Radiation Protection in Radiation Therapy

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Purpose

• To familiarize the resident with the rationale for radiation protection and the basic principles that underlie radiation protection procedures

Benefit vs risk

• Exposure to radiation entails degree of risk
  – Long term effects such as leukemia
• Can’t eliminate risk altogether
  – Would mean eliminating use of radiation as well
Benefit vs risk

- "Philosophy of risk"
  - Accept a certain level of radiation hazard with realization that benefit to be derived from exposure to radiation far outweighs risk

Benefit vs risk

- Difficult to make accurate assessments of low-level radiation risks
  - Adequate data for high-level risks
  - Very little data on low-level risks

Benefit vs risk

- Difficulties in assessing low-level radiation risks
  - Radiation consequences cannot be distinguished from naturally occurring consequences
    - Can only note increase in frequency of occurrence
  - Require very large sample for study
    - Don’t have this for humans, only for some animals
Benefit vs risk

- Can at best extrapolate high-level data to low levels
  - Don't have adequate models
  - Great deal of inaccuracy
- Generally linear hypothesis used
  - But some believe threshold exists
  - Others believe in radiation hormesis

Benefit vs risk

- Note also that costs of protection against very low levels of radiation may be prohibitive

Radiation protection standards

- Organizations establish radiation protection standards
  - ICRP: International Commission on Radiation Protection
  - NCRP: National Council on Radiation Protection and Measurements
Radiation protection standards

• These organizations provide recommendations on radiation protection
• Actual radiation protection legislation done by state and national governments and enforced by a large number of agencies

Radiation protection standards

• Organizations set maximum permissible dose (MPD) levels
  – Acceptable levels for radiation exposure consistent with philosophy of risk

Radiation protection standards

• MPD is only for occupational exposure
  – Does not include background radiation
  – Does not include medically prescribed radiation
Radiation protection standards

- Population divided into two categories: occupational and non-occupational
  - Occupational
    - Exposed to radiation as part of job
    - Receive training in radiation protection
    - Monitored for radiation exposure – film badge, TLD, pocket dosimeter

- Population divided into two categories: occupational and non-occupational
  - Non-occupational
    - Public at large
    - Exposure minimized by control of radiation environment

Some MPD values: (Values revised in 1987 with NCRP Report #91.)

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Occupational Exposure (annual)</th>
<th>Non-occupational Exposure (annual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total body</td>
<td>50 mSv (5 rem)</td>
<td>1 mSv (0.1 rem)</td>
</tr>
<tr>
<td>Lens of eye</td>
<td>150 mSv (15 rem)</td>
<td>Infrequent exposure</td>
</tr>
<tr>
<td>All other organs</td>
<td>500 mSv (50 rem)</td>
<td>5 mSv (0.5 rem)</td>
</tr>
<tr>
<td>Cumulative exposure:</td>
<td>10 mSv + age (1 mSv × age)</td>
<td>Frequent exposure</td>
</tr>
<tr>
<td>Exposures:</td>
<td></td>
<td>50 mSv (5 rem)</td>
</tr>
<tr>
<td>Embryo-fetus exposure:</td>
<td></td>
<td>Embryo-fetus exposure:</td>
</tr>
<tr>
<td>Total limit</td>
<td>5 mSv (0.5 rem)</td>
<td>(5 mSv)</td>
</tr>
<tr>
<td>Month limit</td>
<td>0.5 mSv (0.05 rem)</td>
<td></td>
</tr>
</tbody>
</table>
Radiation protection standards

• Typical occupational doses in radiation oncology very small
  – Should be less than a few mSv/yr

ALARA

• In recent years, regulatory agencies have introduced the ALARA principle
  – “As low as reasonably achievable”
• In addition to keeping doses below MPD, radiation users must document methods for keeping doses as low as reasonably achievable

Control of radiation areas

• Areas in which doses of 15 mSv/yr or more may be received are designated controlled areas
  – Restricted to radiation workers
  – Under supervision of radiation safety officer
  – Workers in controlled areas must be monitored
Reduction of radiation exposure

- T – time
- D – distance
- S – shielding

Effect of time

- Radiation exposure directly proportional to time exposed
- Keep exposure time low through training in handling techniques and adequate practice

Effect of distance

- Exposure (approximately) inversely proportional to square of distance from source
- Work at a distance from radiation source – e.g., use of long tongs for source handling
**Effect of shielding**

- Shielding used to attenuate radiation intensity
- Work behind shielding

**Shielding of radiation facilities**

- All radiation oncology facilities must be shielded to reduce radiation levels
  - 1 mSv/wk – controlled area
  - 0.1 mSv/wk – uncontrolled area
  - Facility operator may designate even lower levels

**Shielding calculation**

- In calculating shielding, must account for primary, leakage, and scattered radiation.
**Primary shielding**

- Compute unshielded dose rate = \( \frac{WU}{d^2} \)
- \( W \) – workload
  - Estimate dose at isocenter in 1-week period
  - NCRP guidelines to those values

**Primary shielding**

- \( U \) – use factor
  - Fraction of time the useful beam is directed toward the barrier of interest
    - floor – 1
    - walls – \( \frac{1}{4} \)
    - ceiling – \( \frac{1}{4} \)

**Primary shielding**

- \( T \) – occupancy factor fraction of the time the area is occupied by an individual
  - For controlled areas use \( T = 1 \)
  - For uncontrolled areas may use factors of \( \frac{1}{4} \) or \( \frac{1}{8} \) for areas such as corridors, rest rooms, waiting rooms, closets, etc
Primary shielding

- Compute unshielded dose rate = WUT/d^2
- Divide desired dose rate by computed dose rate to get attenuation factor B
- Determine how much shielding material would give calculated attenuation factor

Leakage shielding

- Leakage generally taken to be 0.1% of primary beam
- Multiply by attenuation factor to obtain desired dose rate

Scatter shielding

- Scatter generally some fraction of primary beam depending on scatter angle
- Because scatter is of lower energy than primary beam, difference in energy must be considered when computing thickness of attenuator
Shielding calculation

• More complicated problem for photon energies above 10 MV because of neutron production

Radiation monitoring

• Two aspects of radiation monitoring
  – Area monitoring: to ensure that radiation levels in an area are less than specified levels
  – Personnel monitoring: to monitor the dose received by individuals while working with radiation

Area monitors

• Survey meters
  – e.g., “cutie pie” meter, ionization chamber
  – Some survey meters have audible alarm if radiation levels exceed specified levels
• G-M tubes
  – Used for measuring low levels of radiation, e.g. finding lost sources
Personnel monitors

• Film badge
  – Photographic emulsion encased in plastic with metal filters
  – Used for routine personnel monitoring

Personnel monitors

• Film badge
  – Advantages: permanent record
    inexpensive
    can be reread
    compact size
    resistant to mechanical damage

Personnel monitors

• Film badge
  – Disadvantages: relatively insensitive
    can be affected by heat, humidity
Personnel monitors

- TLD
  - Can also be used for routine personnel monitoring

Personnel monitors

- TLD
  - Advantages: reusable
    - Sensitive over wide energy range
    - More resistant to fading than film
  - Disadvantages: higher cost than film
    - Information destroyed when read

Personnel monitors

- Ionization chamber
  - Used for fast readout of personnel exposure, e.g.
    - To obtain exposure for single procedure
### Personnel monitors

- **Ionization chamber**
  - **Advantages:** rapid readout, accurate
  - **Disadvantages:** high cost, condenser discharges with time, fragile

### Regulatory agencies

- **U.S. Nuclear Regulatory Commission**
  - Licenses use of special source material (e.g., 238Pu used in pacemakers), source material (e.g., depleted uranium used for shielding in a linac), byproduct material (e.g., 60Co, 137Cs, etc., used for radiation therapy)

- **NRC has no control over use of naturally occurring radioactive materials (e.g., 226Ra) and accelerator produced materials (e.g., positron emitters used in imaging)**
Regulatory agencies

- Food and Drug Administration
  - Regulates manufacture (not use) of radiation devices (e.g., x-ray machines)

- State radiation control agencies
  - License use of naturally occurring radioactive material and accelerator produced material
  - NRC may enter into agreements with states whereby NRC transfers regulatory responsibility to that state – “agreement state”
  - Texas is example of agreement state

Radioactive material licenses

- NRC and states control use of radioactive materials by means of licenses
**Types of licenses**

- **Limited scope license**
  - Given to institution authorizing specific radioisotopes in specific quantities for specific procedures and by specific users

- **Broad scope license**
  - Given to large institutions authorizing wide range of radioactive materials for broadly defined applications
  - Broad scope licensee has radiation safety committee which acts in place of NRC or state agency to approve specific applications

**License considerations**

- Do users have adequate training in basic radioisotope handling techniques and experience handling types and quantities of radioactive materials to be authorized as well as clinical experience in human use of radioactive material?
  - Generally ABR certification in Therapeutic Radiology is sufficient
License considerations

- Are applicant’s equipment and facilities adequate for the proposed uses?
- Is applicant’s radiation safety program adequate to ensure health and safety of workers, public, and patients?

License application

- To obtain license, proposed user has to fill out application answering these questions
  - Important to note: application is considered part of license and user held to statements made on application

Brachytherapy safety

- Radiation protection
  - Remember T D S
- Radioactive contamination
  - When using sealed sources, best to use afterloading or remote afterloading techniques
  - When using radioactive liquids or solutions, wear gloves and lab coat, and be neat
**Brachytherapy safety**

- Protection against lost sources
  - Plan operations carefully, well in advance, and have written emergency procedures
  - Keep comprehensive records of source movement
  - Have a comprehensive back-up system

**Lost (misplaced) source**

- In the event a source is lost:
  - Make sure patient does not have source
  - Contact radiation safety officer who will supervise search
  - Radiation safety officer may have to file reports with appropriate authorities