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Joint ICTP/IAEA Advanced School on Dosimetry in Diagnostic Radiology and its Clinical Implementation

11 - 15 May 2009

Introduction to Radiological Dosimetry

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And its Clinical Implementation
11 - 15 May 2009; Miramare, Trieste, Italy

Introduction to Radiological Dosimetry

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Diagnostic Radiology : in the beginning…

- German physicist -Roentgen , 1885
- Discovered an "invisible light" or ray capable of passing through heavy paper
- This ‘X-ray’ would pass through most substances casting shadows of solid objects on pieces of film

- X-rays would pass through the tissue of humans leaving the bones and metals visible
- Used clinically in US from 1896

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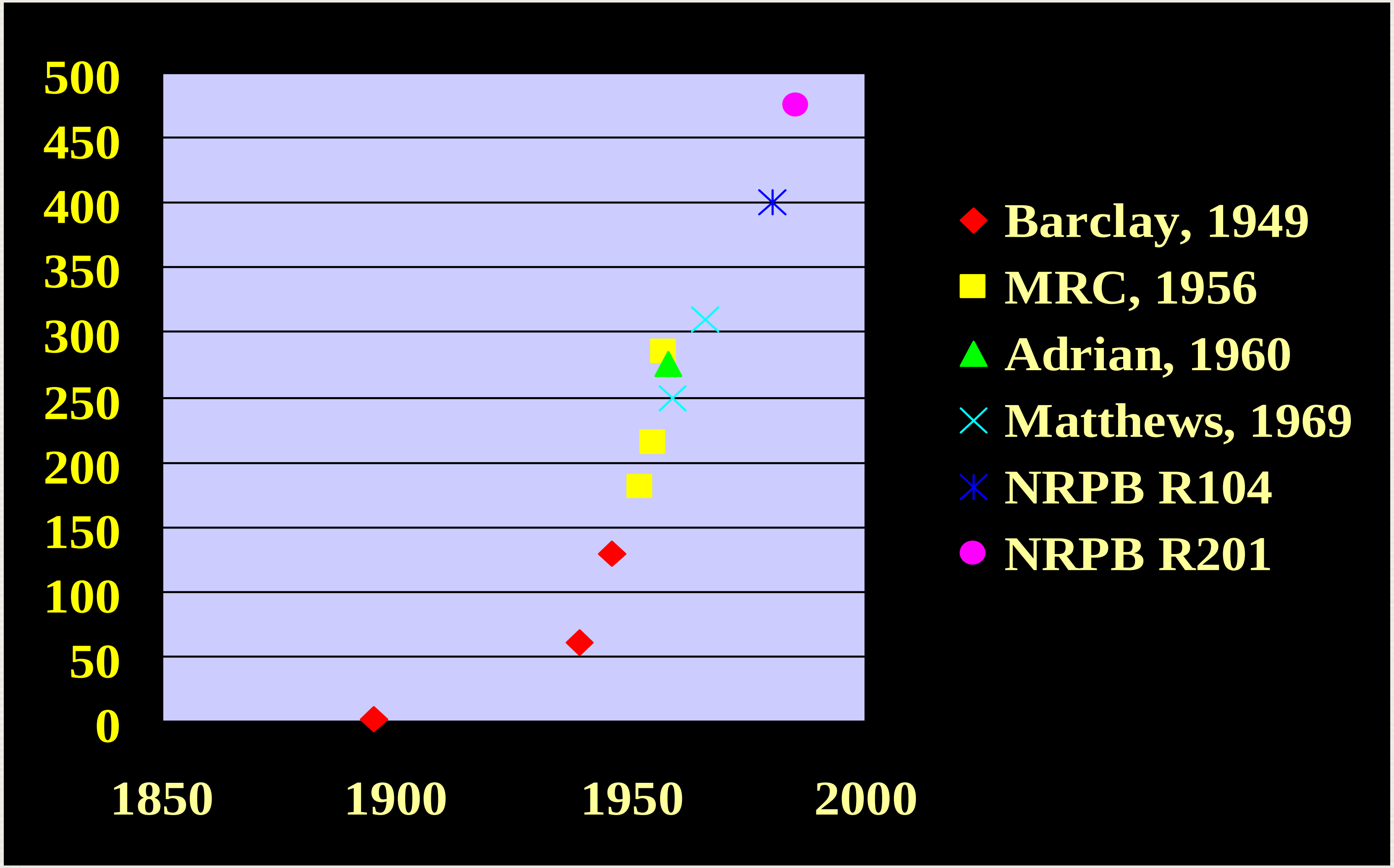
Annual X-ray examinations in Britain per thousand population (excluding mass surveys)



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Global X-ray figures

- In 2000 : 360 examinations / 1000 people
- 1991-1995 : 330 exams / 1000 people

- 75% examinations in countries with Healthcare Level I
- 1% examinations in countries with Healthcare Level III & IV

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Developments in diagnostic radiology

- Screen-film radiography
- Fluoroscopy
- Computed tomography
- Digital fluorography
- Computed radiography
- Direct digital radiography

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Screen-film radiography

- Projection radiography
- Fixed X-ray beam
- Attenuated through patient
- Detected by screens $\Rightarrow$ light photons
- Light detected by film $\Rightarrow$ image (2D)
- Films can be displayed / transported / stored

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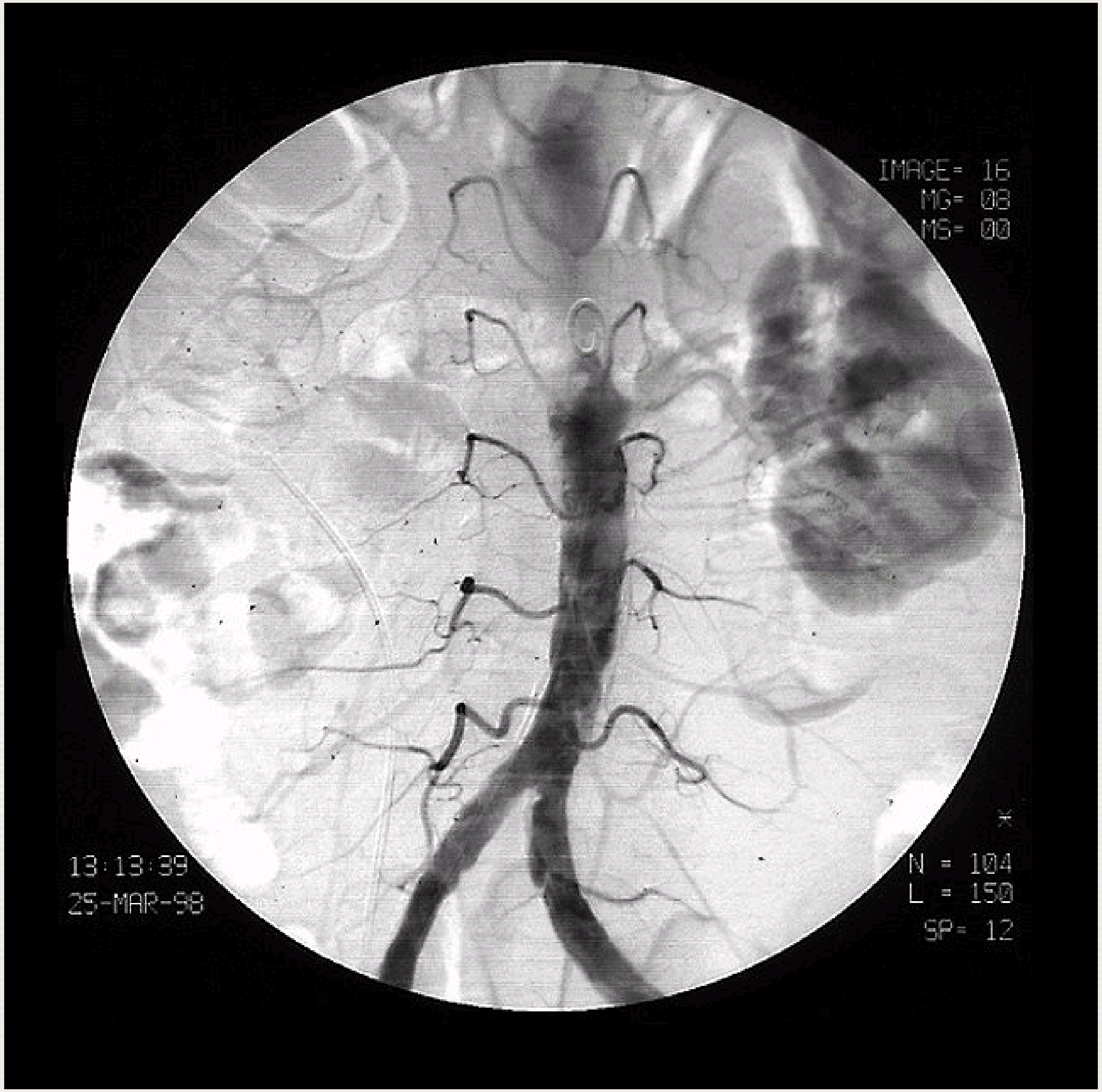
Fluoroscopy

- Allows real-time imaging
- Often uses contrast media for functional imaging
- Uses image intensifier
- Displays images on TV screen
- Can take ‘snapshot’ images for storage
- Specialist applications (cardiology, gastrointestinal etc.)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Computed Tomography

- Rotating fan beam of X-rays & detectors
- Computer reconstructs cross-sectional images (3D)
- Single slice $\Rightarrow$ multi slice
- Axial scanning $\Rightarrow$ helical scanning
- Real time imaging


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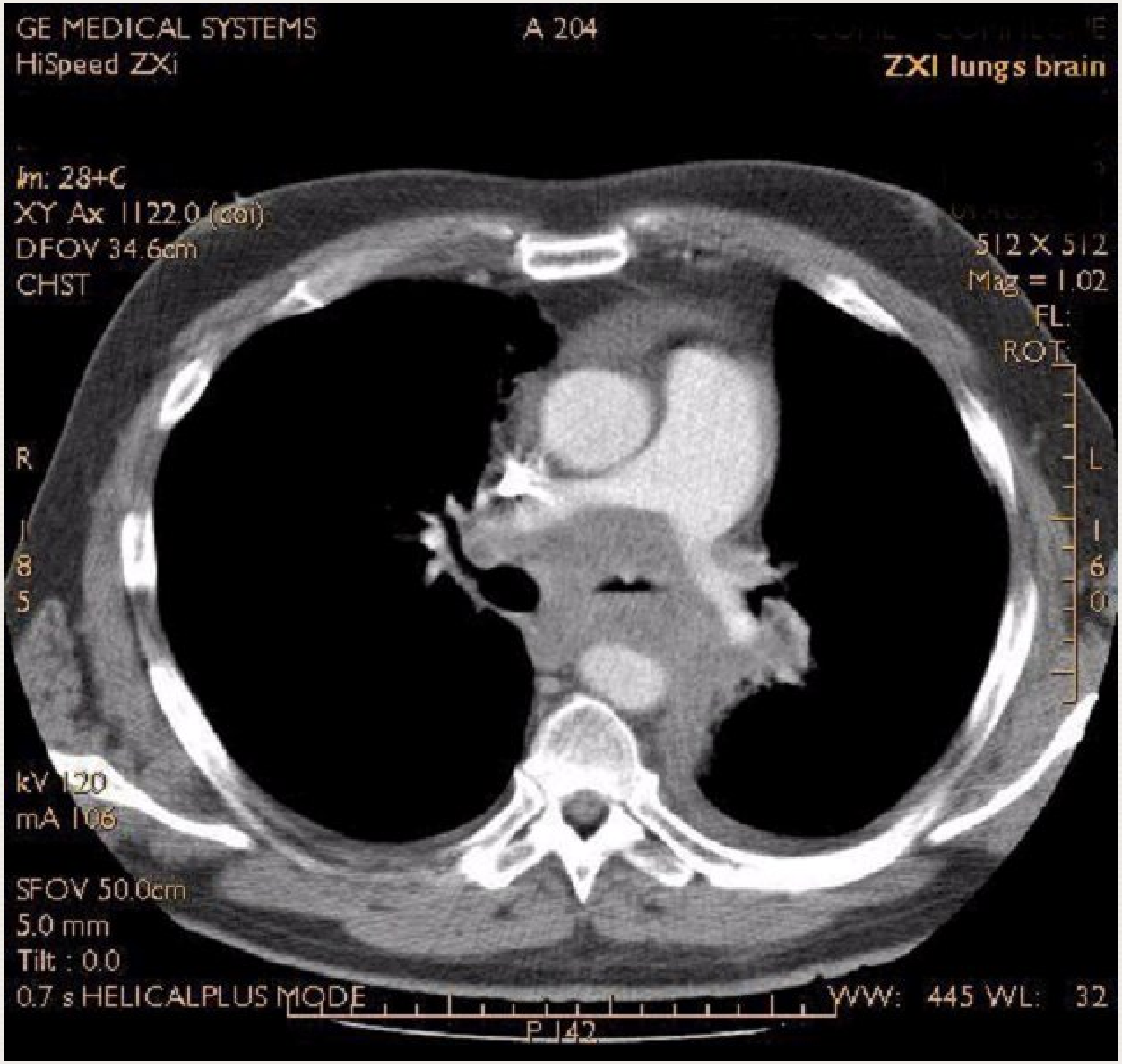
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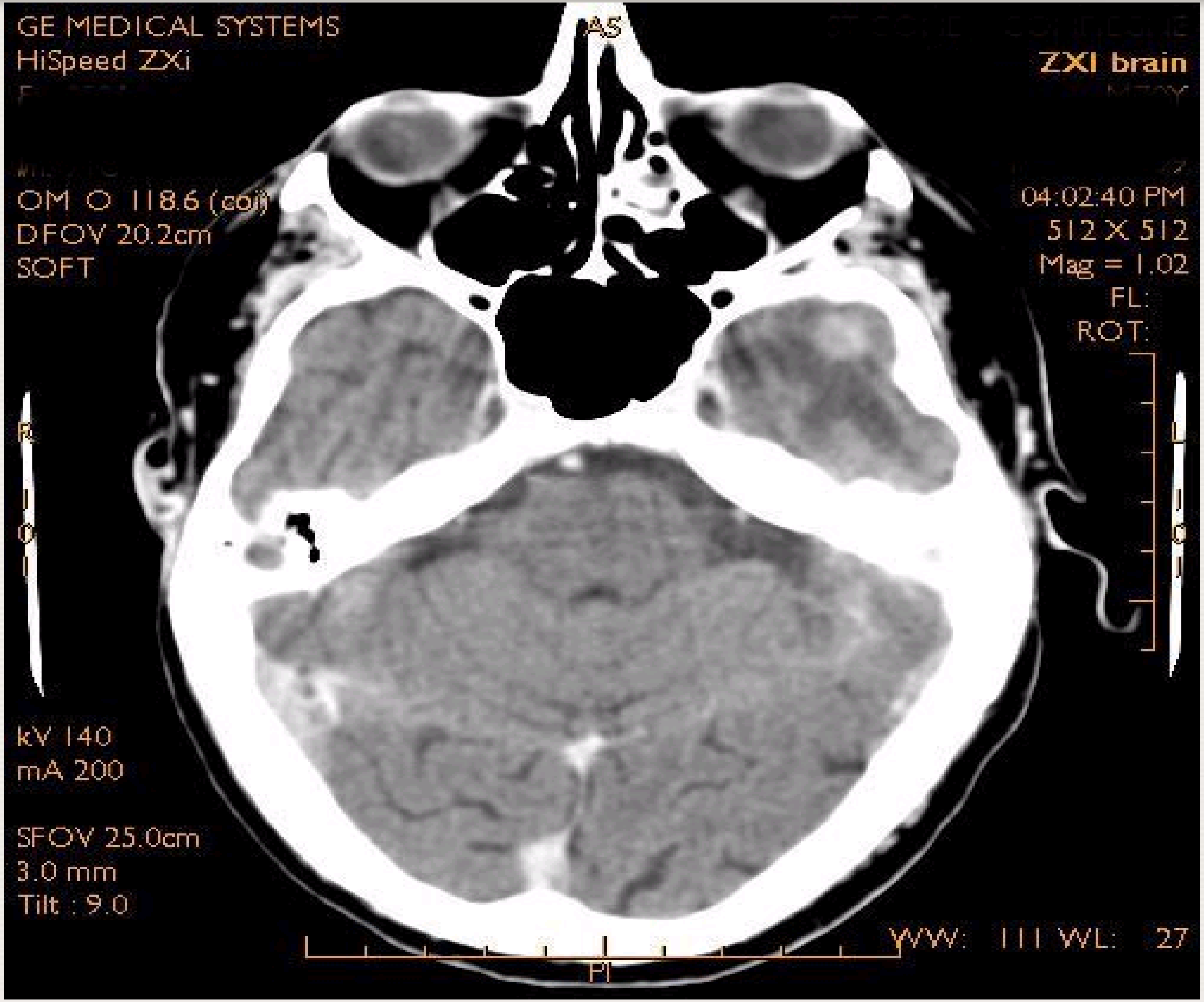
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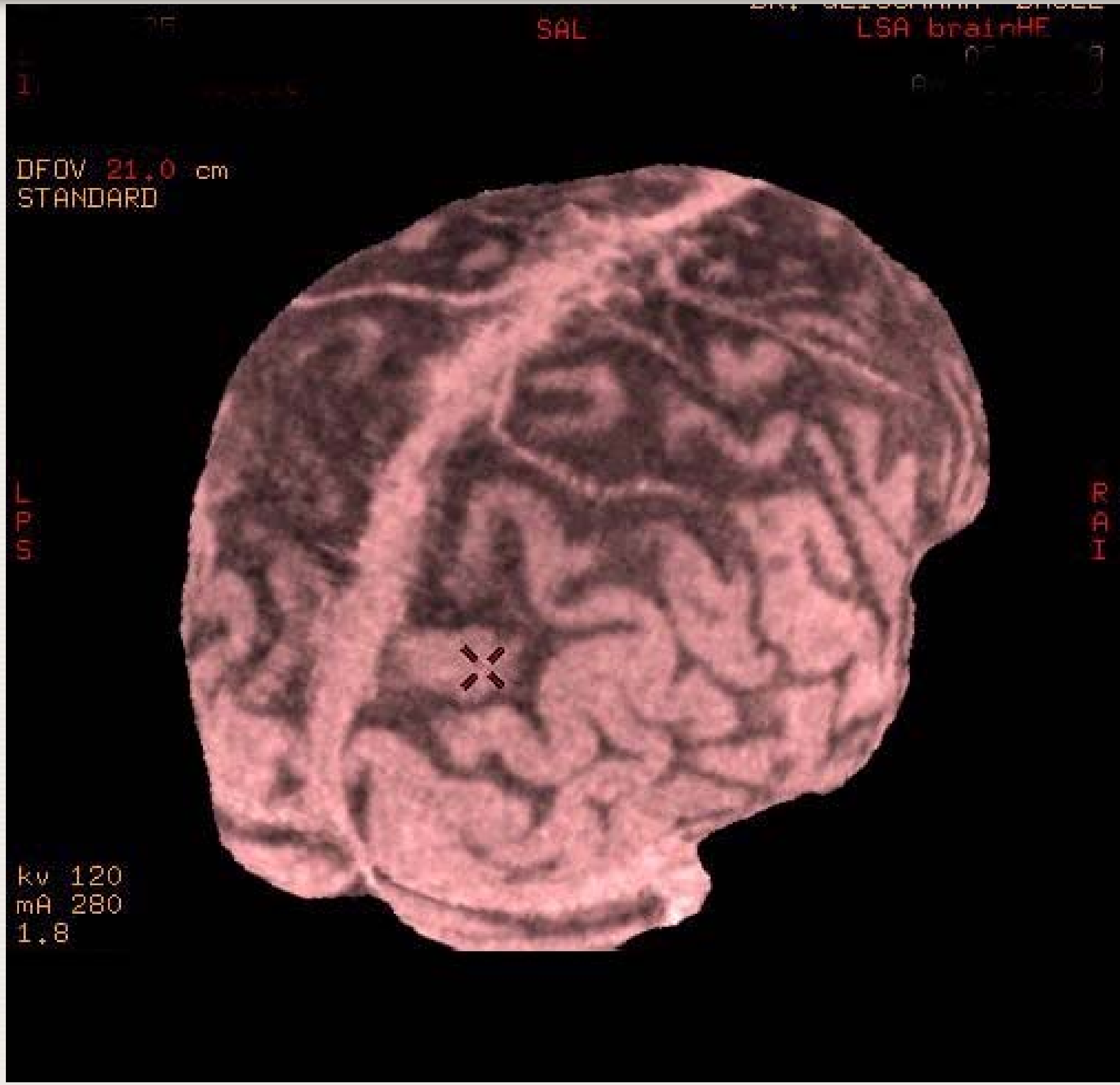

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Digital techniques

- Computed radiography (CR) – film replaced with storage phosphor plate
- Direct digital radiography (DDR) – active matrix detector converts directly to digital signal
- Interventional radiology now possible
- Improved image quality – What's happened to doses?

Radiation effects on humans

- Severe injury and death was an occupational hazard with early radiation workers
- Approx 300 fatalities in early workers
  (names on Hamburg monument)
- Becquerel developed tumours
- Marie Curie died of leukemia at 67

Roentgen ray pioneer Mihran Kassabian (1870-1910)

Radiation effects on humans

1. Stochastic effects

- Probability of effect occurring is proportional to dose (no threshold)
- Evidence: Japanese survivors, early radiologists, uranium miners, radium dial painters
- The stochastic effect of interest is carcinogenesis

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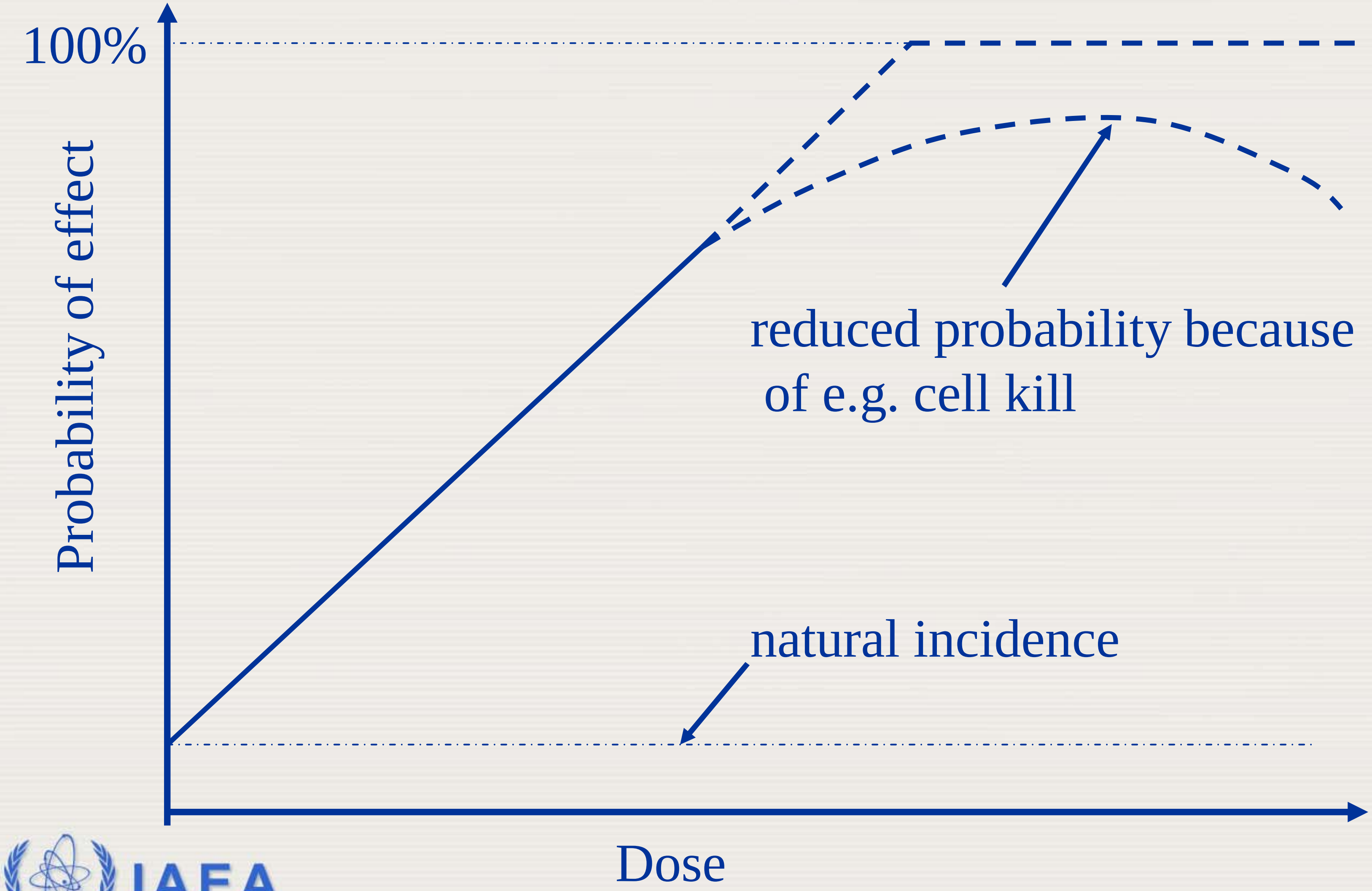
Stochastic effects



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Radiation effects on humans

2. Deterministic effects

- No effect below a threshold dose

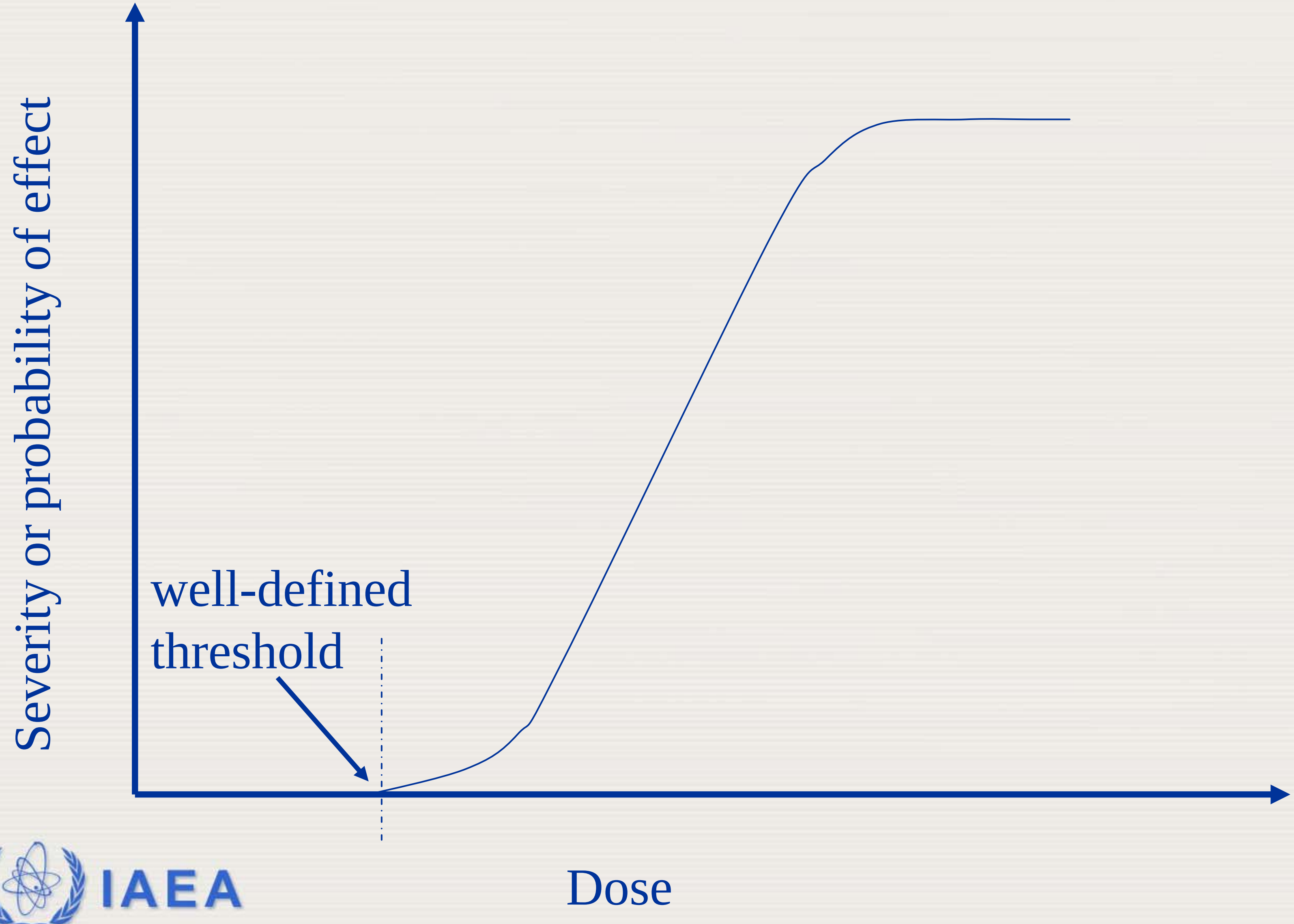
- Above threshold, severity of effect increases with dose

Carcinogenesis & deterministic effects are somatic effects – they affect the irradiated individual

Typical threshold doses for deterministic effects

Tissue & Effect	Threshold dose (brief exp) Gy
Testes	
Temporary sterility	0.15
Permanent sterility	3.5
Ovaries	
Sterility	2.5
Lens	
Opacities	0.5
Cataracts	2.0
Bone marrow	
Depression of haematopoiesis	0.5
Skin	
Erythema	2
Temporary epilation	3

Deterministic effects



Radiation effects on humans

3. Genetic damage

- chromosome damage – breakage followed by faulty repair
  no convincing evidence

Problems of genetic risk assessment

- only gonad exposure is relevant
- mutations may be recessive
- mutations may be unstable

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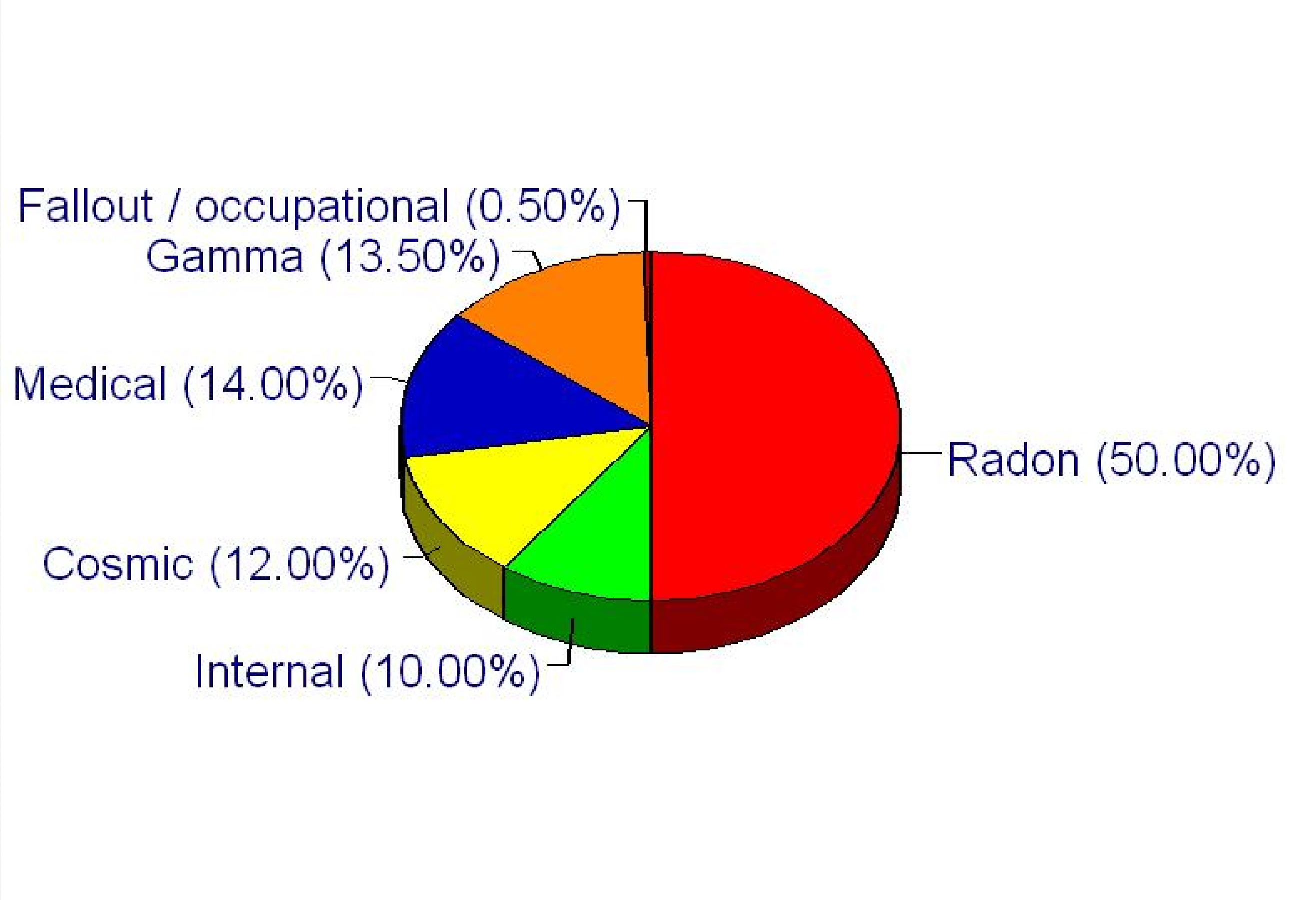
Relative contributions to UK population dose



Per caput doses from medical irradiation

• USA	3 mSv
• UK	0.4 mSv

Relative contribution to UK frequency and collective dose

Examination	% Frequency	% Collective dose
Computed tomography	2.0	20
Lumbar spine	3.3	15
Barium enema	0.9	14
Barium meal	1.6	13
Intravenous urography	1.3	11
Abdomen	2.9	8
Pelvis	2.9	6
Chest	24	2
Limbs & joints	25	1.5
Skull	5.6	1.5
Thoracic spine	0.9	1
Dental	25	1

Typical dose levels

- Projection radiography : 1-20 mGy
- CT : 10-100 mGy
- Fluoroscopy dose rates : 0.02-0.2 Gy/min

Quality assurance

- Diagnostic image quality required with as low as dose as possible
- Framework provided by WHO & BSS
- Includes
  - Measurement of physical X-ray parameters
  - Image quality assessment
  - Dose assessment
- BSS requires guidance levels for achievable doses
- EU requires diagnostic reference levels

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Two good reasons for dosimetry in x-ray diagnostics

- A tool for setting up and control of standards of a good practice
    - Quantities should be easy to measure
- A tool for estimation of radiation detriment and injury
    - Quantities should have a direct link to potential risk from the exposure

Two pillars of dosimetry in diagnostics

- Clinical needs
  - Correct diagnosis is the main goal of any x-ray examination
  - Need to protect a patient
  - Balancing between necessary dose and quality of image (important role of medical physicists)
- International system of measurements
  - Mechanism for consistency in radiation dosimetry (role of SSDLs)

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Historical problems of dosimetry in x-ray diagnostics

- General radiography
  - Backscattered radiation included or not?
  - Absorbed dose or air kerma?
  - Material in which the measured quantity is specified (air, PMMA, water, tissue)
  - Same symbols used for different quantities (ESD)?
  - Different names used for the same quantity
- Similar problems occur for other modalities

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ICRU and IAEA documents

- Patient dosimetry for x rays used in medical imaging
  - ICRU Report 74, published in 2005
- Dosimetry in diagnostic radiology: an international code of practice
  - IAEA Technical Reports Series No 457, 2007