Radiation Hazards Evaluation and Control, Radiation Emergency Procedures

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What is in the presentation

- Radiotherapy facilities in India
- Basics of Radiation & its Protection
- Hazard Evaluation & Control
- Emergency preparedness in RT
- Regulation of RT facilities in India
Radiotherapy Facilities in India
## Teletherapy Facilities in India till June 2016

<table>
<thead>
<tr>
<th>Radiotherapy Centres</th>
<th>Teletherapy Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>: 403</td>
<td>: 600</td>
</tr>
<tr>
<td>Co-60 Units</td>
<td>: 224</td>
</tr>
<tr>
<td>Linear Accelerators</td>
<td>: 358</td>
</tr>
<tr>
<td>Gamma Knife</td>
<td>: 7</td>
</tr>
<tr>
<td>Tomotherapy</td>
<td>: 6</td>
</tr>
<tr>
<td>CyberKnife</td>
<td>: 5</td>
</tr>
</tbody>
</table>

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# Brachytherapy Facilities in India

<table>
<thead>
<tr>
<th>Brachytherapy Devices/Facilities</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote Afterloading Units (HDR/MDR/LDR)</td>
<td>257</td>
</tr>
<tr>
<td>Manual Afterloading kits (Cs-137)</td>
<td>59</td>
</tr>
<tr>
<td>Manual Afterloading Interstitial Implants (Ir-192)</td>
<td>20</td>
</tr>
<tr>
<td>Facilities using Sr-90, Ru-106 and I-125</td>
<td>49</td>
</tr>
<tr>
<td>Intra Operative Radiotherapy (IORT) unit</td>
<td>02</td>
</tr>
</tbody>
</table>
Basics of Radiation & its Protection
Quantities & Units for Radiation Measurement

Exposure

Absorbed Dose

Equivalent Dose

Effective Dose

Ionization produced in unit mass of air
Unit: C/Kg, Roentgen (R)

Energy Deposited in unit mass of medium
Unit: Gray (Gy), Rad

Effect of absorbed dose for radiation type
Unit: Sievert (Sv), Rem

Effect of equivalent dose in tissue
Unit: Sievert (Sv), Rem
System of Radiation Protection

- Justification of practice
- Optimization of protection
- Limitation of doses
Basis for Dose Limit

• To prevent deterministic effects

• To reduce the probability of stochastic risk at an acceptable level
Adult Occupational Dose Limits

Whole Body (everything except extremities)
- 30 mSv maximum per year
- 20 mSv averaged over 5 years

Skin of the Whole Body
- 500 mSv per year

Extremities
- 500 mSv per year

Lens
- 150 mSv

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Public Dose Limits

Whole Body (everything except extremities)
1 mSv per year

Skin of the Whole Body
50 mSv per year

Extremities
50 mSv per year

Lens
15 mSv
Apprentice/Trainee (16-18 yr)
Occupational Dose Limits

Whole Body (everything except extremities)
6 mSv maximum per year

Skin of the Whole Body
150 mSv per year

Extremities
150 mSv per year

Lens
150 mSv
Exposure to Radiation Dose

If a life threatening dose (50% probability) is illustrated by the height of the Eiffel tower (over 300 meters), the dose limit for occupational (radiation) workers corresponds to the height of a man (2 meters) and the limit for the public to the thickness of a brick (0.1 meters).

Life threatening dose – more than 3000 mSv

Radiation illness – Passing Symptoms

No symptoms, temporary changes in blood picture (A Skyscraper)

No detectable effects (A House)

Limit for the Occupational Worker (A Man)

Limit for the public (A Brick)
# Comparison of Risk

<table>
<thead>
<tr>
<th>Accident type</th>
<th>Individual risk/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicle</td>
<td>1 in 4 000</td>
</tr>
<tr>
<td>Fires</td>
<td>1 in 25 000</td>
</tr>
<tr>
<td>Air travel</td>
<td>1 in 100 000</td>
</tr>
<tr>
<td>Electrocution</td>
<td>1 in 160 000</td>
</tr>
<tr>
<td>Lightning</td>
<td>1 in 2 000 000</td>
</tr>
<tr>
<td>Radiation Industry</td>
<td>1 in 5 000 000 000</td>
</tr>
</tbody>
</table>

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## Average annual exposures

<table>
<thead>
<tr>
<th>Practice</th>
<th>Average annual dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial radiography</td>
<td>0.9</td>
</tr>
<tr>
<td>Nucleonic gauges</td>
<td>0.13</td>
</tr>
<tr>
<td>Gamma irradiators</td>
<td>not significant</td>
</tr>
<tr>
<td>Teletherapy</td>
<td>0.55</td>
</tr>
<tr>
<td>Brachytherapy</td>
<td>0.49</td>
</tr>
<tr>
<td>Nuclear medicine</td>
<td>0.54</td>
</tr>
<tr>
<td>Diagnostic radiology</td>
<td>0.49</td>
</tr>
</tbody>
</table>
Basic Safety Objective

- Protection of occupational workers, patient, public and environment
- ALARA during normal operations
- Radiation exposure during normal operations within relevant dose limits
- Potential exposures and the magnitude of such exposures are kept ALARA
Hazard Evaluation & Control
Basic Radiation Protection Techniques

- For External Hazards:
  I. Time
  II. Distance
  III. Shielding
Reduce Time

Time Relationship

Exposure rate = 1 mR/hr

\[ \times \] Time = Total Exposure

1 hour = 1 mR

2 hours = 2 mR
Less time = Less radiation exposure
Use Radioactive Material only when necessary
Dry runs (without radioactive material)
Shorten time when near Radioactive Material
Obtaining higher doses in order to get an experiment done quicker is NOT “reasonable”!
Increase Distance

Distance Effect

Inverse Square Law

at 1 cm from source

12,000 mR/hr at 1 cm from source

4.8 mR/hr
Effect of Distance on Dose Rate

25 mrem/hr @ 6 ft  
100 mrem/hr @ 3 ft

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Distance

- **Effective & Easy**
- **Inverse Square Law**
  - Doubling distance from source, decreases dose by factor of four
  - Tripling it decreases dose nine-fold
- **More Distance = Less Radiation Exposure**
- **Tongs, Tweezers, Pipettes, Pliers**
Use Shielding
Shielding

- **Alpha Emitters** ($^{238}$U, $^{230}$Th, $^{241}$Am, $^{222}$Rn)
  - Paper
- **Low Energy Beta Emitters** ($^3$H, $^{14}$C, $^{35}$S, $^{33}$P)
  - Paper
- **Medium / High Energy Beta Emitters** ($^{32}$P)
  - Plastic
- **X-ray & γ-ray Emitters** ($^{60}$Co, $^{137}$Cs, $^{192}$I, $^{125}$I)
  - Lead, concrete, steel, etc.
- **Neutron Sources** (Accelerators, Reactors, Am/Be)
  - Water, plastic, paraffin, etc.
Shielding of X-ray/\(\gamma\)-ray

\[ I = I_0 e^{-\mu x} \]
**Half value & Tenth value thickness (HVT & TVT)**

**HVT** - It is that thickness of the shielding material which will reduce the radiation intensity to half of the original intensity.

**TVT** - It is that thickness of the shielding material which will reduce the radiation intensity to one tenth of the original intensity.

$$TVT = 3.3 \times HVT$$
Reduction Factor

1 HVT of a shielding material provide a reduction factor of 2
2 HVT produces a reduction factor of $2 \times 2$ or $2^2 = 4$
The reduction factor offered by $n$ number of HVT of shielding material is $2^n$

1 TVT of a shielding material provide a reduction factor of 10
2 TVT produces a reduction factor of $10 \times 10$ or $10^2 = 100$
The reduction factor offered by $n$ number of TVT of shielding material is $10^n$
# HVT & TVT Values

<table>
<thead>
<tr>
<th>Radio-isotope</th>
<th>Concrete (cm)</th>
<th>Steel (cm)</th>
<th>Lead (cm)</th>
<th>Depleted Uranium (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HVT</td>
<td>TVT</td>
<td>HVT</td>
<td>TVT</td>
</tr>
<tr>
<td>$^{192}\text{Ir}$</td>
<td>4.6</td>
<td>14</td>
<td>1.25</td>
<td>4.0</td>
</tr>
<tr>
<td>$^{137}\text{Cs}$</td>
<td>4.8</td>
<td>15.7</td>
<td>1.5</td>
<td>5.2</td>
</tr>
<tr>
<td>$^{60}\text{Co}$</td>
<td>6.6</td>
<td>21.8</td>
<td>2.0</td>
<td>6.6</td>
</tr>
</tbody>
</table>
Radiation Monitoring Instruments
Emergency Preparedness in RT
Emergency Preparedness

- Availability of Devices and Survey Meter for handling emergency and display of procedure to be followed
  - In control room of telecobalt/RAL Brachytherapy unit
  - In source handling area of manual brachytherapy
- Emergency situations include
  - failure of source movement mechanism of telegamma and remote after-loading brachytherapy equipment
  - loss of source in manual brachytherapy
Preparation of Emergency Action Plan

- Foreseeable emergencies, include
  - Radioactive source failing to return to the safe shielding position
  - Dislodge/loss/theft of radioactive source during use, storage, transport, loss of shielding
  - Natural calamities such as fire, flood, or earthquake
  - Death of patient, with sources *in situ*
  - Selection of wrong treatment mode
  - Selection of wrong beam modifiers and wrong dose delivery.
Emergency Handling and Reporting

- Display of Emergency Procedures
- Ensure that all workers are familiar with the emergency action plan
- Release of dead body containing sources, after removal and monitoring by RSO
- Report to licensee/employer immediately and to the competent authority within 24 hours
- Lodge written complaint with police in case of loss or theft of radioactive sources, if not traced within 24 hours.
Reporting of emergency/unusual occurrences/accidental medical exposures

Investigation report on emergency to be submitted to AERB which includes

(i) any equipment failure, accident, mishap, miscalculation or other unusual occurrence with the potential for causing a patient dose significantly different from that intended, and

(ii) any therapeutic treatment delivered to either the wrong patient, or the wrong tissue, or using wrong source, or with a dose or dose fractionation differing substantially from the value prescribed by the radiation oncologist, or that may lead to undue acute secondary effects.
Regulation of Radiotherapy Facilities in India
WHAT IS REGULATION?

- **Regulation** refers to “controlling human or societal behavior by rules or restrictions”
- **Costs** for some and **benefits** for others
- **Efficient** where the total benefits to some people exceed the total costs to others
- **Regulatory agencies** deal in regulation or rulemaking and enforcing rules and regulations for the **benefit of the public at large**

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System of Regulatory Control

Issued by Central Government

❖ Act
(Atomic Energy Act, 1962)

❖ Rules

❖ Notifications
(Radiation Surveillance Procedures for Medical Applications of Radiation, 1989)

Published by AERB

❖ Safety Code
AERB/RF-MED/SC-1 (Rev.1)

❖ Safety Standards
❖ Safety Guides
❖ Safety Manuals

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The mission of AERB is to ensure that the use of ionizing radiation and nuclear energy in India does not cause unacceptable impact on the health of workers and the members of the public and on the environment.
Total Radiation Safety is achieved by

Built-in Safety

combined with

Operational Safety
Built-in Radiation Safety

- **Sealed Source – Classification**
  (safety of worker and public)

- **Equipment – Type-approval**
  Electrical, Mechanical, Radiological
  (safety of rad. worker and patient)
**Built-in Radiation Safety**

- **Installation – Plan Approval**
  Thick concrete walls, maze
  (safety of rad. worker, public and patients’ relatives)

- **Transport Package – Package approval**
  (safety of worker, public)
Operational Safety

Components of operational safety
- Qualified and certified persons
- Work place monitoring
- Personnel monitoring
- Safe and secure storage place
- Desirable equipment for safety, dosimetry, QA
- Preventive Maintenance
- Interaction with regulatory body
- Emergency planning and preparedness
Operational Safety- Manpower, PMS

- Adequate No. of Qualified and certified persons
  (Radiation Oncologist, Medical Physicist, Radiation Therapy Technologist)

- Personnel monitoring
  (TLD for all radiation worker)
Operational Safety – Monitoring, Maintenance

- Work place monitoring
  - (Gamma Zone Monitor)
  - (Switches, Interlocks, Indicators)

- Preventive maintenance
Operational Safety – Survey, Dosimetry

- Appropriate Monitoring equipment (survey meter, contamination monitor, gamma zone monitor [auto/manual] etc.)

- Appropriate Measuring equipment (RFA, SSD with thimble /parallel plate/well type chamber etc.)
Operational Safety – QA & others

- TPS
- Simulator
- CT-Simulator
- Beam modifiers
- Moulds
- QA test tools
Radiation Symbol

- Radiation symbol to be posted at:
  - Entrance of treatment room
  - Entrance of the controlled and supervised areas

- A legend in Hindi, English and Local language indicating radiation hazard

For Telegamma/Brachytherapy facility

For Linac/Simulator or facility
Control measures adopted in India

- **Pre-licensing stage**
  - Design Approval of Room layout
  - Approval for procurement of source
  - Commissioning approval
  - Licence for operation

- **During the useful life**
  - Information for any change in working condition
  - Radiation safety report
  - Reporting incidents or accidents

- **Post use**
  - Approval for Decommissioning/Disposal
e-Licensing of Radiation Applications (eLORA)
Stages in eLORA for Radiotherapy

- Institute Registration
- Obtaining Layout Plan Approval
- Radiation Professional Registration (RO/MP/RTT)/their tagging/availability of Personnel Monitoring Badges
- Declaring availability of survey, dosimetry and QA equipment
- Obtaining RSO Approval
- Obtaining Equipment Procurement Permission/Intimation of Receipt
- Obtaining Source Procurement Permission/Intimation of Receipt
- Obtaining Commissioning Approval
- Submission of Survey Report and its clearance
- Obtaining License for operation
- Submission of Safety Status Report annually
- Obtaining permission for Disposal/Decommissioning
THANK YOU

Any container bearing this symbol probably houses a radioactive material.