Minimizing Risks from Radiation and Trace Gases

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Objectives

- Review the types of radiation
- Discuss how exposure is measured and what levels of radiation are dangerous
- Consider the risk to anesthesia providers
- Discuss the risk to pregnant women
- Consider protective strategies
- Review the occupational hazards of inhalational anesthetics

What is Radiation?

Radiation is energy transmitted through space in the form of electromagnetic waves or energetic particles

Sources of Radiation

- ½ average dose comes from natural background sources:
  - cosmic radiation from space
  - naturally occurring radioactive minerals in the ground and body
  - radon and thoron (created when other naturally occurring elements undergo radioactive decay)
- The other ½ comes from medical diagnostics and treatments
Types of Ionizing Radiation

- Ionizing Radiation
  - High energy radiation that is potent enough to remove electrons from the orbit of an atom causing the particle to become charged or ionized

  A. Particulate
     1. alpha
     2. beta – produced by radioactive decay

  B. Electromagnetic (short wave length, high frequency)
     1. X rays
     2. Gamma

- Alpha Particles
  - certain radionuclides
    - Ra226, U238, Pu239
  - radioactive decay causes release of 2 protons and 2 neutrons (positive charge)
  - health effects depend upon exposure
    - alpha particles lack energy to penetrate outer dead layer of skin
    - if inhaled, ingested, or absorbed can cause cancer
  - greatest exposure to alpha radiation comes from inhalation of radon and its decay products
    - lung cancer
Beta Particles

- high speed electron
- nucleus with an unstable ratio of neutrons to protons decays through the emission of a high speed electron (negative charge)
- I\textsuperscript{131} - people who have taken radioactive iodine will emit beta particles

Gamma Rays

- nucleus which in an excited state may emit one or more photons (packets of electromagnetic radiation)
- nucleus moved from a higher to a lower energy state (unstable to stable)
- gamma ray emission frequently follows beta decay, alpha decay, and other nuclear decay processes
- Co\textsuperscript{60} use in gamma knife radiation

Penetration of Particles and Rays

X-rays: Typically Man Made
Distance is Protective

- “Inverse Square Law”
- Amount of radiation passing through a specific area is inversely proportional to the square of the distance from the source
- When you double your distance from the source, you get $\frac{1}{4}$ as much radiation

Dose Calculations

- Equivalent and Effective Dose Calculations
  - Calculated from quantities that can be measured with personal dosimeters
- **Equivalent Dose** (SI unit = Sievert = Sv) = mean absorbed dose in a tissue or organ (SI unit = Gray = Gy) multiplied by a radiation weighting factor (wR)
  - For diagnostic radiography, wR = 1 so the tissue dose and the equivalent dose are equal
- **Effective Dose** = the weighted sum of the equivalent doses in all specified tissues and organs
  - Units:
    - 1 Sievert = 100 Rem or 0.01 Sieverts = 1 rem
    - 0.1 mSv = 1 mRem
    - 0.01 Gy = 1 rad

Maximum Safe Doses

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Recommended dose limits for occupational exposure in x-ray imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose quantity</td>
<td>Occupational dose limit*</td>
</tr>
<tr>
<td>Effective dose</td>
<td>20 mSv/year averaged over 5 consecutive years (100 mSv in 5 years), and 50 mSv in any single year</td>
</tr>
<tr>
<td>Equivalent dose in Ocular lens</td>
<td>150 mSv/year</td>
</tr>
<tr>
<td>Skin</td>
<td>500 mSv/year</td>
</tr>
<tr>
<td>Hands and feet</td>
<td>500 mSv/year</td>
</tr>
</tbody>
</table>

ICRP, International Commission on Radiological Protection. Adapted from ICRP [8].
*These limits can be different in national regulations.
This limit is currently being reviewed by an ICRP Task Group.
*Average over 1 cm$^2$ of the most highly irradiated area of the skin.

Curr Op Anes 2011,24:445-450

Radiation Exposure

- Average exposure in US: **360 mRem/year**
- Transoceanic flight 10 hours: **3-5 mRem**
- Interventional cardiologist at a high volume center: ~**600 mRem/year**
- Chest Xray: delivers 6 to 11 mRem
- CT Scan: about **700 mRem**
Stochastic versus Non-Stochastic Effects of Radiation

- Stochastic Effects: (refers to the likelihood that something will happen) associated with long term low level chronic exposure to radiation
  - Malignancy
  - DNA mutations
- Non-Stochastic Effects: appear in cases of exposure to high levels of radiation, and become more severe as the exposure increases
  - Burns
  - Radiation Sickness

What is Our Risk in Health Care?

- Difficult to assess, given that 1/4 - 1/3 of the population in western countries develops cancer at some point in their lifetime
- Hard to attribute small increase in cancer risk to small increase in ionizing radiation exposure

Cancer Risks among Radiologists and Radiologic Technologists: Review of Epidemiologic Studies

- Authors reviewed data on cancer risks from 8 cohorts of over 270,000 radiologists and technologists in various countries from 1920-1980’s
- High radiation exposure among early medical workers led to excess risk of leukemia and cancers of skin and breast
- No excess cancer risk among recent workers
- Improvements in protection has led to reductions

Yoshinaga et al; Radiology 2004
Radiation Exposure to Anesthesia Personnel: The Impact of an Electrophysiology Laboratory

- 330 bed community hospital
- Study designed to examine the change in radiation exposure absorbed by anesthesia care providers in one department after the introduction of an electrophysiology lab
- Anesthesia providers wore standard lead aprons and thyroid collars; a lead lined screen was placed between the source of radiation and the provider
- Each provider was given a dosimeter; the dosimeter was analyzed monthly
- PRE total radiation exposure = 503 mrem and POST total radiation exposure = 1006 mrem

Radiation Exposure of the Anesthesiologist in the Neurointerventional Suite

Background:
- scatter radiation during interventional procedures can produce cataracts
- standard safety equipment for the radiologist includes leaded eye protection
- typical configuration directs radiation scatter away from the radiologist

Methods:
- radiation exposure to the forehead of the anesthesiologist and radiologist were measured during 31 adult neuroradiologic procedures involving the head and neck

Results:
- exposure 6-fold greater than for noninterventional angiographic procedures
- exposure to the anesthesia provider’s face was more than 3-fold the exposure of the radiologist
- exposure of the anesthesiologist correlated with the number of pharmacologic interventions and total exposure of the radiologist

Distribution of scatter from a lateral x-ray source
- higher concentrations on side with source
Radiation Exposure of the Anesthesiologist in the Neurointerventional Suite

Conclusions:
• Current guidelines for occupational radiation exposure to the eye are undergoing review and are likely to be lowered (below the current 100-150 mSv/yr limit)
• Anesthesia providers who spend significant time in neurointerventional radiology suites may have ocular radiation exposure approaching radiologists
• To ensure parity with safety standards of radiologists, these anesthesia providers should wear protective eyewear

Anastasian et al: Anesthesiology: V 114 N0 3 2011

Radiation Safety for Anesthesiologists

• Review article looking at recent literature on the implications of occupational radiation exposure in anesthesia practice
• Eyes are likely the most sensitive organ and may be subject to stochastic effect → use eye protection at all times
• What about pregnant anesthesia providers?

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What are the Risks in Pregnancy?

First Trimester Radiation Exposure > 0.5 Gy

< 2 weeks – unknown
2 – 7 weeks – death, miscarriage, growth retardation and neuromuscular deficiencies
> 8 weeks – miscarriage, severe mental retardation, growth retardation of the body or skull, and brain and major malformations

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What are the Risks in Pregnancy?

• National Committee for Radiation Safety (NCRP) recommends occupational radiation exposure of fetus must not exceed 5 mSv (500 mrem) for the duration of the pregnancy or 0.5 mSv/month
• International Commission on Radiological Protection recommends a limit of < 1 mSv (more strict guidelines)
• Risk of induced miscarriages, cancer, or congenital malformations in embryos or fetuses exposed to doses of < 50 mGy (dose absorbed) is negligible
• The use of standard radiation protection techniques result in negligible risks to the fetus
• HOWEVER, most personnel choose to avoid radiation

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Radiation Safety for Anesthesiologists

• Modifiable Risk Factors
  – Duration
  – Distance
    → exposure minimal at a distance of > 36 inches
  – Barriers
    → structural shielding or mobile shields
    → equipment mounted leaded shielding (drapes)
    → personal: aprons, thyroid shields, eyewear, gloves

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Dosimeter Recommendation

• National Council of Radiation Protection Recommendation:
  – Combine the Hp10 values from both body and collar dosimeters to estimate effective dose:
    • \( E \) (estimate) = 0.5\( H_w \) + 0.025\( H_N \) where \( H_N \) is the reading from the dosimeter at the neck, outside the protective apron and \( H_w \) is the reading from the dosimeter at the waist or chest under the protective apron

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Personal Dosimeters

• Provides 2 values:
  – \( H_{p0.07} \) – equivalent dose in soft tissue at 0.07 mm below the surface of the body
    • \( H_{p0.07} \) from the collar dosimeter worn over protective garments provides a reasonable estimate of the dose delivered to the surface of the unshielded skin and the lens of the eye
  – \( H_{p10} \) – equivalent dose in soft tissue at 10 mm below the surface of the body

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Radiation Safety for Anesthesiologists

• Modifiable Risk Factors (continued)
  – Education
    → International Atomic Energy Agency (IAEA) material for diagnostic and IR
    → Multimedia and Audiovisual Radiation Protection Training in Interventional Radiology (MARTIR) project
  – Monitoring
    → dosimeters

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**Occupational Hazards of Inhalational Anesthetics**

- Proposed risks include reproductive effects, perceptual cognitive and motor skills
- Neither animal nor epidemiological studies have proved that adverse effects develop after a person is exposed to trace levels of waste anesthetic gases
- National Institute for Occupational Safety and Health (NIOSH) recommends a maximum of 25 ppm for N₂O during a period of anesthetic administration and 2 ppm over a 1 hour period for halogenated agents
- Scavenging of waste anesthetic gases is recommended for all anesthetic gases, with a documented maintenance schedule for all anesthesia machines and the ventilation system in the operating room and PACU

Burm; Best Practice and Research Clin Anes; 2003: 147-161

**Take Home Points**

- Understand how radiation can affect personnel
- Obtain Dosimetry Badges
  - Consider wearing 2
- Consider wearing eye protection (leaded glasses)
- Wear lead (including thyroid shield) and place a barrier between you and the radiation source
- Add extension tubing onto IVs to maintain an adequate distance from the radiation source (also keeps the anesthesia provider behind the barrier!)
- Avoid radiation during pregnancy; wear lead if exposure is necessary
- Trace anesthetic gases do not likely pose a risk if the operating room has an appropriate ventilation and scavange system

**Occupational Hazards of Inhalational Anesthetics**

- To limit exposure:
  - Use a scavenging system when administering inhalational anesthetics and after anesthesia until extubation
  - Use vaporizers provided with keyed filling systems
  - Use cuffed ETT
  - Test equipment for leaks
  - Ensure sufficient room ventilation
  - Periodic monitoring of exposure levels

Burm; Best Practice and Research Clin Anes; 2003: 147-161