Introduction to possible bioeffects and safety concerns in medical imaging

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Objectives

To let the learner be able:

- to identify the possible effects that arises from use of the various types of energy to the human body
- to distinguish between the two effects of exposure to ionizing radiation
- familiarize themselves to the safety measures applied in diagnostic imaging

Introduction

1. Ionizing Vs Non- ionizing radiation

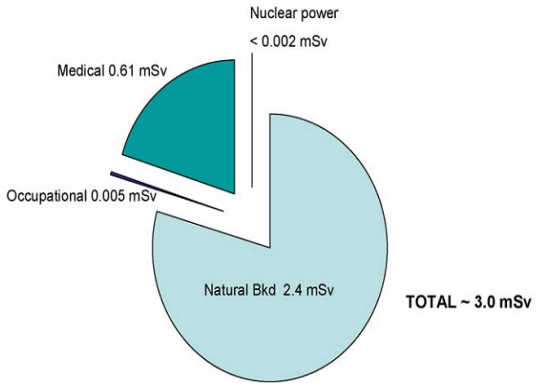
- Ionizing radiations include:
  - x-rays and gamma rays (photons)
  - charged particles (electrons, protons, alpha particles)
  - neutrons
- Non-ionizing radiation include:
  - Ultrasound
  - Optical radiation
  - Radiowaves

2. Sources of ionizing radiation

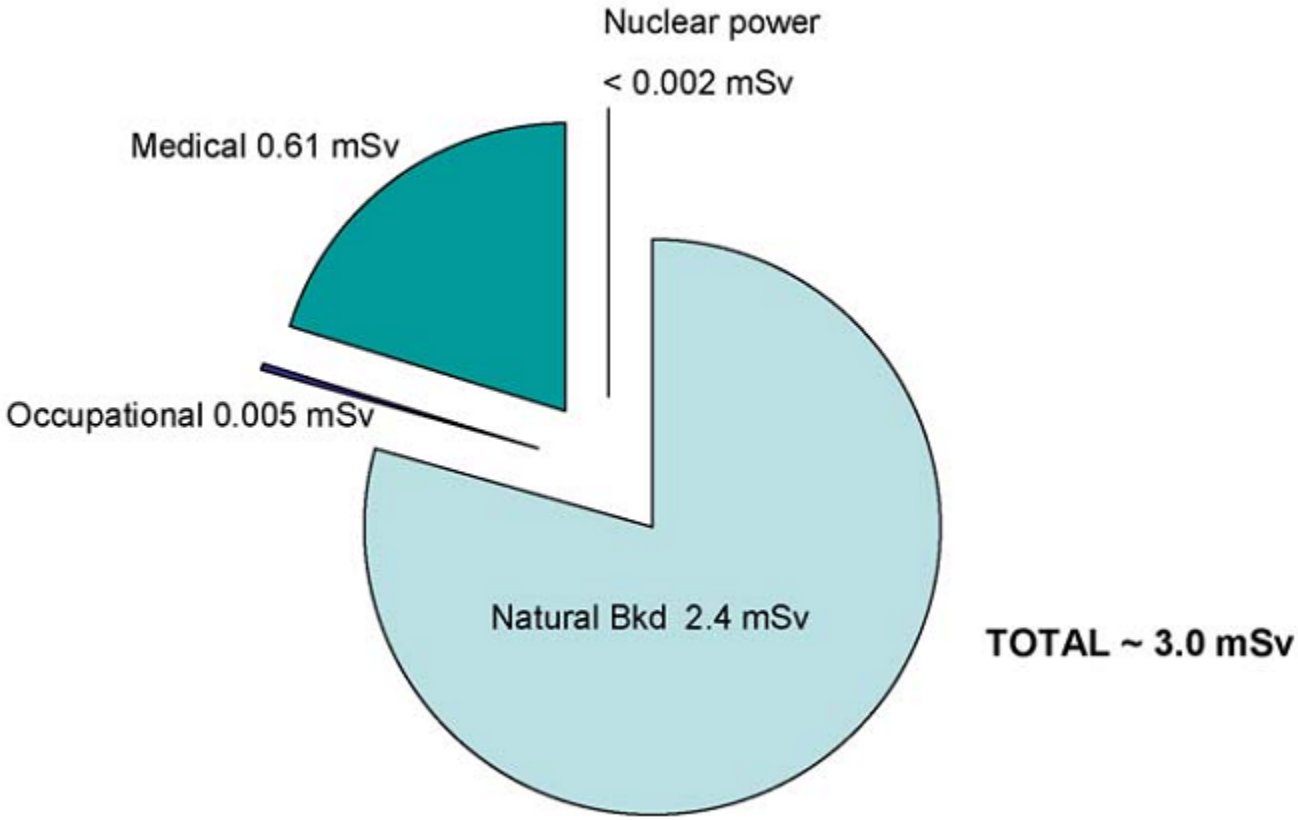
- Natural sources include:
  - Cosmic radiation from outer space
  - Terrestrial radiation in soil, rocks, water

  (these sources constitute natural background)

- Artificial sources:
  - All man-made radiation



Estimated per caput effective dose to the world's population in 2007



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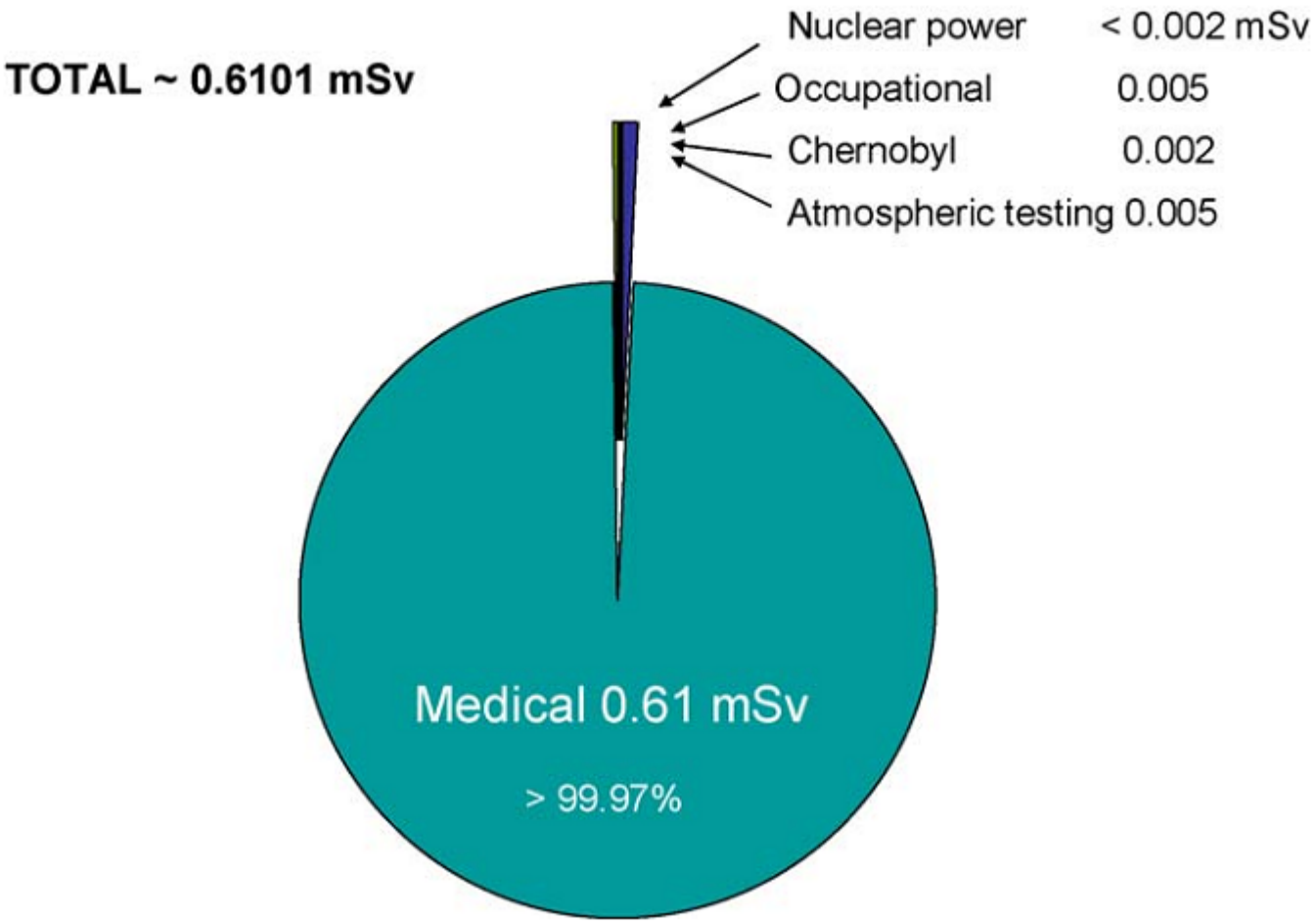
3. Exposure of populations

- Most important source is natural background
- From artificial sources, medical exposure is most important
- Within medical exposure, X-ray diagnosis is the leading contributor

4. Modalities of Exposure

- External exposure
- Internal exposure

Estimated per caput effective dose to the worlds population in 2007 from man-made exposures



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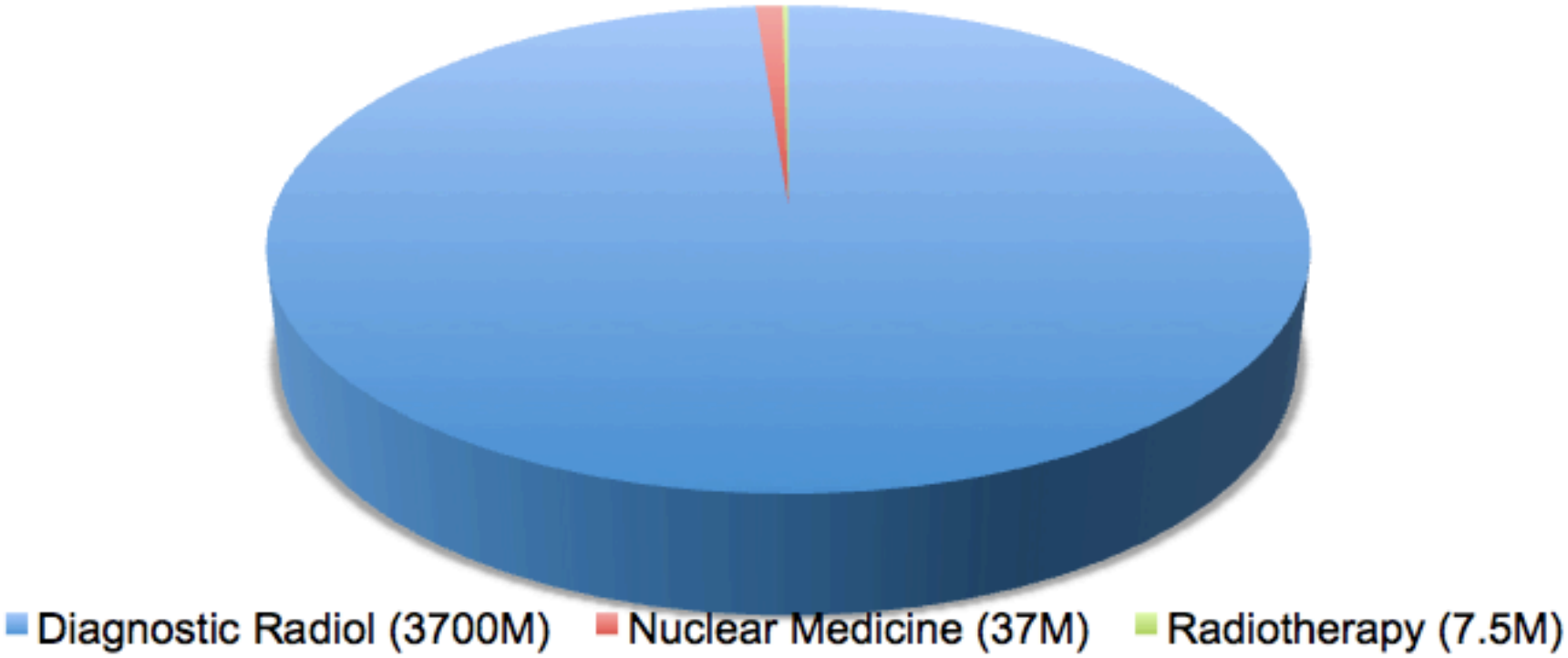
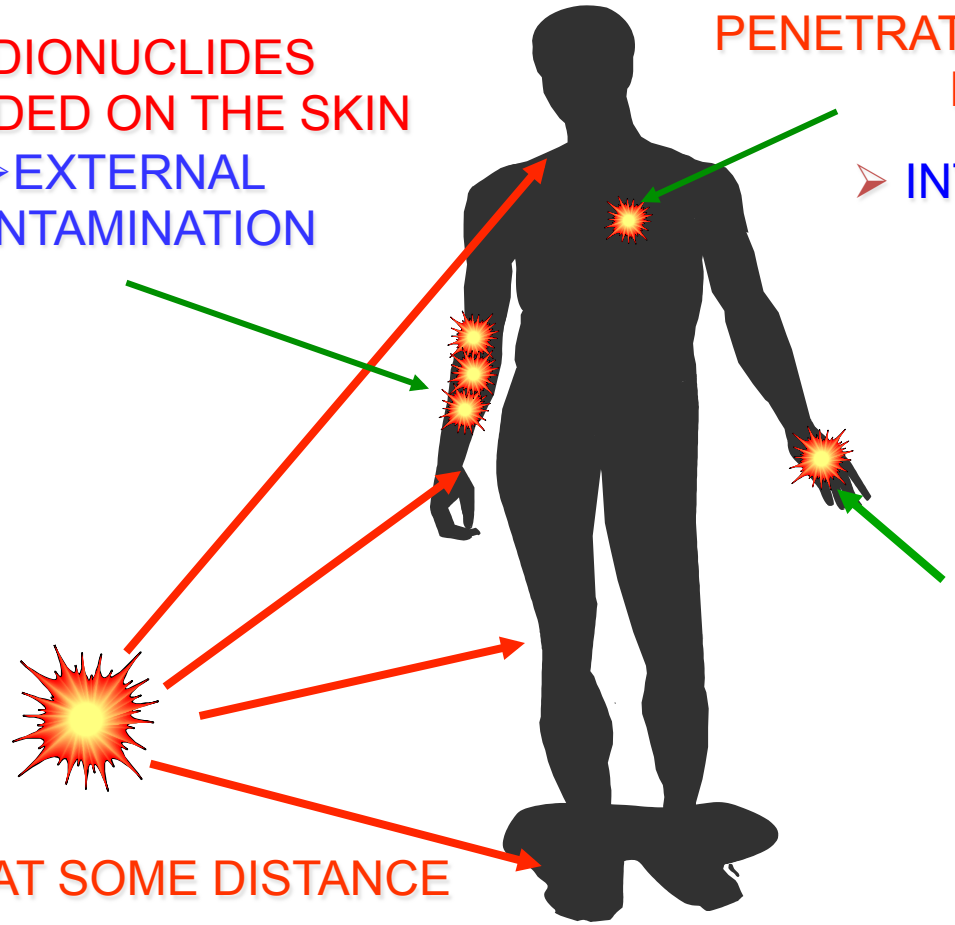
Annual global distribution of medical procedures that use ionizing radiation



http://www.who.int/mediacentre/factsheets/fs371/en/

Potential effects of radioactive materials



RADIONUCLIDES SPREADED ON THE SKIN

➢EXTERNAL CONTAMINATION

PENETRATION OF RADIO-NUCLIDES INTO THE BODY

➢ INTERNAL EXPOSURE

SOURCE ON THE SKIN

➢ SKIN EXPOSURE

SOURCE AT SOME DISTANCE

➢ IRRADIATION (external exposure)

5. Biological effects of ionizing radiation

- Evidence exists for biological effects
- Effects at cellular level include:
  - Cell killing
  - Mutations
  - Loss of proliferative capacity
- Cellular effects may affect organ/ tissue function
- Effects on organism, including possible death

6. Classification of radiation effects

- Acute vs Delayed
- Somatic, Hereditary or Foetal/ Embryonic
- Tissue reactions (deterministic) vs Stochastic

7. Radiation effects

Tissue reactions

- Have a threshold dose below which they do not occur
- Severity is dose-dependent
- (erythema, tissue necrosis, cataract, syndromes)

Stochastic effects

- Have no threshold dose
- Probability of occurrence depends on dose
- Severity is independent of dose
- (cancer, leukaemia)

8. Implications

- no amount of radiation exposure (no matter how little) is completely safe
- even very low doses of radiation may induce severe health detriment (carcinogenesis and hereditary effects are stochastic)
- all unnecessary exposures to ionizing radiation should be avoided (principle of justification)
- All necessary exposures to radiation should be kept As Low As Reasonable Achievable (ALARA principle)

9. Aims of radiation protection

- prevent the occurrence of tissue reactions
- limit the probability of occurrence of stochastic effects

• Philosophy of radiation protection

- justification of practices
- optimization of procedures
- dose limitation

10. Categories of radiation exposure

- Occupational exposure
- Medical exposure
- Public exposure

11. Medical Exposure

- exposure of patients during diagnostic or therapeutic procedures, based on medical decisions
- includes exposure from artificial body implants emitting ionizing radiation
- when radiation workers are exposed as patients, that component of exposure is classified as medical exposure
- no dose limits prescribed for medical exposure
- however, ALARA principle applies
  - guidance dose levels should be noted
- Radiation dose monitoring not done on a routine basis

- Strategies
  - clinical judgement (necessity of examination)
  - trained personnel
  - radiological equipment in good condition
    - performance specifications
    - maintenance
    - quality assurance programmes
  - sensitive image receptors
  - adequate preparation, proper instruction, of patient
  - Proper performance of examination
    - Positioning, views, exposure factors, limitation of beam size, gonad shields, etc

- Proper image processing practice (e.g. film)
- Through quality control programmes, minimize repeat examinations
- Consider alternatives to use x-rays when appropriate, e.g. ultrasound

Sensitive patient groups

- children
- the pregnant female

12. Safety in diagnostic ultrasound

- biological effects observed with animal experimentation using very high intensities of ultrasound
- biological effects may be due to:
  - tissue temperature elevation
  - formation of bubbles in liquids
- diagnostic ultrasound employs beam intensities well below the thresholds for observed effects
- diagnostic ultrasound is considered to be a safe method of medical imaging, with a wide margin of safety

13. Safety in MRI

- Risk of biological effects considered remote
- The environment around powerful magnets presents some risks to patients, relatives, and staff
  - Attraction of objects into magnet
  - Rapid evaporation of cryogens
- Restricted access (0.5 mT) if necessary , monitor entrants
- Warning signs and symbols
- Screening of patients
- Pre-exam instructions

- Design with faraday cage
  - Confines high magnetic field to restricted zone
  - Keeps out extraneous sources of e.m. fields
- Design to facilitate escape route in case of cryogen boil-off
- Staff awareness and good practice

Examples of some of health effects as a consequence of exposure to ionizing radiation

Handling of radioactive materials/ sources

Skin necrosis, underlying tissue from overexposed during cardiac catheterization procedure

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References

1. International Commission on Radiological Protection (ICRP) Publication 103

2. The Essential Physics of Medical Imaging, Bushberg *et al*, 2012

3. Holmberg et al. European Journal of Radiology 76 (2010) 6–10
4. www.who.int/mediacentre/factsheets/fs371/en/