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radiographic techniques for upper limbs(lec2)



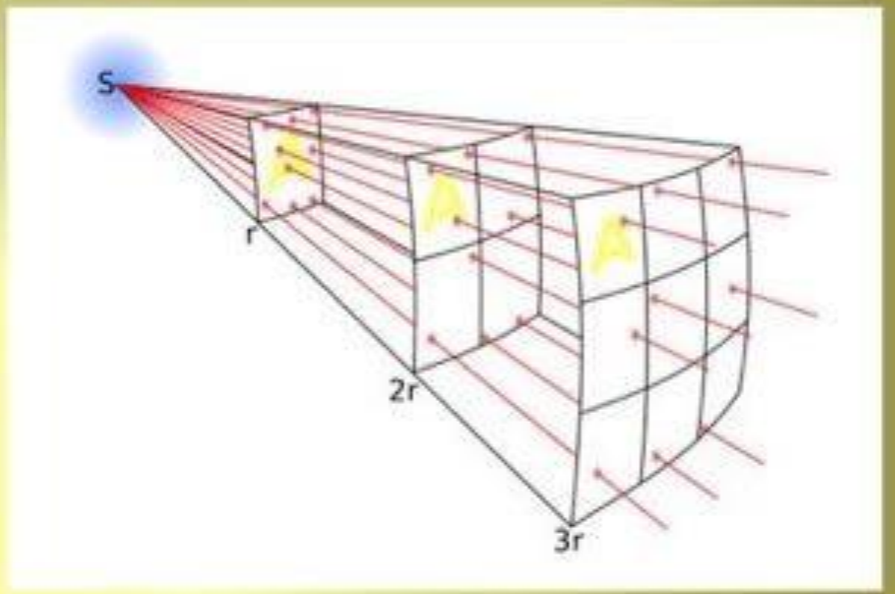
What is 'image quality'

- Image quality describes the overall appearance of the image and its *fitness for purpose*
  - **Remember:** There is always a play-off between image quality and patient dose
  - We only need images that are of diagnostic quality (fit for purpose) – not pretty pieces of art!
- The main factors to consider are:
  - **Contrast**
  - **Spatial resolution**
  - **Noise**

Image Quality

Focus-to-skin Distance:

The Inverse Square Law

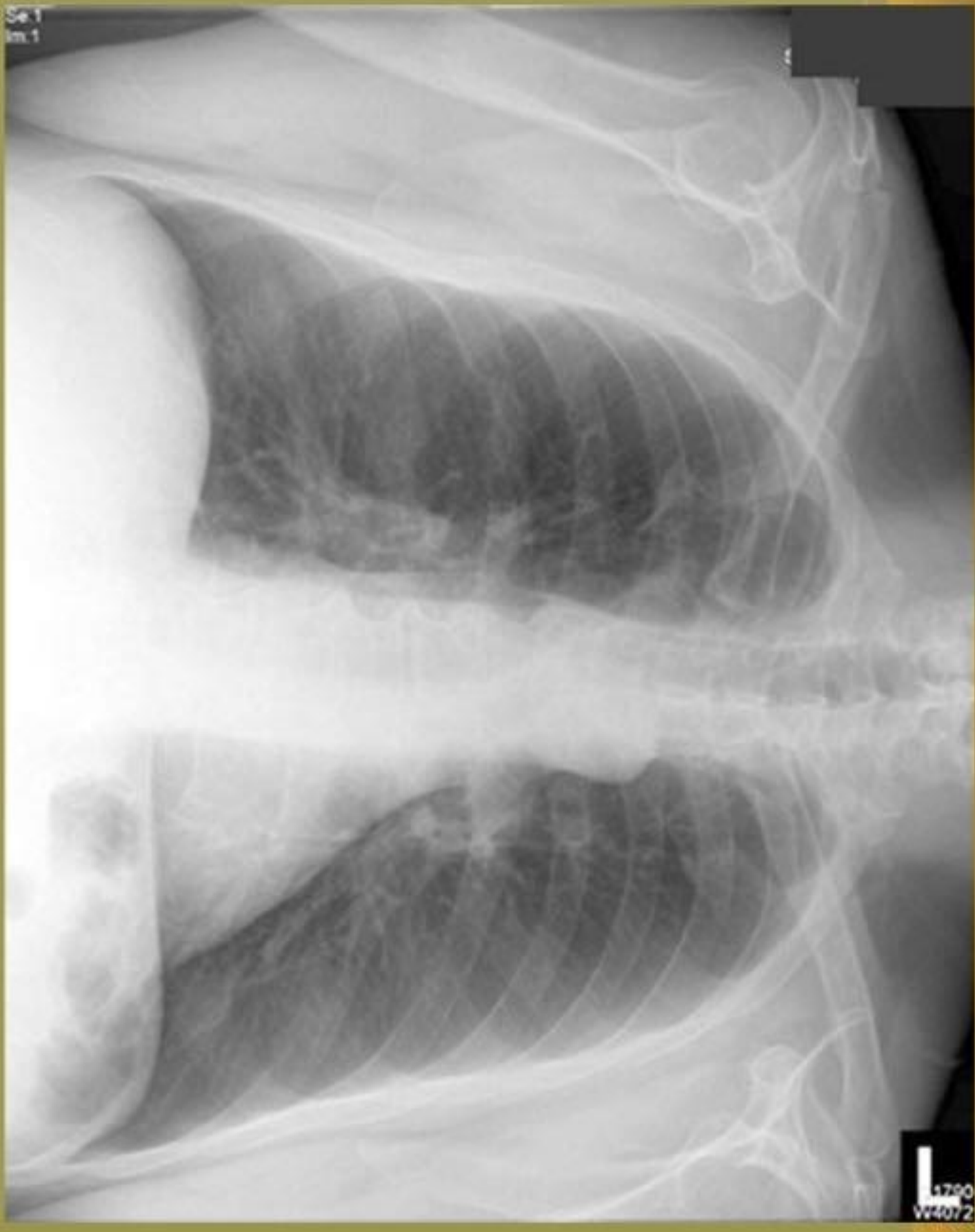


- **For a point source, and in the absence of attenuation, intensity decreases as the inverse of the square of the distance**
- This is a statement of the conservation of energy

$$\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$$

Image contrast

- The final contrast in the image will depend on a number of factors, such as;
  - **Subject contrast** – an inherent property of the patient being imaged that will depend on the attenuation coefficients of the tissues (or contrast media), the thickness of structures, the nature of any overlapping tissues and the incident X-ray spectrum (kVp, filtration, etc – discussed previously)
  - **Detector properties** – film and digital detectors each have different implications for the contrast in the final image
  - **Scattered radiation** – scatter can degrade image contrast if it reaches the detector as it conveys no information about where it came from. Scatter rejection techniques may be used to remove this.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Contrast

- Most medical images presented as shades of grey from black to white (greyscale)
- Contrast resolution is the ability to distinguish between regions of the image
- The amount of contrast between tissues is intrinsically linked to their properties and the imaging modality being used
- Also influenced by the technique and specification of the equipment being used, and how it is displayed
  - Digital imaging techniques allow image processing to be applied to improve the visibility of details

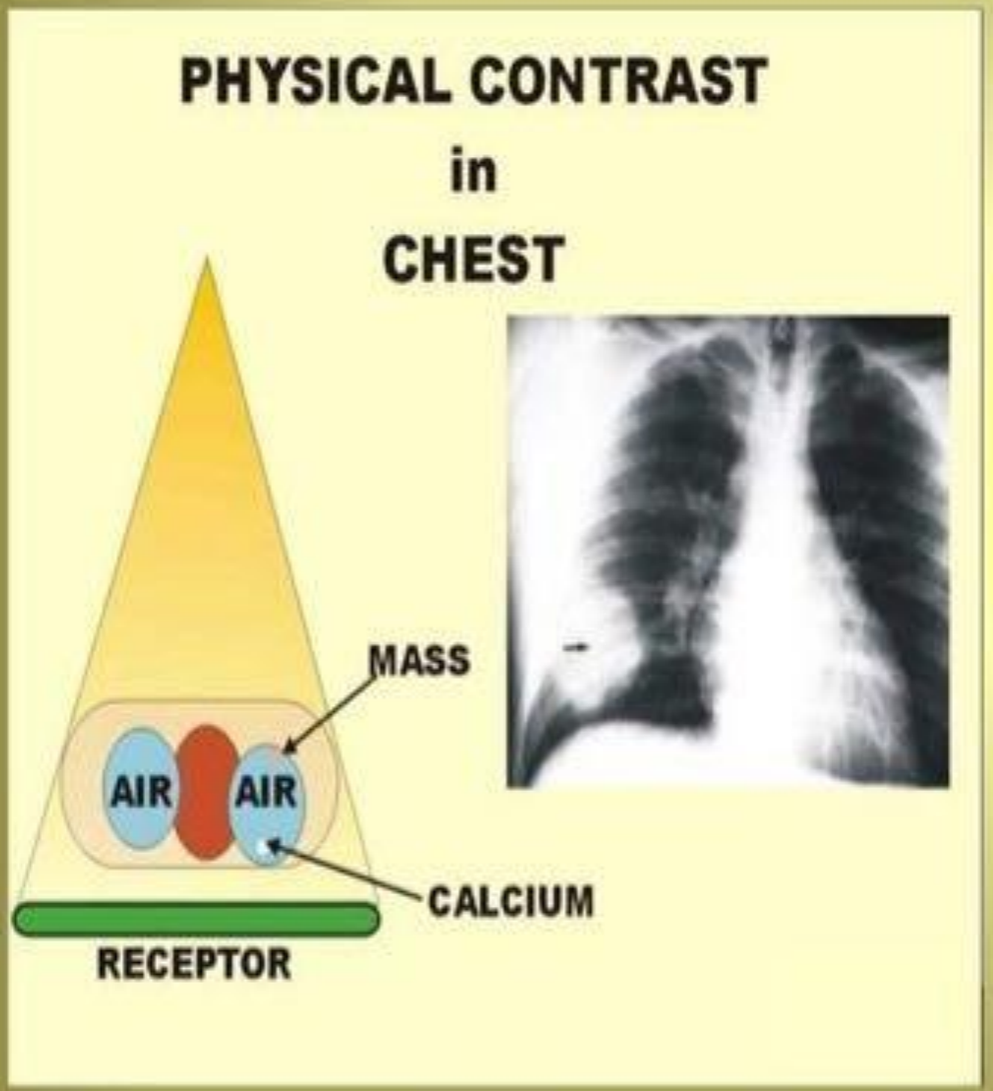
Subject contrast

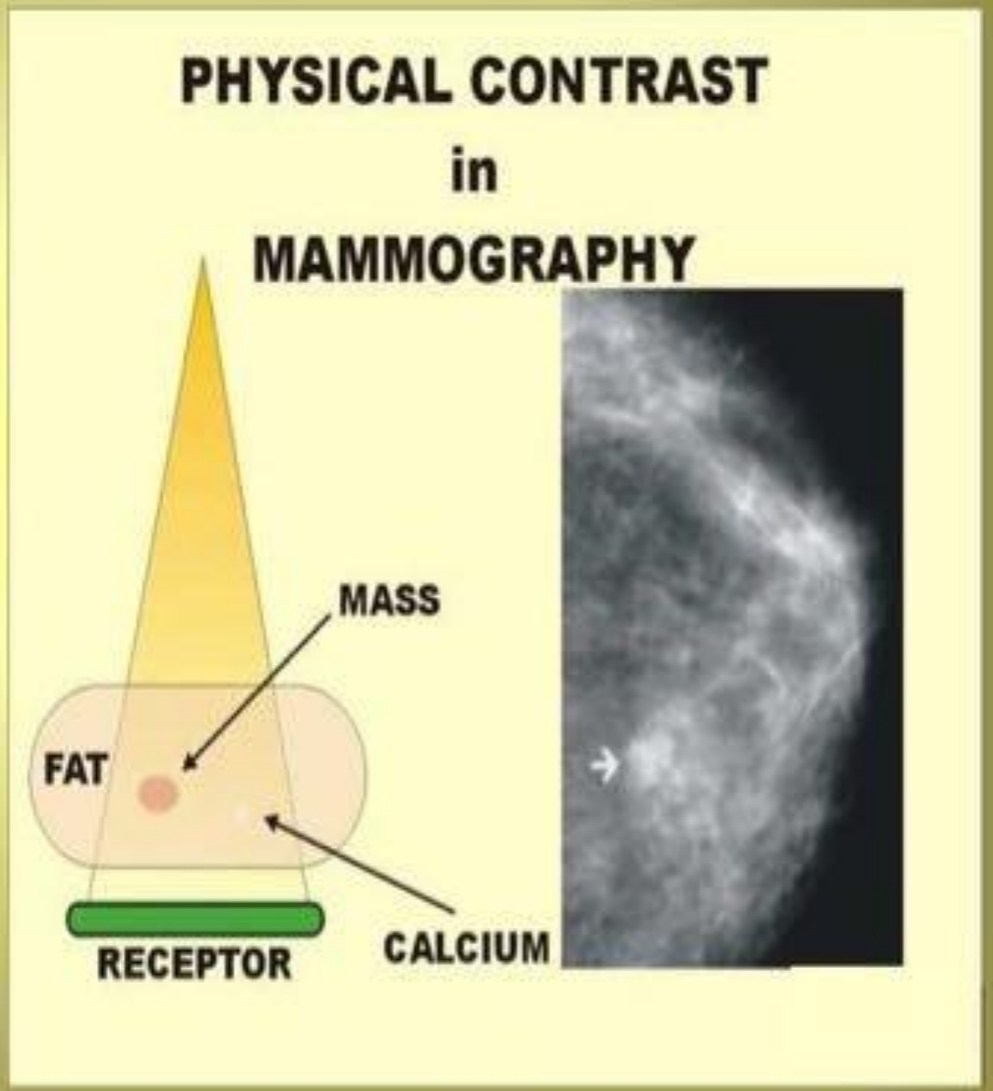
Material	Effective Atomic Number Z	Density g cm^{-3}	Contrast Index Density x thickness = 4
Soft Tissue	7	1	4cm
- Fat	6	0.9	4.4cm
- Water	7.4	1	4cm
- Muscle	7.5	1	4cm
Air	7.6	0.00129	3100cm
Bone	14	1.85	2.1cm
Calcium	20	1.55	
Tooth		2.4	1.7cm
Iodine	53	4.9	
Barium	56	3.5	1.1cm
Barium Contrast Media	56	4.25	
Lead	82	11.3	0.35cm

Subject contrast

- Visibility of object structure – requires physical contrast between the object to be imaged and the surrounding tissues
- The contrast may be based on a difference in densities or atomic number (chemical composition), coupled with the thickness of the particular material through which the radiation has to pass
  - Proportional to object density x object thickness
- Also remember, higher kVp = less photoelectric absorption = poorer contrast

Subject contrast





Balancing Contrast & Patient Dose

Low Energy (kV) = Low Penetration = High Contrast = High Patient Dose

High Energy (kV) = High Penetration = Low Contrast = Low Patient Dose

Optimal Situation = kV that gives adequate contrast for an acceptable patient dose – will vary for the clinical application

Balancing Contrast & Patient Dose

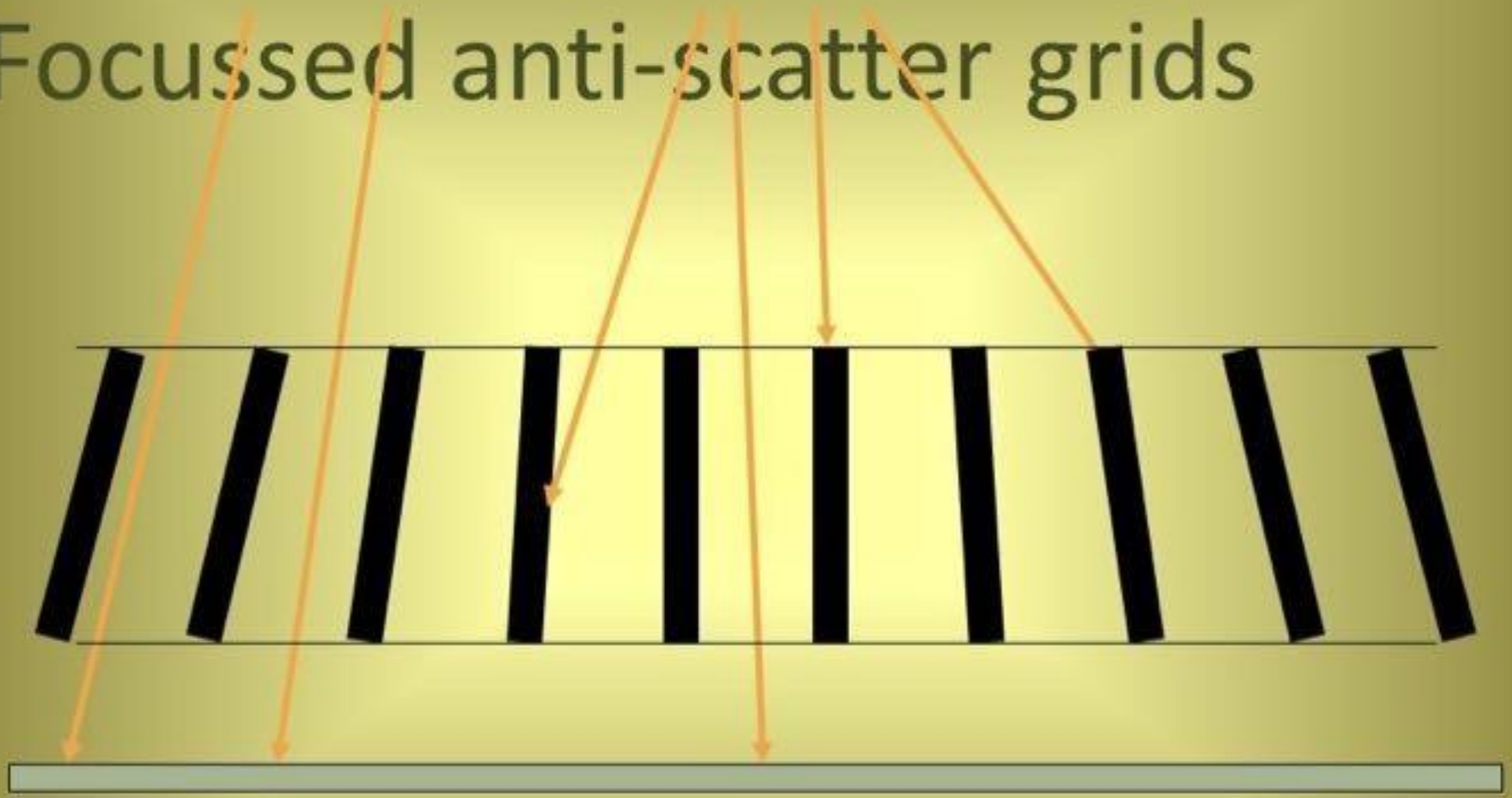
- Penetration, contrast and patient dose depend on the x-ray beam spectrum. The 'best' spectrum provides **adequate** penetration and contrast, whilst keeping the patient dose as low as possible

- The spectrum produced is dependent upon the target material, inherent and added filtration, and kilo-voltage

Subject contrast

- Contrast between bone and muscle is large at low kV, but decreases with increasing kV
- Contrast between low atomic number soft tissues is low, **even at low kV**
- The contrast between air and tissue (similar Z) is large **due to the difference in density**

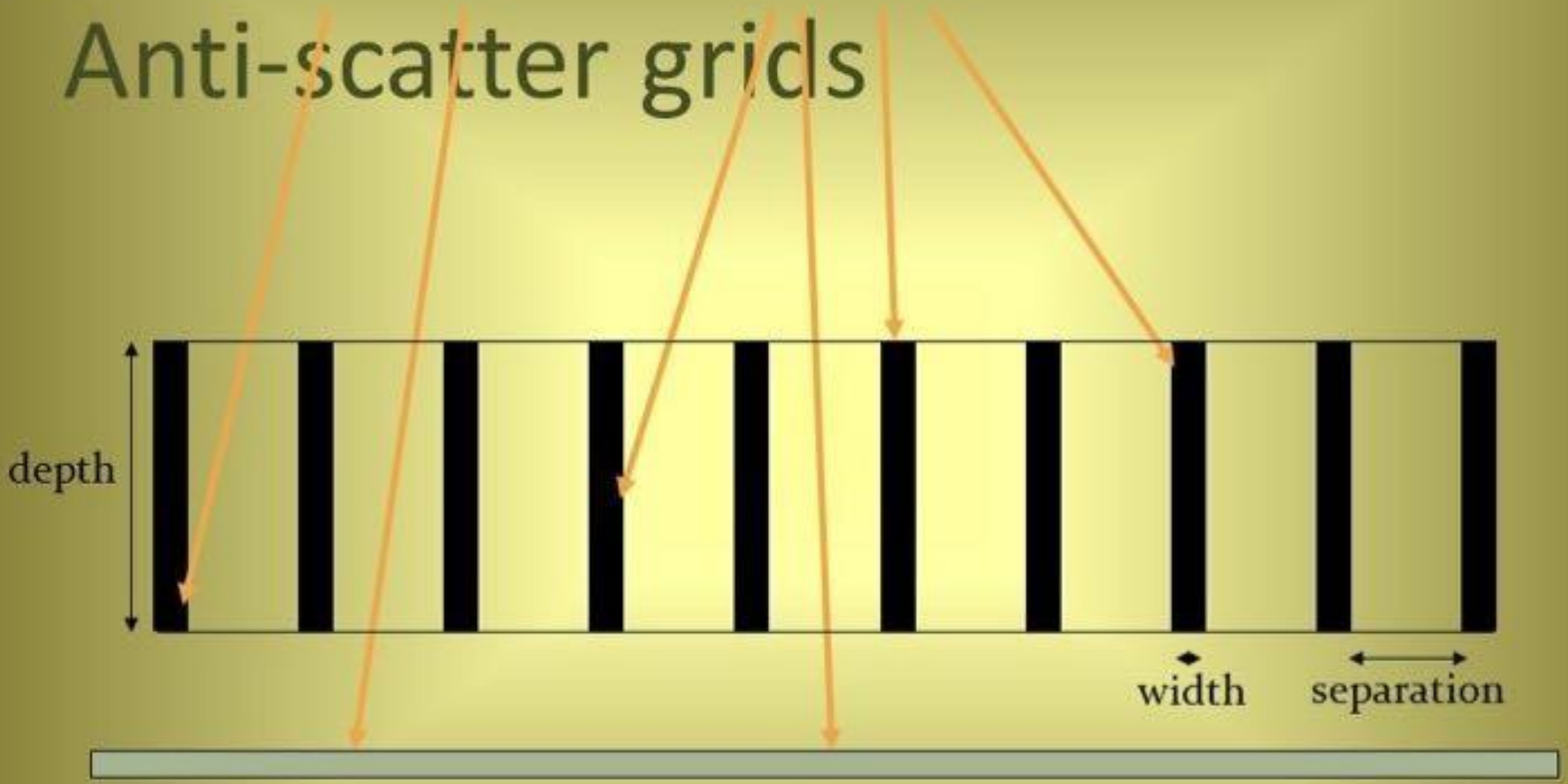
Focussed anti-scatter grids



Anti-scatter grids

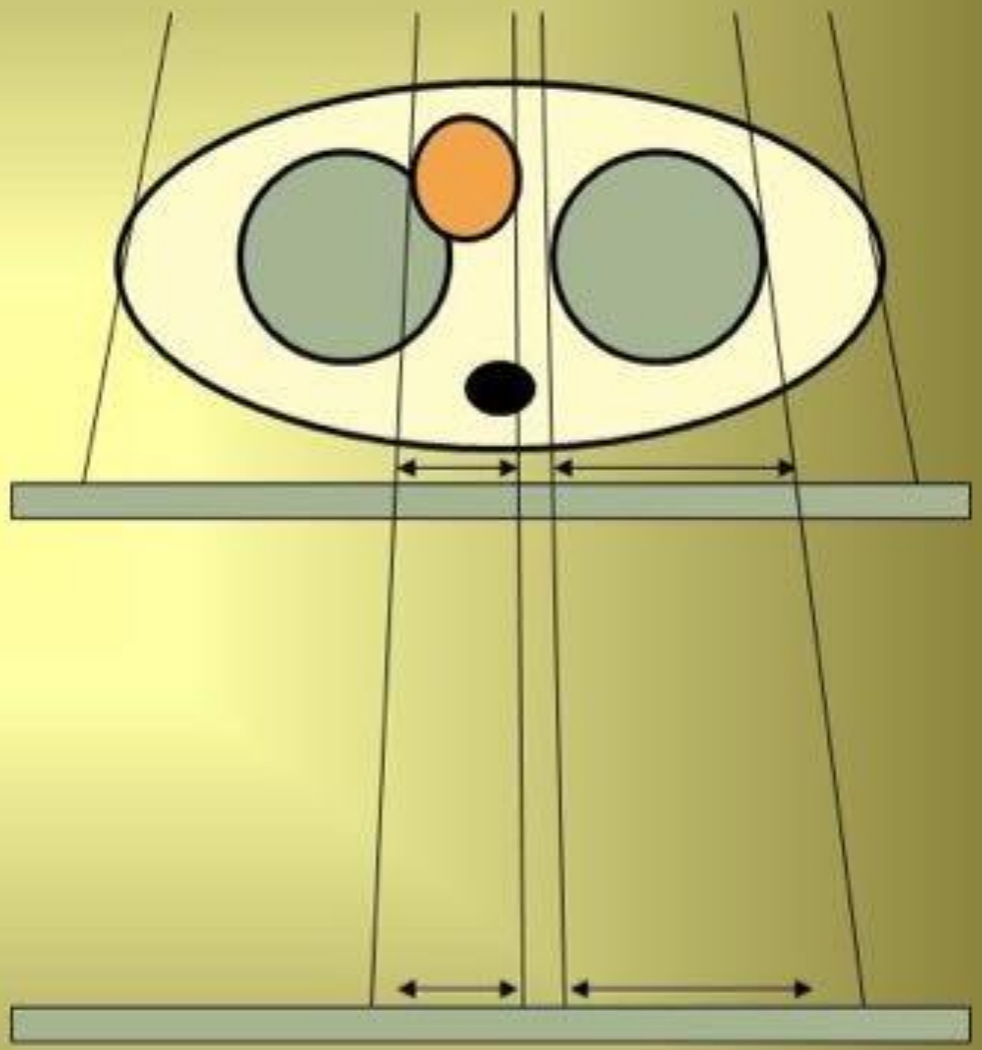
- Large fields tend to require higher grid ratios (12:1 or 16:1)
- Grids generally not used for thin parts of the body or children as less scatter is generated (and increase in dose not justified)
- *Contrast improvement factor* is defined as contrast with a grid divided by contrast without
  - Typically between 2 and 4

Anti-scatter grids

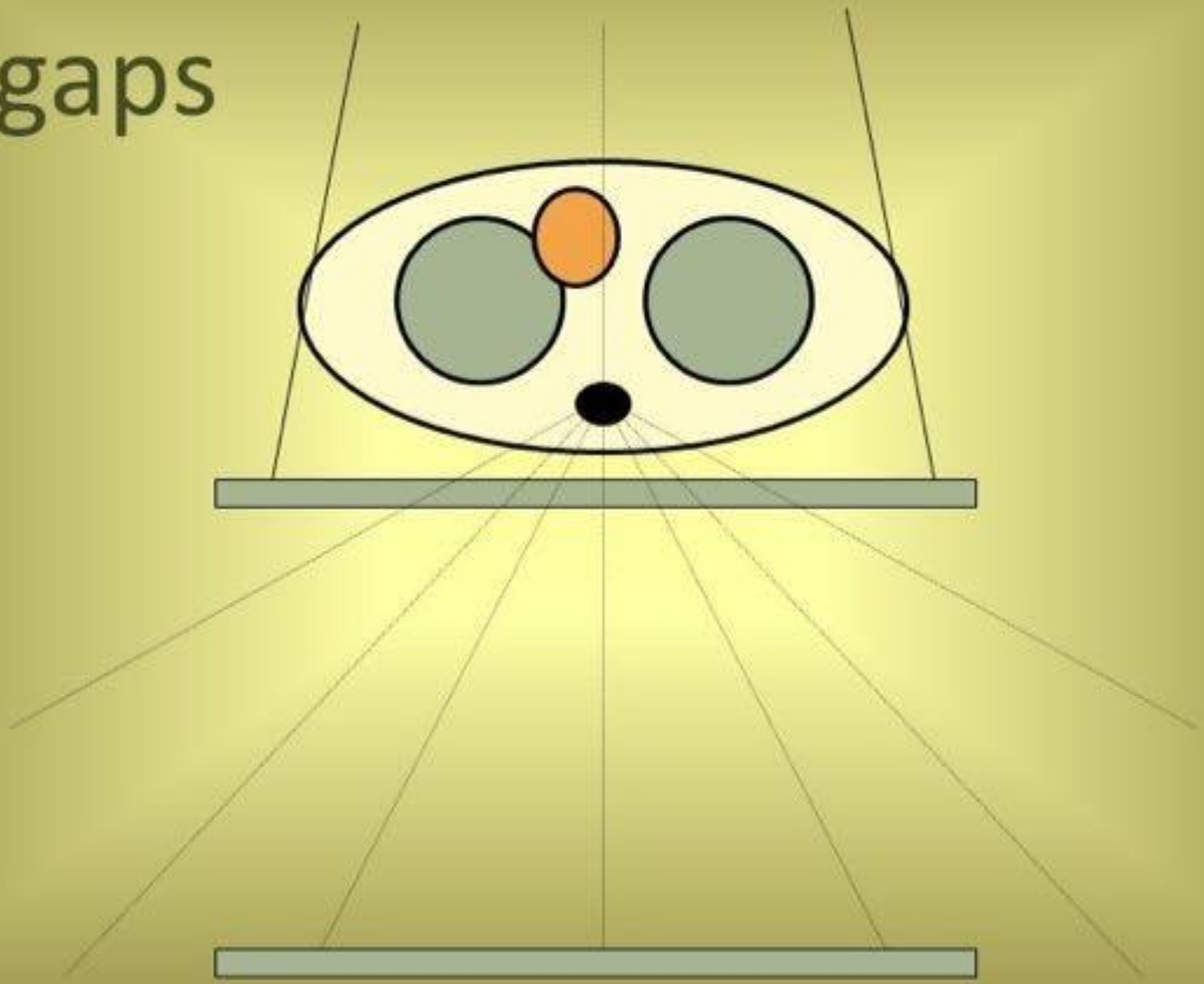


Magnification

- Magnification is the result of the diverging X-ray beams travelling in straight lines
- Reduce by using longer focus-to-film distance or shorter object-to-film distance
- Magnification exploited in some modalities e.g. mammography



Air-gaps



Noise

- Image noise is most apparent in image regions with low signal level, such as shadow regions or underexposed images
- Noise gives a grainy, mottled, textured or snowy appearance to an image
- Noise can mask fine detail in a radiograph
- Noise reduces visibility of parts of a radiographic image
- Noise is particularly an issue with image details that are already of low contrast

Noise

- **Noise** is a random, usually unwanted, variation in brightness or colour information in a visible image
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- Noise is one of the most important limiting factors to contrast and spatial resolution
- The most significant source is **quantum noise** (or mottle) due to the low levels of radiation used to form an image
- Other sources include film grain and electronic noise in the image receptor

Spatial Resolution

- Spatial resolution describes the ability to see fine detail within an image
- Fine detail is clearer when the contrast is high
  - e.g. microcalcifications
- May be expressed as the smallest visible detail, but **most common descriptor is the highest frequency of lines that can be resolved in a high-contrast bar pattern**

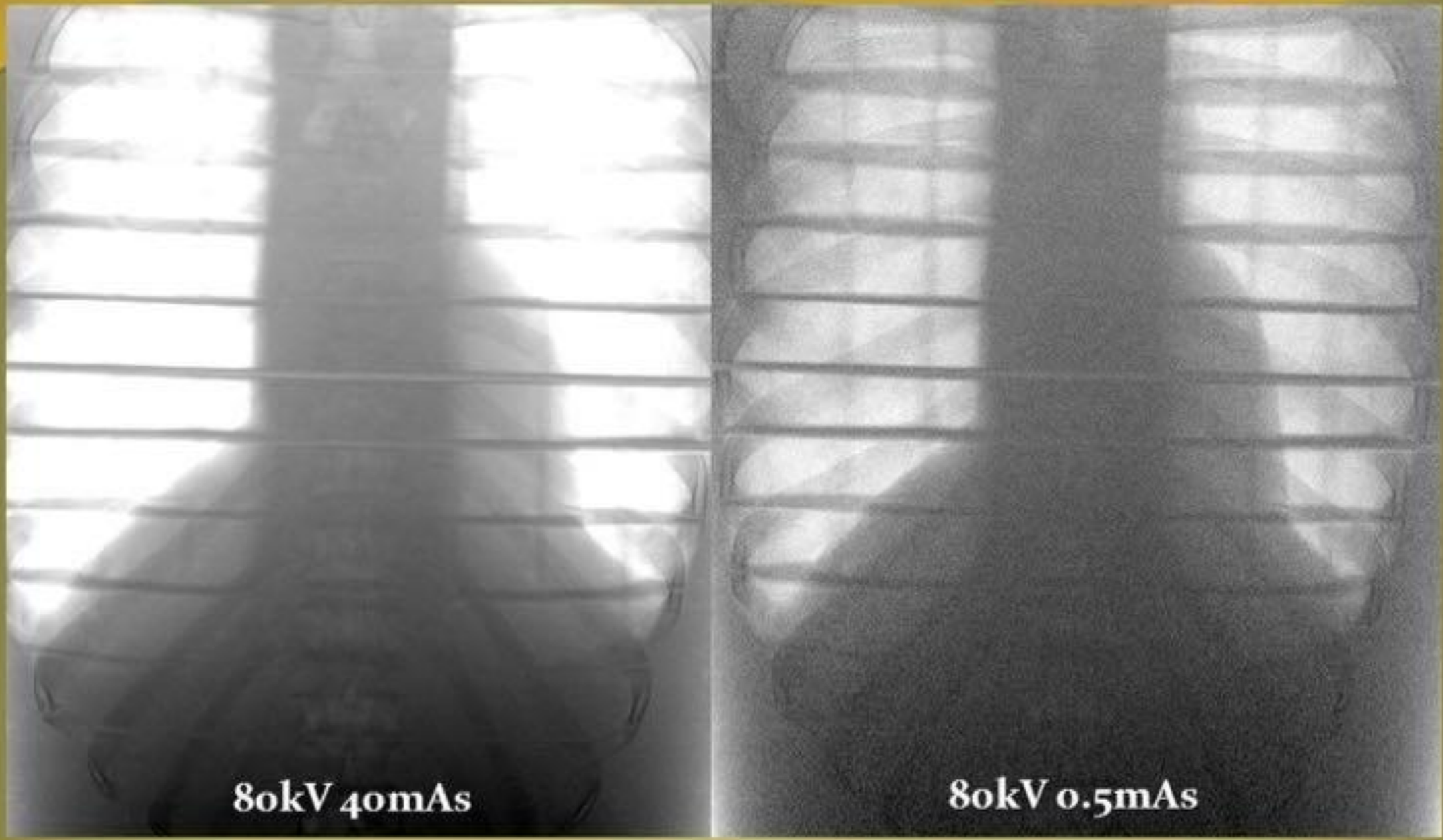


Striking the right balance

Reduced Exposure = Low Patient Dose = Increased Q-Noise = Reduced Image Quality

Increased Exposure = High Patient Dose = Reduced Q-Noise = Improved Image Quality

Optimal Situation = Exposure high enough to give a **diagnostic** image with **acceptably** low quantum noise, whilst maintaining an **acceptable** patient dose.


80kV 40mAs
80kV 0.5mAs

Types of noise

- Several types of noise contribute to the overall image quality, these are:
  - **Quantum Noise** – from statistical nature of the interactions of the X-ray beam
  - **Secondary Quantum Noise** – associated with secondary carriers at each conversion stage in image formation e.g. CR, Image Intensifiers, etc
  - **Structural Noise** – films/screens/intensifier tube screens/digital receptors. Only tends to be important at high doses where all other sources are negligible
  - **Electronic Noise** – circuit noise, thermal noise, external electrical device signals. Only obvious at low doses