

Digital Radiography: An Overview

From film to pixels to PACS

Diagnostic Imaging · Homework 1, Topic 1

Group: A · B · C · D (replace with names)

Same mistake, two outcomes



Film

almost black: repeat needed

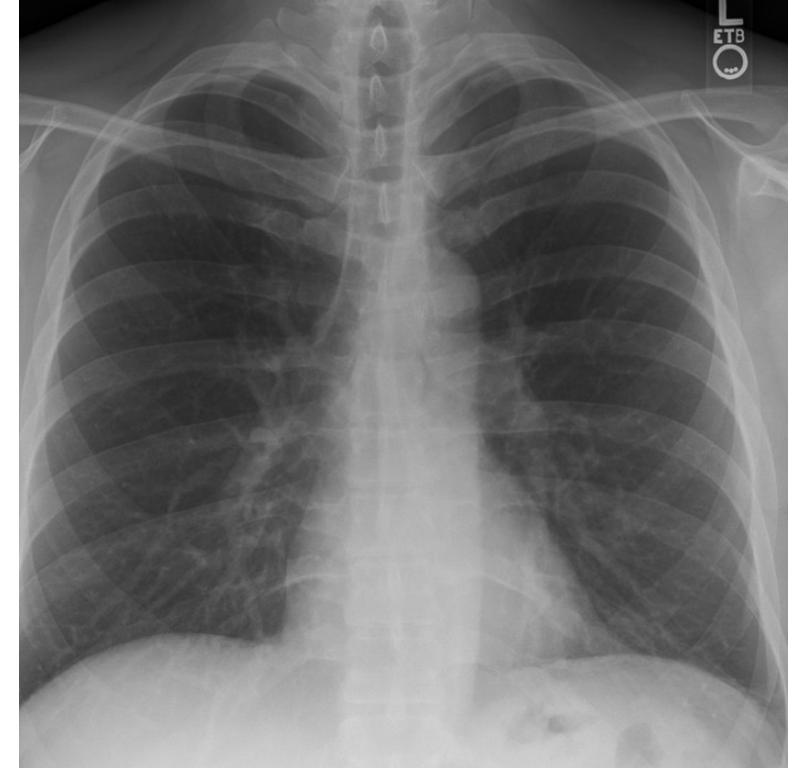
Same chest.
Same 4× mAs.

Film

Detectors

Dose

PACS



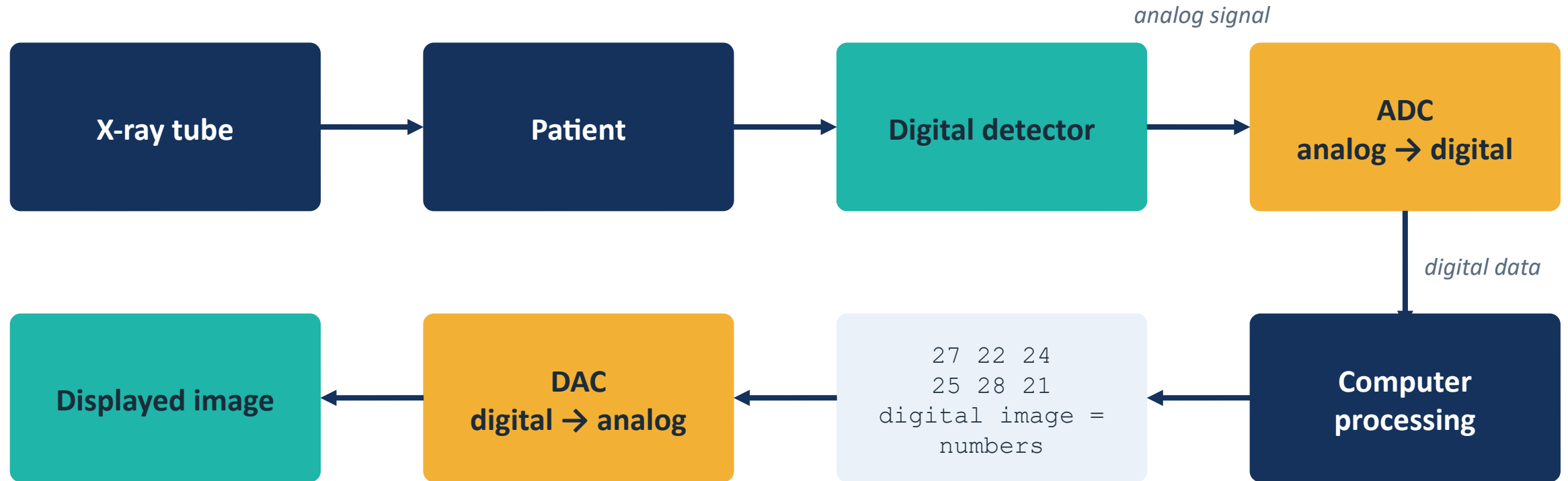
Digital (DR)

looks normal

Which patient received too much radiation?

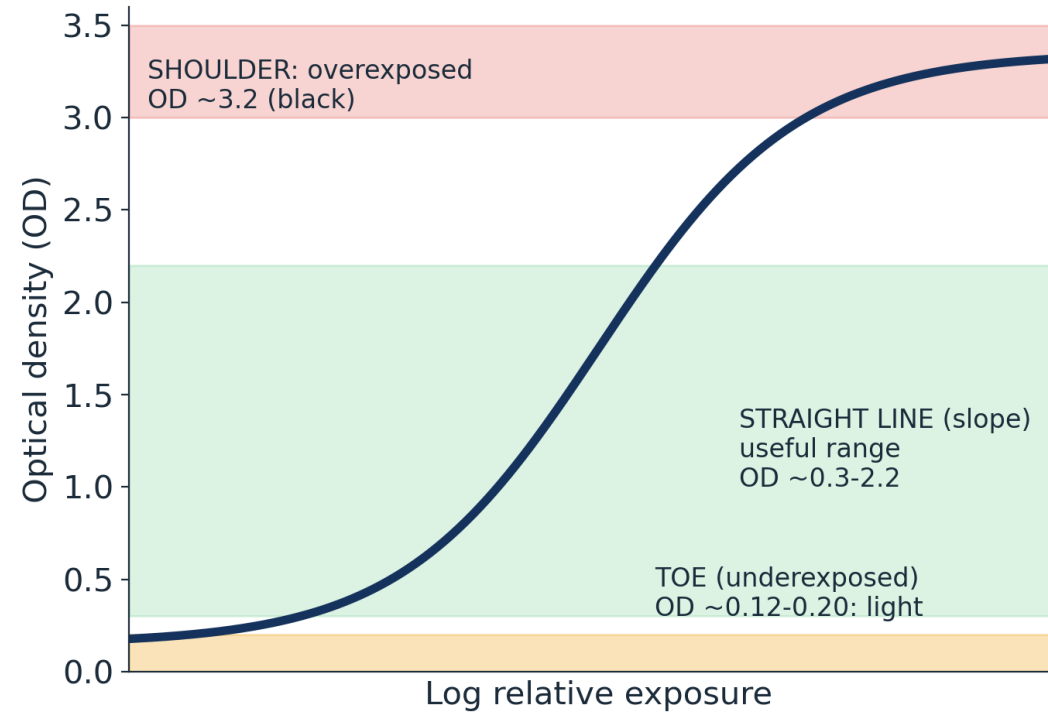
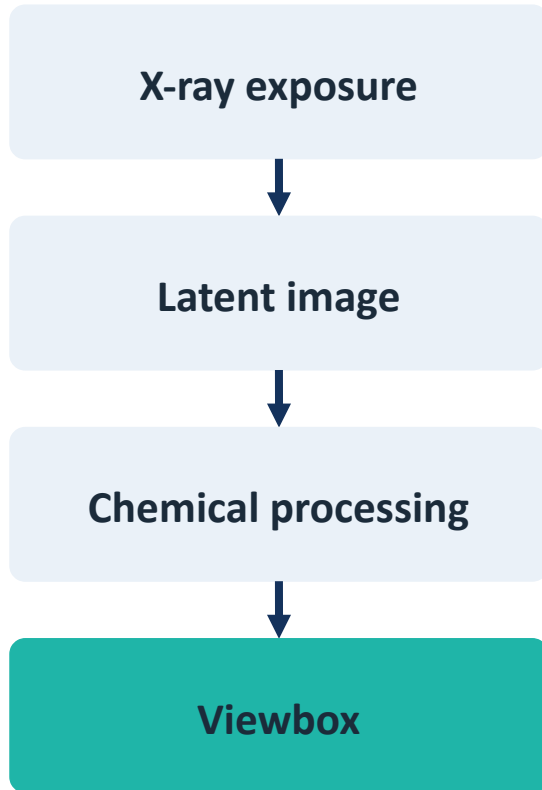
What is digital radiography?

Digital detectors turn X-ray exposure into numbers, and give usable images over a wider range of exposures than film.



Radiologists never see the numbers, only the displayed image.

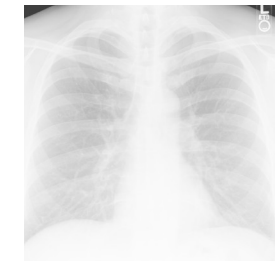
How film works, and its S-curve



Shoulder
overexposed



Straight line
useful



Toe
underexposed

$$OD = \log_{10} (I_0 / I_t) \quad \cdot \quad \text{Film} = \text{detector} + \text{display} + \text{archive in one}$$

Exposure factors: what the technologist controls

	kVp (tube voltage)	mAs (tube current × time)
Controls	Beam quality: penetrating power	Beam quantity: number of photons
Main image effect	Contrast: lower kVp = higher contrast	Noise: low mAs = grainy (quantum mottle)
Patient dose	$\approx \text{kVp}^2$ at fixed mAs	Proportional: $2\times \text{mAs} = 2\times \text{dose}$

AEC stops the exposure at a preset detector level (film: optical density · digital: signal-to-noise)

Why film had to go

1

Wrong exposure = repeat

Too light or too dark film is unusable. A repeat means extra dose.

2

The display is fixed

Brightness and contrast are set at exposure. A change needs a new exposure.

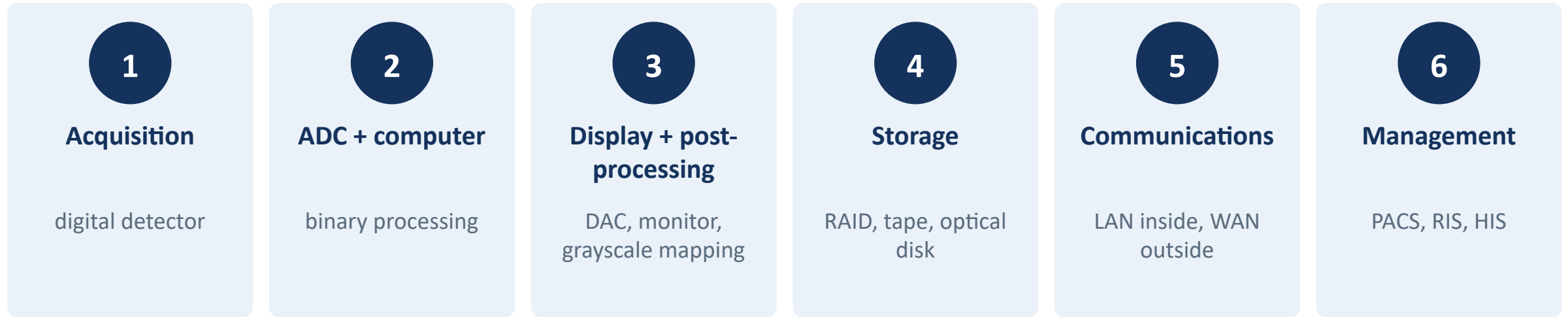
3

The archive is physical

Envelopes, large rooms, manual retrieval. One copy in one place.

Film's one strength: spatial resolution $\approx$ 5–15 lp/mm

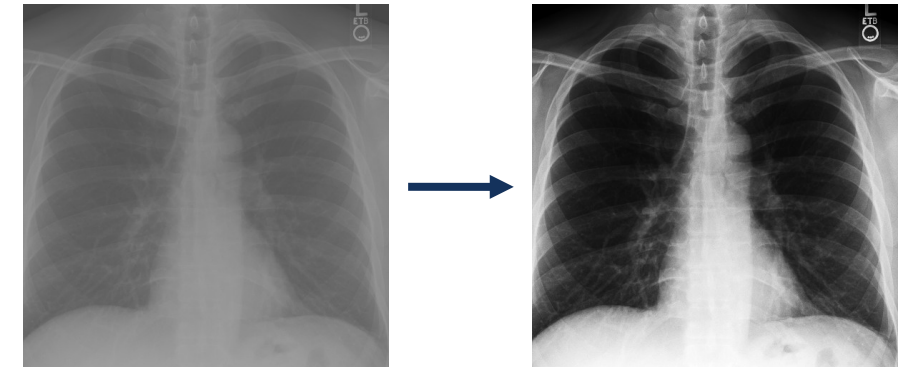
Inside a digital radiography system



Computers store everything as bits

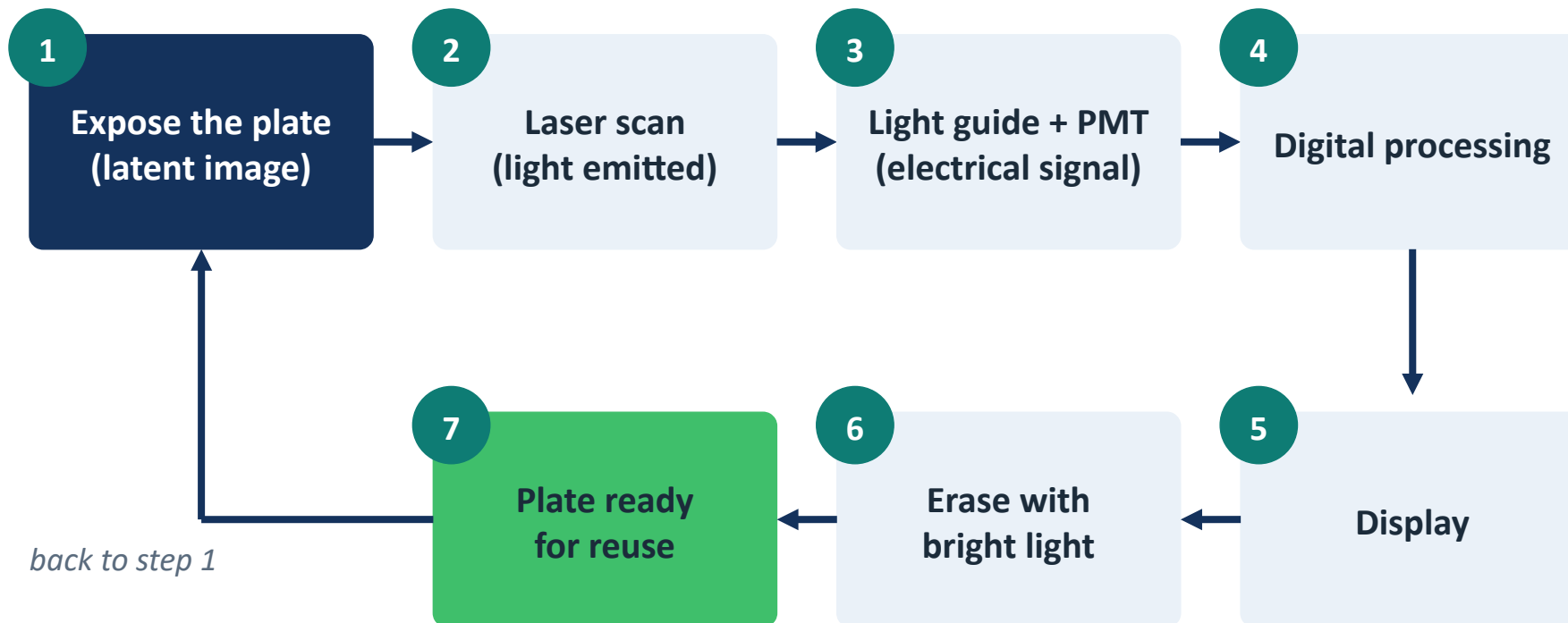
EUCLID in binary:

```
01000101 01010101 01000011
01001100 01001001 01000100
```



Grayscale mapping: low → high contrast

Computed radiography (CR): the reusable plate



Phosphor
BaFBr:Eu²⁺ on an imaging plate (IP)

Introduced
Fuji, 1983

Spatial resolution
≈ 3–5 lp/mm

Dynamic range
≈ 10,000 : 1 (far wider than film)

Latent image = trapped electrons; the laser frees them as light

Flat-panel detectors: indirect vs direct

Indirect: X-ray → light → signal

X-ray photons ↓

Scintillator (CsI)

light

a-Si photodiode + TFT array

Electrical signal → digital image

Direct: X-ray → signal

X-ray photons ↓

Photoconductor (a-Se)

light

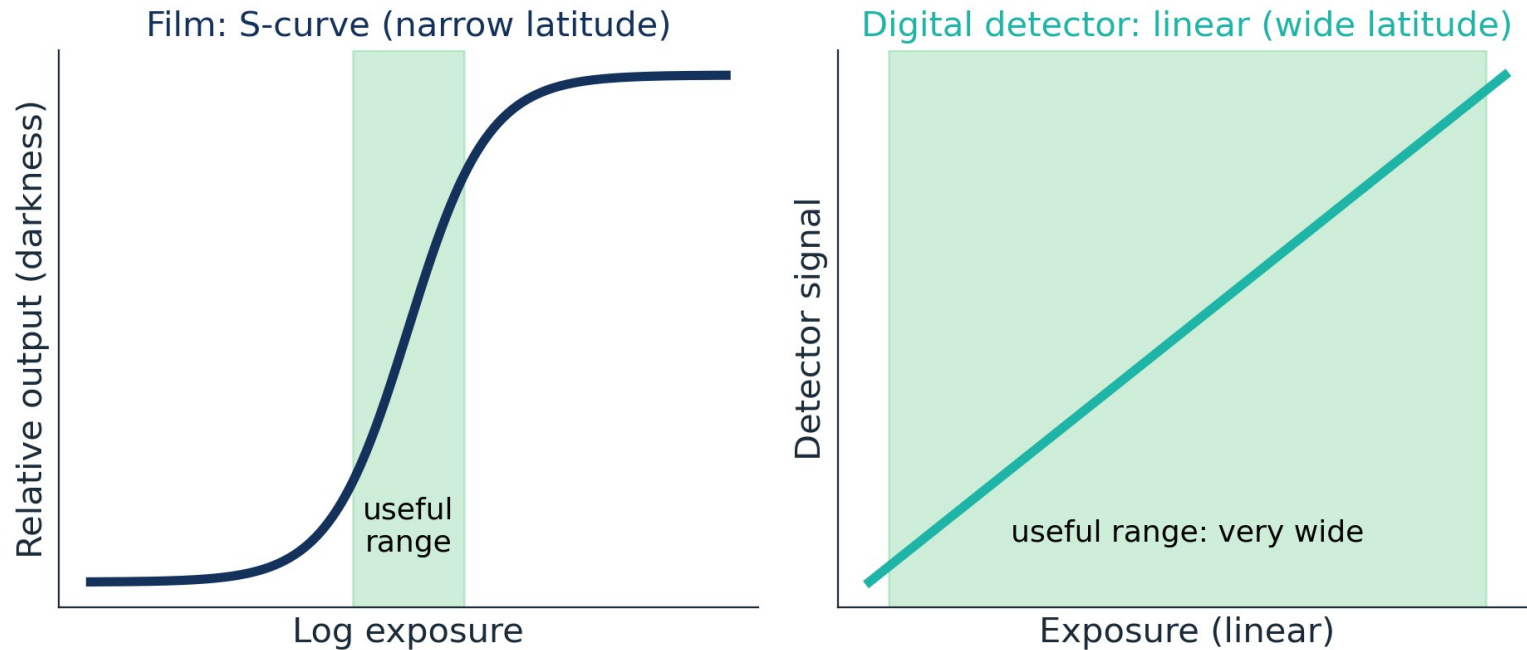
no light step

TFT array

Electrical signal → digital image

Both: immediate readout · high DQE · resolution comparable to CR · (variant: scintillator + optics + CCD)

Straight line vs S-curve: exposure latitude



**Too little exposure
→ grain (noise) shows**

**Too much exposure
→ looks fine, dose is hidden**

Digital dynamic range $\approx 10,000 : 1$; film's useful latitude is far narrower.

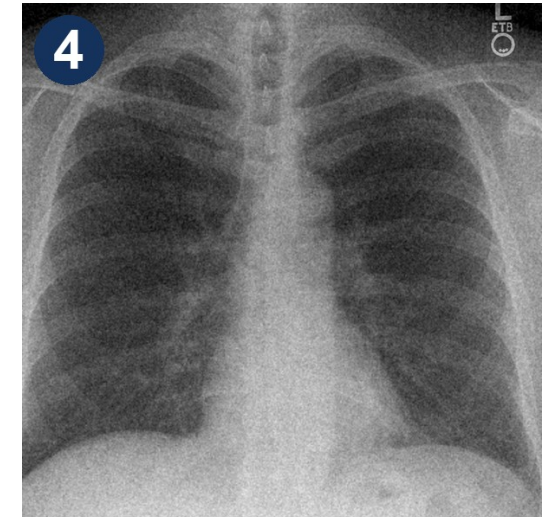
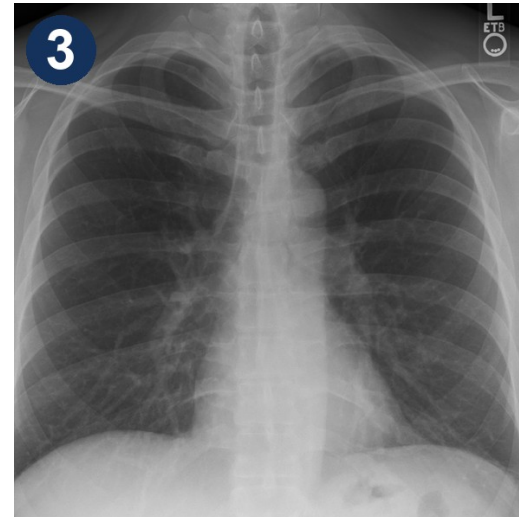
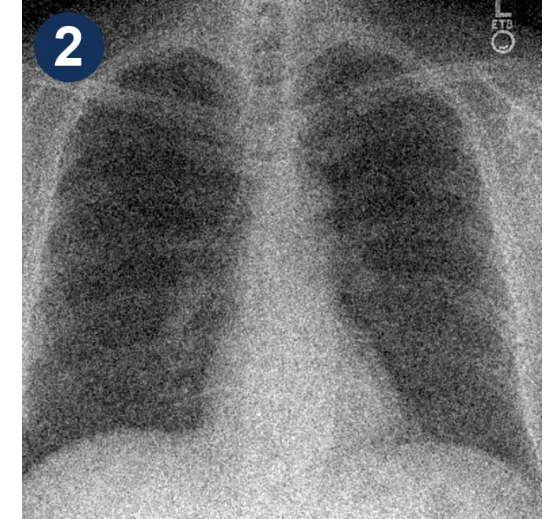
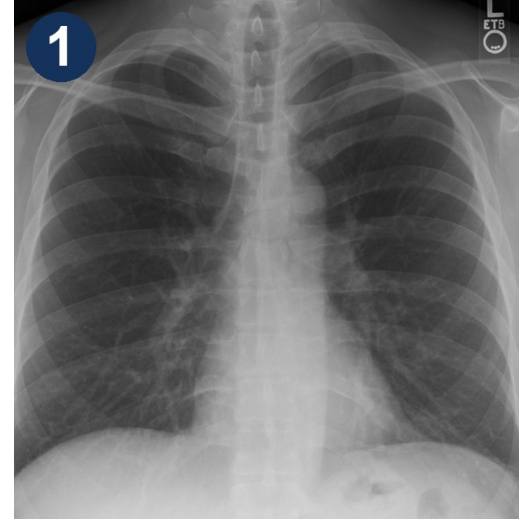
So how good are your eyes at judging exposure?

Activity 1: the Radiologist Eye Test

ACTIVITY 1 · 1 min

- Four chest X-rays: same patient, different dose.
- Hold up 1–4 fingers: which got the LOWEST dose?
- Now: which got the HIGHEST?

Open [DR_Lab.html](#) → tab 2 “Warm-up”



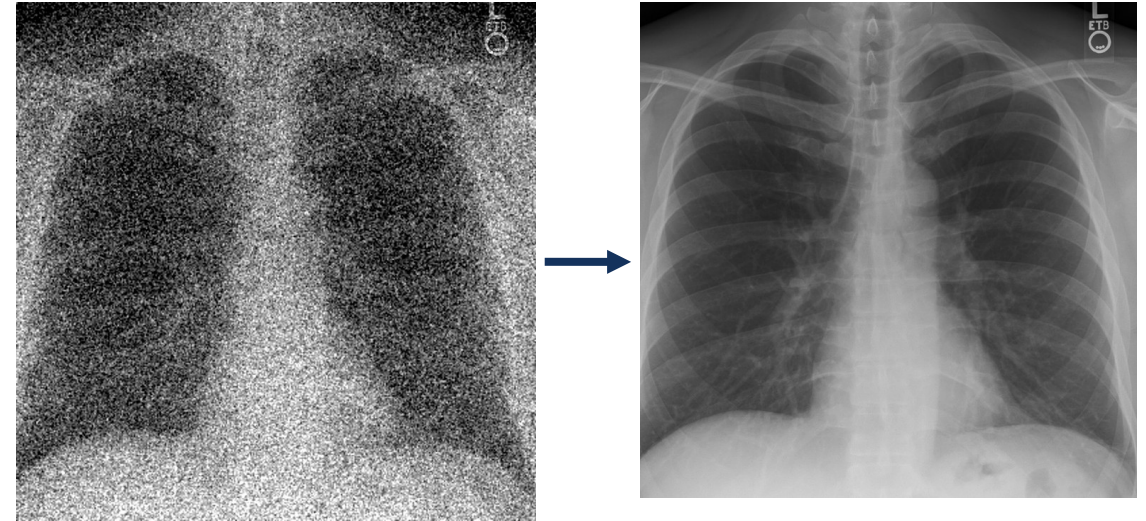
Activity 2: X-ray Blackjack

ACTIVITY 2 · 3 min

30 s per turn · 3:00 total

- 1 Both teams start from the same grainy image.
- 2 Each turn: play a $\times$ card. It multiplies your last scan, so cards chain.
- 3 Order: first team once, then the other twice in a row, then alternate (L R R L R L R L). No copying: not the card your opponent just played.
- 4 4 scans each, or STAND (timeout = STAND). Last image counts.

$$\text{Score} = \text{Quality} \times 2 - \text{Dose}$$



Start: both teams

Ideal



Cards chain on your last scan

start

1

play $\times 6$

$= 6 \times \text{start}$

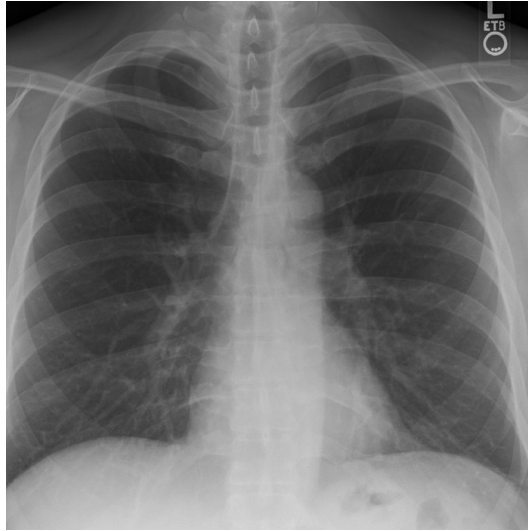
then $\times 1.5$

$= 9 \times \text{start}$

The number your eyes can't see: EI, DI and dose creep



1× · DI 0.0



3× · DI +4.8

Both look right. Only the DI shows who gave 3× the exposure.

$$DI = 10 \cdot \log_{10} (EI / EI_t)$$

EI: standardized detector-exposure number (not patient dose).

EI_t: target for the exam. +3 ≈ 2× exposure · -3 ≈ ½×

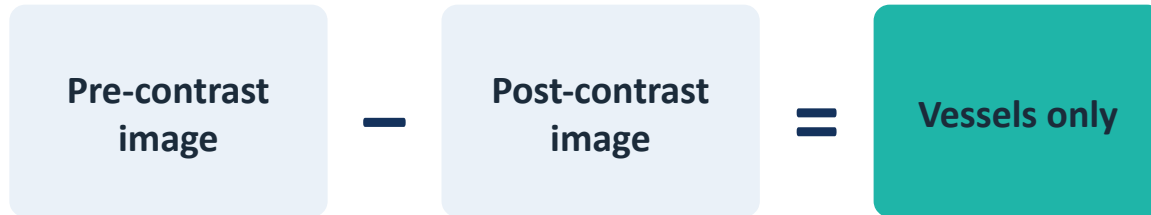


Dose creep: exposures drift upward because over-exposed digital images look fine.

ALARA: read the number, not just the image

Beyond the chest X-ray: fluoroscopy and mammography

Digital fluoroscopy and DSA



- Real-time moving images (GI tract, vessels)
- Image intensifier + TV/CCD → ADC
- Subtraction: temporal (in time) or energy (two kVp)

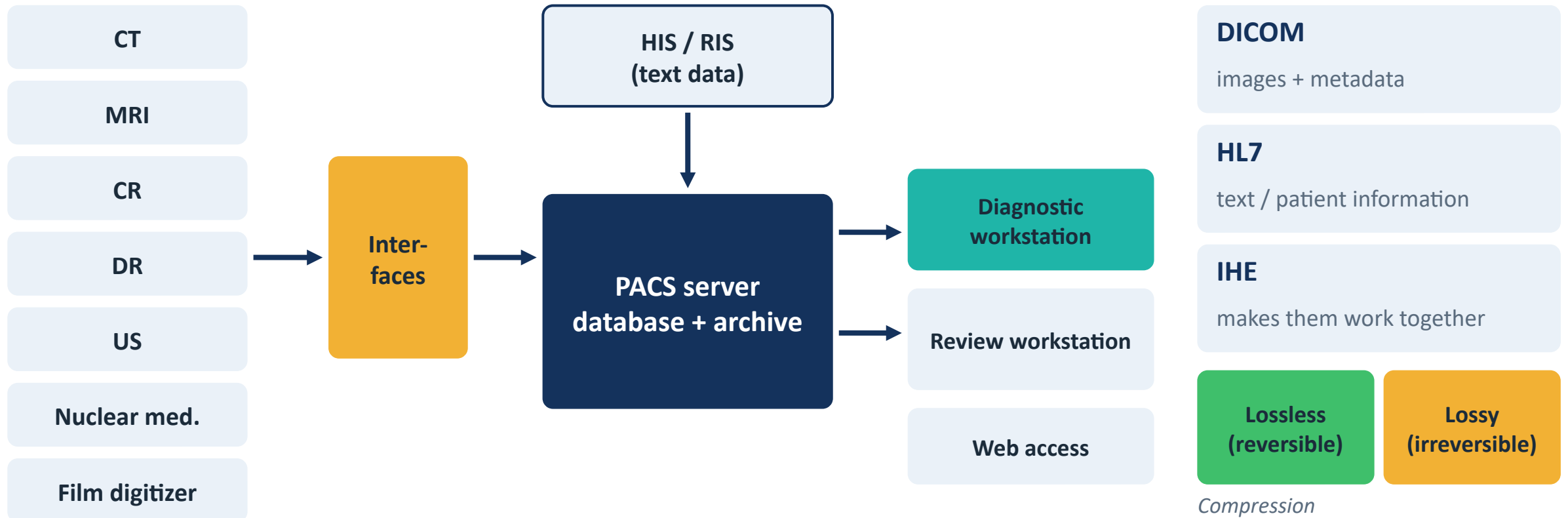
Digital mammography



- Digital post-processing to enhance interpretation
- CAD = “second reader” for microcalcifications and masses
- Leads to digital tomosynthesis

Digital tools: process, subtract and flag, after the exposure

PACS: the department's backbone



Next era: enterprise imaging · cloud · Big Data (volume, variety, velocity, veracity) · machine / deep learning · AI

Quality assurance and take-home

1

Film = detector + display + archive in one, with narrow latitude.

2

DR splits them: detector (CR / indirect / direct) → computer → display → PACS.

3

Wide latitude hides overexposure: read the EI / DI, not just the image.

QA / QC aims

Minimum dose (ALARA)

Optimum image quality for diagnosis

Lower the cost of radiology operations

The technologist of the future is also an informaticist

References and AI declaration

- Seeram E. Digital Radiography: Physical Principles and Quality Control. 2nd ed. Springer; 2019. Ch. 1. doi:10.1007/978-981-13-3244-9_1 (primary source)
- Seibert JA. Dose metrics: exposure index (summary of AAPM TG-116 / IEC 62494-1). IUPESM teaching slides, 2015.
- Leblans P, et al. Storage phosphors for medical imaging. Materials 2011;4:1034-86 (PMC5448636).
- AAPM Report No. 116. An exposure indicator for digital radiography. 2009.
- IEC 62494-1:2008. Exposure index of digital X-ray imaging systems.
- Chest radiograph: "Chest Xray PA 3-8-2010.png", Stillwaterising, Wikimedia Commons, CC0 1.0. All exposure/film simulations were generated by the group from it.

AI declaration: Claude (Anthropic) assisted with planning, game design, scripting and slide drafting. The group checked all content against Seeram (2019) and the references above, and re-derived the game scores by simulation.