fragments

# Bullet fragments

# Surgical fixator rods

# Foreign objects in the large intestine

# Battery

# Earring in the hepatic flexure


R

Port

R
UPRIGHT

# Motion

# Motion

# Wheelchair railing + metal buttons

# Wheelchair

# Wires

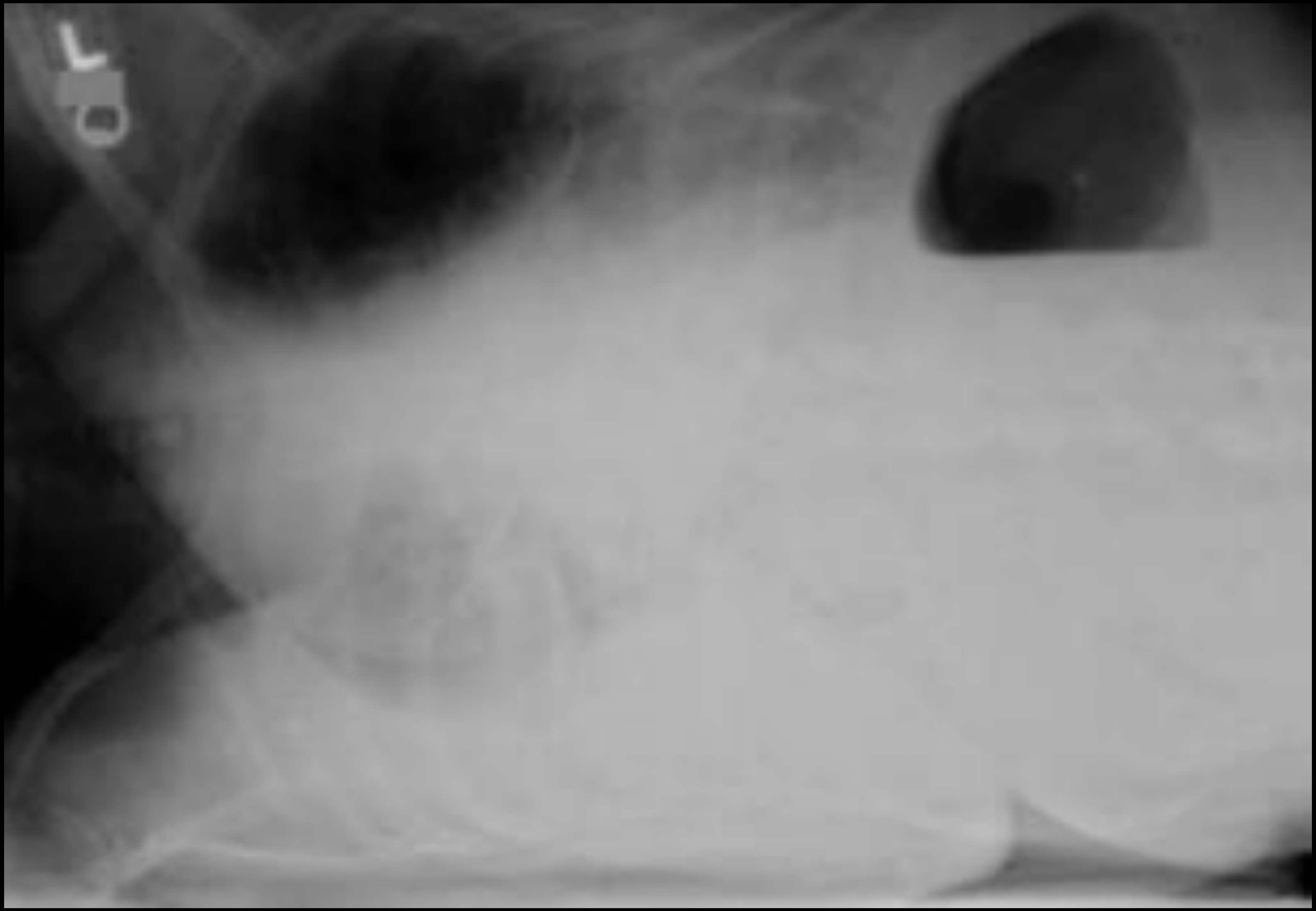
# Mechanical heart assisting device

# Dust on the IP

# Breast implants

# Breast implants

# Pendulous breasts



# Arms in the way

# Backscatter + surgical fixating device

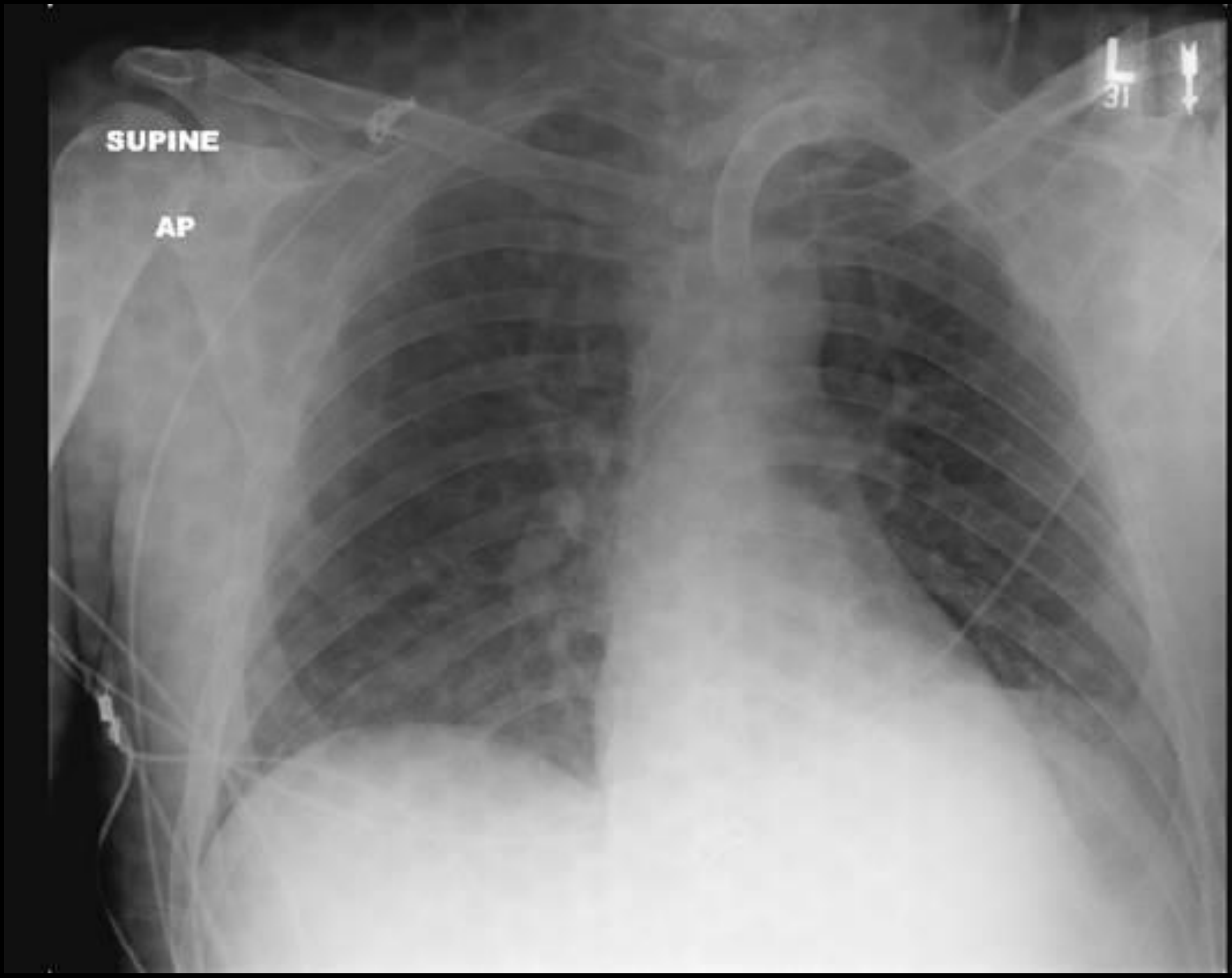
# clothes

# Backscatter

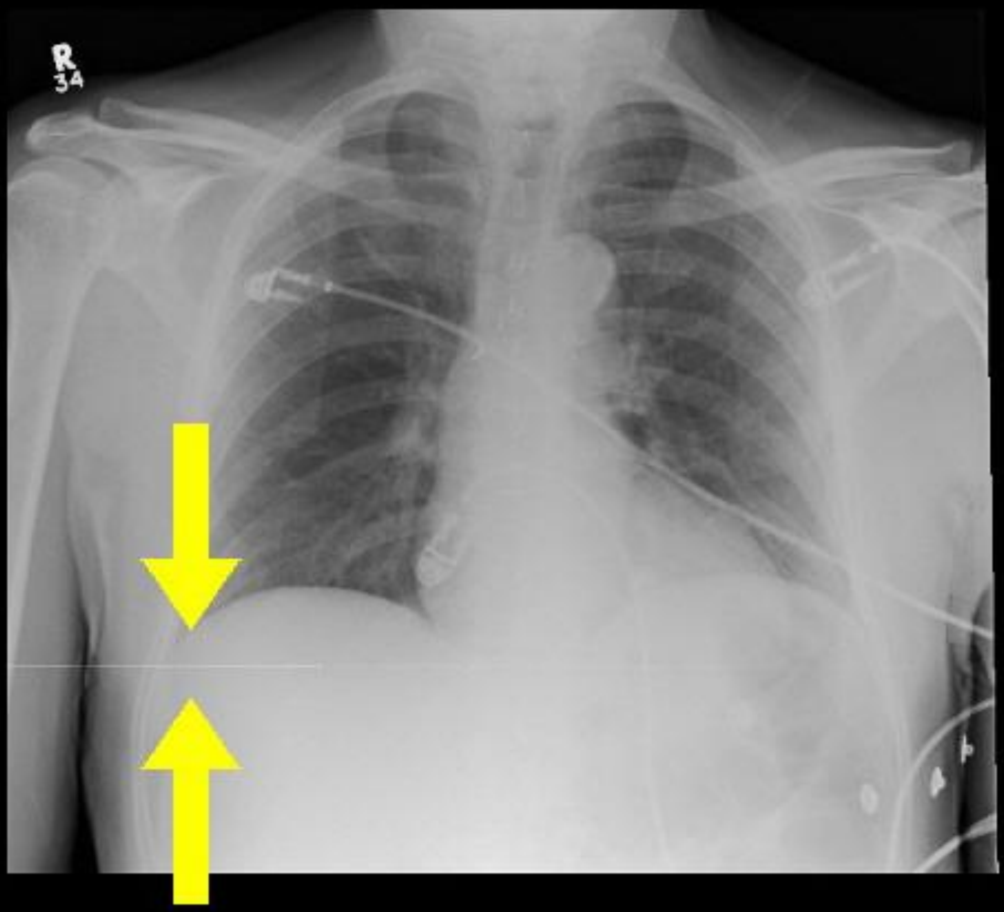
# Double exposure + cardiac monitoring wires

# Kyphotic patient (chin)

# Warming blanket (bair hugger)



# Dirt on CR reader



# Dust on IP

# Dust on IP

# Dirt on the CR reader transport system