Radiation Protection & Regulatory Control in Radiation Therapy

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What is in the presentation

- Radiotherapy facilities in India
- Basics of Radiation & its Protection
- Hazard Evaluation & Control
- Regulation of RT facilities in India
Radiotherapy Facilities in India
# Teletherapy Facilities in India

## Radiotherapy Centres

<table>
<thead>
<tr>
<th>Facilities</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-60 Units</td>
<td>159</td>
</tr>
<tr>
<td>Linear Accelerators</td>
<td>534</td>
</tr>
<tr>
<td>Gamma Knife</td>
<td>6</td>
</tr>
<tr>
<td>Tomotherapy</td>
<td>22</td>
</tr>
<tr>
<td>CyberKnife</td>
<td>8</td>
</tr>
</tbody>
</table>

## Teletherapy Facilities

- 500
- 729

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Dr. P. K. Dash Sharma, RSD, AERB
Brachytherapy Facilities in India

Brachytherapy Devices/Facilities:

- Remote Afterloading Units (HDR/MDR/LDR): 318
- Manual Afterloading kits (Cs-137): 35
- Facilities using Sr-90, Ru-106 and I-125: 57
- Intra Operative Radiotherapy (IORT) unit: 01
Basics of Radiation & its Protection
Quantities & Units for Radiation Measurement

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

- **Absorbed Dose**
  - Energy Deposited in unit mass of medium
  - Unit: Gray (Gy), Rad

- **Equivalent Dose**
  - Effect of absorbed dose for radiation type
  - Unit: Sievert (Sv), Rem

- **Effective Dose**
  - Effect of equivalent dose in tissue
  - Unit: Sievert (Sv), Rem
System of Radiological Protection

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

- To prevent deterministic effects
- To reduce the probability of stochastic risk at an acceptable level
**Adult (>18 years) Occupational Dose Limits**

Whole Body
- **30 mSv** maximum per year
- **20 mSv** averaged over 5 years

Extremities
- **500 mSv** per year

Lens: **150 mSv**
Public Dose Limits

Whole Body
1 mSv per year

Extremities
50 mSv per year

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

Whole Body
6 mSv maximum per year

Extremities
150 mSv per year

Lens
50 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 300 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>
## Typical 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 \text{Time} = \text{Total Exposure}

- 1 hour = 1 mR
- 2 hours = 2 mR
Time

- 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

12,000 mR/hr at 1 cm from source

4.8 mR/hr at 50 cm
Effect of Distance on Dose Rate

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

\[
I = I_0 e^{-\mu x}
\]

- \(I_0\): Initial intensity
- \(I\): Intensity after shielding
- \(x\): Thickness
- \(HVT\): Half Value Thickness
- \(\mu\): Linear attenuation coefficient

Graph showing the intensity decrease with thickness.
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.

\[ \text{TVT} = 3.3 \times \text{HVT} \]
Reduction Factor

1 HVT of a shielding material provide a reduction factor of 2

2 HVT produces a reduction factor of $2 \times 2 = 4$

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 $10 \times 10 = 100$

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>$^{192}$Ir</td>
<td>4.6</td>
<td>14</td>
<td>1.25</td>
<td>4.0</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>4.8</td>
<td>15.7</td>
<td>1.5</td>
<td>5.2</td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>6.6</td>
<td>21.8</td>
<td>2.0</td>
<td>6.6</td>
</tr>
</tbody>
</table>
Radiation Monitoring Instruments
Regulation of Radiotherapy Facilities in India
Why Regulation?

- **RISK**
  - **NOT ALLOWED**
  - **NOT ENCOURAGED**
  - **HIGHLY ENCOURAGED**
  - **REGULATED**

- **BENEFIT**
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**
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
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.
Responsibility of Safety?

Though AERB oversee Safety in use of Radiation Sources in the country,

the Prime Responsibility of ensuring Radiation Safety in the facility lies with the Licensee.
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/Simulat 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
Preparation of Emergency Preparedness 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.
Security Plan in case of Radioactive Sources

- Security Plan is required to be prepared for radioactive sources.
- Security plan for Telecobalt and Gamma Knife units need to be registered with local law enforcement agency.
e-Licensing of Radiation Applications (eLORA)

Government of India
Atomic Energy Regulatory Board
e-Licensing of Radiation Applications (eLORA) System

Ways to achieve Radiation Safety

My Inbox

<table>
<thead>
<tr>
<th>Date and Time</th>
<th>Message to User</th>
</tr>
</thead>
<tbody>
<tr>
<td>30/05/2016 03:06 PM</td>
<td>You have successfully submitted the application for Change licensee with application no: 16-138481 and application is accepted.</td>
</tr>
<tr>
<td>13/05/2016 05:30 PM</td>
<td>Your Application ref no. 16-134637 is Rejected.</td>
</tr>
<tr>
<td>22/01/2016 05:32 PM</td>
<td>Your Application no. 16-103480 has been discarded successfully.</td>
</tr>
<tr>
<td>22/01/2016 05:32 PM</td>
<td>You have successfully froze Application For Site and Layout Approval with application no: 16-104840 for Accelerator,Precise Digital</td>
</tr>
<tr>
<td>22/01/2016 05:27 PM</td>
<td>Non compliance has been modified against your institute with NC reference no [MH-21818-NC-3916]. Refer ‘My Institute Details’ for further information.</td>
</tr>
<tr>
<td>15/12/2015 11:58 AM</td>
<td>Your Application ref no. 15-93255 is Rejected.</td>
</tr>
<tr>
<td>10/12/2015 02:01 PM</td>
<td>Your Application no. 15-92092 has been discarded successfully.</td>
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<td>10/12/2015 01:56 PM</td>
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<tr>
<td>03/12/2015 12:28 PM</td>
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<tr>
<td>03/12/2015 12:27 PM</td>
<td>You have successfully froze Application For Site and Layout Approval with application no: 15-90391 for Accelerator,Vital Beam with FFF</td>
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</tbody>
</table>

Showing 1 to 10 of 57 entries
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 periodic Safety Status Report
- Obtaining permission for Disposal/Decommissioning
THANK YOU

Any container bearing this symbol probably houses a radioactive material