Radiation Protection Issues in Radionuclide Therapy

Maria Rosa Malisan
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History-Therapy

1936  Therapeutic use of Na-24 (leukemia)  Hamilton et al
1936  Therapeutic use of P-32 (leukemia and polycythemia vera)  Lawrence
1941  Therapeutic use of iodine in hyperthyroidism  Hertz et al
1942  Therapeutic use of iodine in treatment of metastasis from thyroid cancer
1945  Therapeutic use of Au-198 in treatment of malignant effusion  Muller
1958  Treatment of bone metastasis with P-32  Maxfield
1963  Medical synovectomy using Au-198  Ansell
Properties of some radionuclides used in radionuclide therapy

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Half-life</th>
<th>Emission</th>
<th>$E_\alpha$ MeV</th>
<th>$E_{\beta_{\text{max}}}$ MeV</th>
<th>$E_\gamma$ keV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{32}$P</td>
<td>14.3 d</td>
<td>$\beta$</td>
<td>1.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{67}$Cu</td>
<td>2.58 d</td>
<td>$\beta\gamma$</td>
<td>0.58</td>
<td>185</td>
<td></td>
</tr>
<tr>
<td>$^{89}$Sr</td>
<td>50.5 d</td>
<td>$\beta$</td>
<td>1.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{90}$Y</td>
<td>2.67 d</td>
<td>$\beta$</td>
<td>2.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{125}$I</td>
<td>60.0 d</td>
<td>Auger e\textsuperscript{-}</td>
<td></td>
<td>(X:27)</td>
<td></td>
</tr>
<tr>
<td>$^{131}$I</td>
<td>8.04 d</td>
<td>$\beta\gamma$</td>
<td>0.61</td>
<td>364</td>
<td></td>
</tr>
<tr>
<td>$^{153}$Sm</td>
<td>1.95 d</td>
<td>$\beta\gamma$</td>
<td>0.81</td>
<td>103</td>
<td></td>
</tr>
<tr>
<td>$^{165}$Dy</td>
<td>2.33 d</td>
<td>$\beta\gamma$</td>
<td>1.29</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>$^{169}$Er</td>
<td>9.5 d</td>
<td>$\beta$</td>
<td>0.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{177}$Lu</td>
<td>6.71 d</td>
<td>$\beta\gamma$</td>
<td>0.50</td>
<td>208</td>
<td></td>
</tr>
<tr>
<td>$^{186}$Re</td>
<td>3.77 d</td>
<td>$\beta\gamma$</td>
<td>1.08</td>
<td>137</td>
<td></td>
</tr>
<tr>
<td>$^{188}$Re</td>
<td>20.0 h</td>
<td>$\beta\gamma$</td>
<td>2.1</td>
<td>155</td>
<td></td>
</tr>
<tr>
<td>$^{198}$Au</td>
<td>2.7 d</td>
<td>$\beta\gamma$</td>
<td>0.96</td>
<td>411</td>
<td></td>
</tr>
<tr>
<td>$^{211}$At</td>
<td>7.2 d</td>
<td>$\alpha$</td>
<td>6.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{212}$Bi</td>
<td>1.0 h</td>
<td>$\alpha$</td>
<td>7.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{223}$Ra</td>
<td>11.4 d</td>
<td>$\alpha\beta\gamma$</td>
<td>5.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Radionuclides

- The selection of the appropriate radionuclide depends on its nuclear decay properties, specifically, emission characteristics and physical half-life.
- The treatment of bulky tumors by radionuclides that emit high energy alpha or beta particles is the preferred approach;
- however, for the eradication of small clusters of cancer cells or small tumor deposits, radionuclides that emit Auger electrons are considered to be beneficial because of their high level of cytotoxicity and short-range biological effectiveness. (Cancers 2011, 3, 3838-3855)
## Radiopharmaceuticals

(Cancers 2011, 3, 3838-3855)

<table>
<thead>
<tr>
<th>Radiopharmaceutical</th>
<th>Targeting mechanism</th>
<th>Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-131 as iodide</td>
<td>Thyroid hormone synthesis</td>
<td>Differentiated thyroid carcinomas</td>
</tr>
<tr>
<td>I-131 Tositumomab</td>
<td>CD20 Antigen binding</td>
<td>Non-Hodgkin’s lymphoma</td>
</tr>
<tr>
<td>Y-90 Zevalin</td>
<td>CD20 Antigen binding</td>
<td>Non-Hodgkin’s lymphoma</td>
</tr>
<tr>
<td>Y-90 microspheres</td>
<td>Intravascular trapping</td>
<td>Liver metastasis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hepatocellular carcinoma</td>
</tr>
<tr>
<td>Sr-89 chloride</td>
<td>Calcium analogue</td>
<td>Bone pain palliation</td>
</tr>
<tr>
<td>Sm-153 EDTMP</td>
<td>Chemoadsorption</td>
<td>Bone pain palliation</td>
</tr>
<tr>
<td>Y-90 Octreotide</td>
<td>Somatostatin receptor binding</td>
<td>Neuroendocrine tumors</td>
</tr>
<tr>
<td></td>
<td>Active transport into</td>
<td>Neuroblastoma</td>
</tr>
<tr>
<td></td>
<td>neuroendocrine cells and intracellular storage</td>
<td>Pheochromacytoma</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carcinoid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Paraganglioma</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medullary thyroid carcinoma</td>
</tr>
</tbody>
</table>
## Typical activity and absorbed dose per administration

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{90}$Y-Zevalin®</td>
<td>1000</td>
<td></td>
<td>Kidneys: 2.4</td>
<td>Red marrow: 2.7</td>
</tr>
<tr>
<td>$^{131}$I-Bexxar®</td>
<td>3000</td>
<td></td>
<td>Thyroid: 8.1</td>
<td>Kidneys: 5.9</td>
</tr>
<tr>
<td>$^{153}$Sm-EDTMP</td>
<td>2500</td>
<td></td>
<td>Bone surfaces: 17</td>
<td>Red marrow: 3.8</td>
</tr>
<tr>
<td>$^{89}$Sr-chloride</td>
<td>150</td>
<td></td>
<td>Bone surfaces: 2.6</td>
<td>Red marrow: 1.7</td>
</tr>
<tr>
<td>$^{177}$Lu-octreotate</td>
<td>7400</td>
<td>200</td>
<td>Kidneys: 23</td>
<td></td>
</tr>
<tr>
<td>$^{32}$P-phosphate</td>
<td>185</td>
<td></td>
<td>Red marrow: 2.0</td>
<td>Bone surfaces: 2.0</td>
</tr>
</tbody>
</table>

$^{131}$I-Iodide  5500  > 80  thyroid ablation

$^{131}$I-MIBG  ~ 660 MBq/kg  pediatric neuroblastoma
Routes of administration of radiopharmaceuticals to a therapy patient

(AAPM Report 71 (2001))
### Annual Numbers of Therapies with Radiopharmaceuticals in all Health-care Levels

(As per UNSCEAR Report 2008)

**Number of Patients per million population**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Patients per million population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thyroid Malignancy</td>
<td>1950.1</td>
</tr>
<tr>
<td>Hyperthyroidism</td>
<td>4616.6</td>
</tr>
<tr>
<td>Polycythemia vera</td>
<td>168.1</td>
</tr>
<tr>
<td>Bone Metastases</td>
<td>316.5</td>
</tr>
<tr>
<td>Synovitis</td>
<td>380.6</td>
</tr>
<tr>
<td>Others</td>
<td>120.5</td>
</tr>
</tbody>
</table>

**Total** 7552.4
“3.167. Registrants and licensees shall ensure that dosimetry of patients is performed and documented by or under the supervision of a medical physicist, using calibrated dosimeters and following internationally accepted or nationally accepted protocols, including dosimetry to determine the following:

- ......
- (c) For therapeutic medical exposures, absorbed doses to the tissues or organs for individual patients, as determined to be relevant by the radiological medical practitioner.”
Need for action wrt patients

- Dose planning before therapy. No therapy without dose planning!
- Individual patient biokinetics
- Individual dose calculations
- Dose distributions within organs and tissues
- Same protocol for different hospitals and clinics for measurements of biokinetic data and for dosimetry
- A formalism for the addition of doses from nuclear medicine therapy, external radiation therapy and brachytherapy for patients receiving various treatments (Biologically Effective Dose, BED)
Absorbed Dose-Administered Activity
I-131

Example of method to calculate administered activity from Prescribed absorbed dose to the thyroid

Thyroid mass (g) 30
Prescribed dose (Gy) 100

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>Standard (cpm)</th>
<th>Patient (cpm)</th>
<th>Bg (cpm)</th>
<th>Uptake (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>73,5</td>
</tr>
<tr>
<td>2</td>
<td>21736</td>
<td>5521</td>
<td>100</td>
<td>25,1</td>
</tr>
<tr>
<td>24</td>
<td>18286</td>
<td>12338</td>
<td>100</td>
<td>67,3</td>
</tr>
<tr>
<td>48</td>
<td>17165</td>
<td>10565</td>
<td>100</td>
<td>61,3</td>
</tr>
<tr>
<td>144</td>
<td>13171</td>
<td>5754</td>
<td>100</td>
<td>43,3</td>
</tr>
</tbody>
</table>

Effective half-life (d): 4,0
Activity to administer (MBq): 240

Activity (MBq) = 23.4*mass(g)*dose (Gy)uptake at t=0 (%)*T_{eff} (d)

Thyroid Cancer Therapy with Iodine-131

Acquisition of Pharmacokinetic Patient Data

Gamma Camera Examination

Uptake Measurement

Used to determine the size of the organ
Factors Affecting Safety in Radionuclide Therapy

- Safe handling of radionuclides
  - ordering
  - receipt and unpacking
  - storage
  - dispensing
  - internal transports
  - radioactive waste

- Safe administration
  - Identification
  - pregnancy
  - breastfeeding

- The radioactive patient and dose constraints

- The hospitalized patient
  - instructions to nursing staff
  - personal monitoring
  - discharge of the patient
  - contamination survey
  - radioactive waste

- Emergency procedures
Ordering, Receipt & Unpacking

• The hospital routines for ordering radionuclides should be followed.

• When ordering, be sure the delivery service knows where in the hospital to deliver the material.

• Make sure that the package is expected and that no unauthorized person will open it upon arrival.

• Before unpacking, check the package. In case of damage, contact your RPO.
Storage of I-131

- The radionuclide should be stored in a controlled area, according to national regulations and local rules.

- The radionuclide should always be stored in a lead container and preferably in a fridge to prevent evaporation.

- To reach an acceptable external dose rate, a thickness of 1-4 cm lead is generally required.
Dispensing

• Protective clothing

• Lead shields (bench top shield, vial shield, syringe shield)

• Keep the vial in the fume hood and on a tray with lips, lined with plastic backed absorbent pads.

• Handle the vial with forceps or similar long handled instruments.

• Cover the vial with lead after use.

• Check the activity

• Fill in the necessary records
Internal Transport

If the administration of radiopharmaceutical to the patient takes place far from the dispensing room, use a transport container with absorbent pads.

Make sure that a warning sign is on the container together with patient name, activity and date.

Travel by the most direct route avoiding more heavily occupied areas
Precautions Before Administration

• Be prepared for an emergency situation.
• Careful identification of the patient (hospital routines shall be followed).
• Questions to the patient:
  - Pregnant?
  - Breastfeeding?
  - Incontinent?
  - Nausea?
  - Living conditions?
  - Type of work?
  - Public transportation back home?
• Verbal and written individual instructions to the patient.
Need for action with regard to patients (II): Women of fertile ages (15-55 years)

1. Careful check of pregnancy

2. Careful check of breast feeding

If you are breast-feeding, please notify the staff before you have your injection for the nuclear medicine examination.
Foetal thyroid

Warning! Radioactive iodine. Especially therapy!

Radioiodine administered to a woman, after 10-13 wk post-conception → the fetal thyroid concentrates the iodine which crosses the placenta.

<table>
<thead>
<tr>
<th>Gestational Age (mo)</th>
<th>I-123</th>
<th>I-124</th>
<th>I-125</th>
<th>I-131</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2.7</td>
<td>24</td>
<td>290</td>
<td>230</td>
</tr>
<tr>
<td>4</td>
<td>2.6</td>
<td>27</td>
<td>240</td>
<td>260</td>
</tr>
<tr>
<td>5</td>
<td>6.4</td>
<td>76</td>
<td>280</td>
<td>580</td>
</tr>
<tr>
<td>6</td>
<td>6.4</td>
<td>100</td>
<td>210</td>
<td>550</td>
</tr>
<tr>
<td>7</td>
<td>4.1</td>
<td>96</td>
<td>160</td>
<td>390</td>
</tr>
<tr>
<td>8</td>
<td>4.0</td>
<td>110</td>
<td>150</td>
<td>350</td>
</tr>
<tr>
<td>9</td>
<td>2.9</td>
<td>99</td>
<td>120</td>
<td>270</td>
</tr>
</tbody>
</table>

Watson EE, 1992
Treatment of thyroid cancer
3700 MBq at 18 weeks
Recognised after 25 days
Foetus: Whole body dose: 700 mGy
Thyroid dose: 300 Gy


Figure 1. Gamma camera examination 6 days after administration of 3 700 MBq 131-I in Case 2. Note small uptake in the thyroid bed, uptake in mammary glands, and uptake in the fetal thyroid and fetal body/amniotic fluid.
3.175. Registrants and licensees shall ensure that there are procedures in place for ascertaining the pregnancy status of a female patient of reproductive capacity before the performance of any radiological procedure that could result in a significant dose to the embryo or fetus, so that this information can be considered in the justification for the radiological procedure (para. 3.154 and 3.156) and in the optimization of protection and safety (para. 3.165).
Radioiodine Therapy and Pregnancy

• As a rule, a pregnant woman should not be treated with a radioactive substance unless the therapy is required to save her life: in that extremely rare event, the potential absorbed dose and risk to the fetus should be estimated and conveyed to the patient and the referring physician. Considerations may include terminating the pregnancy.

• Thyroid cancers are relatively unaggressive compared to most cancers. As a result both surgical and radioiodine treatment are often delayed until after pregnancy. In general, if any therapy is to be performed in pregnancy, it will be surgery during the 2nd or 3rd trimester.
Menstrual history is often not adequate to ensure that a patient is not pregnant. In most developed countries, it is common practice to obtain a pregnancy test prior to high-dose 131 I scanning or therapy for women of childbearing age unless there is a clear history of prior tubal ligation or hysterectomy precluding pregnancy.

In spite of the above, it still happens that pregnant women are treated, either because of false histories or because the pregnancy is at such an early stage that the pregnancy test is not yet positive.
Becoming Pregnant after Irradiation

ICRP has recommended that a woman not become pregnant until the potential fetal dose from remaining radionuclides is less than 1 mGy.
## Pregnancy after Therapy

<table>
<thead>
<tr>
<th>Radiopharmaceutical</th>
<th>All activities up to (MBq)</th>
<th>Avoid pregnancy (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au-198 colloid</td>
<td>10000</td>
<td>2</td>
</tr>
<tr>
<td>I-131 iodide (thyroid ca)</td>
<td>5000</td>
<td>4</td>
</tr>
<tr>
<td>I-131 iodide (thyrotoxicosis)</td>
<td>800</td>
<td>4</td>
</tr>
<tr>
<td>I-131 MIBG</td>
<td>5000</td>
<td>4</td>
</tr>
<tr>
<td>P-32 phosphate</td>
<td>200</td>
<td>3</td>
</tr>
<tr>
<td>Sr-89 chloride</td>
<td>150</td>
<td>24</td>
</tr>
<tr>
<td>Y-90 colloid (arthritic joints)</td>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>Y-90 colloid (malignancy)</td>
<td>4000</td>
<td>1</td>
</tr>
</tbody>
</table>

Radiation Protection in Radionuclide Therapy
Breast Feeding (BSS: Interim Edition)

• “3.176. Registrants and licensees shall ensure that there are arrangements in place for establishing that a female patient is not breast-feeding before the performance of any radiological procedure involving the administration of a radiopharmaceutical that could result in a significant dose to an infant being breast-fed, so that this information can be considered in the justification for the radiological procedure (para. 3.154 and 3.156) and in the optimization of protection and safety (para. 3.165).”

•
Breast Feeding


Uptake of pertechnetate in the breast of a lactating woman scheduled for a thyroid scan. The activity in the breasts is about 50% of the administered. The thyroid has an uptake of 1-2%.
“3.166. In accordance with para. 3.153(d) and (e), the medical physicist shall ensure that:

(a) All sources giving rise to medical exposure are calibrated in terms of appropriate quantities using internationally accepted or nationally accepted protocols;

3.164. For therapeutic radiological procedures in which radiopharmaceuticals are administered, the radiological medical practitioner, in cooperation with the medical physicist and the medical radiation technologist, and if appropriate with the radiopharmacist or radiochemist, shall ensure that for each patient the appropriate radiopharmaceutical with the appropriate activity is selected and administered so that the radioactivity is primarily localized in the organ(s) of interest, while the radioactivity in the rest of the body is kept as low as reasonably achievable.”
Safe Administration

- I-131 should be **administered in a controlled area** (hot lab or the patient’s hospital bedroom).
- A plastic bag for contaminated items should be available as well as paper tissues.
- The patient is asked to sit at a table covered with adsorbent pads and the floor beneath the patient should also be covered by adsorbent pads.
- If the I-131 is administered in capsules they should be transferred to the patient mouth by tipping from a small shielded (>1 cm Pb) container.
Safe Administration

• I-131 administered in an oral solution (50 ml) should be sucked up through a straw from the shielded vial by the patient.
• The vial should be flushed with water several times.
• The patient should drink several glasses of water to clean the mouth.
Safe Administration

• The prolonged infusion time and requirements for patient monitoring create a significant radiation hazard for staff.
• Local shielding will often be required to limit irradiation of the staff.
• Automatic methods of administration (e.g. a syringe pump) and remote patient monitoring devices should be used to minimise the time the staff need to spend in close proximity to the patient.

Procedure for intravenous administration:

• Dispense the radionuclide into a shielded syringe
• Put the radionuclide in an infusion bottle
• Line the bottle to the patient using an intravenous catheter
• Keep the patient in bed until the bottle is empty
• Remove the bottle and the catheter and dispose of them as radioactive waste
Shall the Patient be Hospitalized?

Can the patient leave?
Any restrictions?
Dose Constraints
(BSS: Interim Edition)

“3.172. Registrants and licensees shall ensure that relevant dose constraints (para. 3.148(a)(i)) are used in the optimization of protection and safety in any procedure in which an individual acts as a carer or comforter.”
Exposures From Patient

Contamination:
- saliva
- perspiration
- breath
- urine

External:
- 0.5 m
- 0.1 m
- 0.06 m
- 0.03 mSv/h

1000 MBq I-131
Biodistribution of I-131
Contamination

Administered activity: 1000 MBq I-131

<table>
<thead>
<tr>
<th>Excretion</th>
<th>Concentration</th>
<th>Contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saliva</td>
<td>&lt;2 MBq/g</td>
<td>utensils</td>
</tr>
<tr>
<td>Perspiration</td>
<td>&lt;20 Bq/cm²</td>
<td>surfaces</td>
</tr>
<tr>
<td>Breathing</td>
<td>100 Bq/l</td>
<td>air</td>
</tr>
<tr>
<td>Urine</td>
<td>&lt; 500 kBq/ml</td>
<td>toilet</td>
</tr>
</tbody>
</table>

Generally larger than the derived limits for contamination given by ICRP (publ 57)
Exposures from Patient

Sm-153

Activity concentration in urine: 0.3 MBq/ml/GBq
External Exposure from Patient Sm-153

Dose rate at 0.5 m

Mean dose rate (µSv/h\(^{-1}\)•GBq\(^{-1}\))

Time after injection (h)
For hyperthyroidism treatment, the patient should be kept at least 2h, and if possible one day in the hospital. In the case of cancer treatment, the patient should generally be hospitalized for several days.

In all cases, the dose rate at 1 m from the patient should be down to an acceptable level established by the RPC.
Patient Survey

Typical Graph of the Exposure Rate at 1 m from the Patient Administered with 5.5 GBq I-131

Days of Isolation

Exposure Rate (mR/hr)
Hospitalized Patient

- separate room with toilet and shower
- patient instructions (verbal and written)
- local rules for nursing the patient
- local rules for visitors (?)
- local rules for body fluid samples
- local rules for decontamination
- local rules for emergency situations
Room for Iodine Therapy (controlled area)

- only one patient in the room
- easily cleanable surfaces and utensils
- extra lead shields
- door closed
- warning sign outside
- restrictions for visitors
- decontamination equipment
Isolation Ward

Areas are covered with plastic backed absorbent material.

Bed shield is positioned

King Faisal Specialist Hospital and Research Center, Riyadh

― Radiation Protection in Radionuclide Therapy

M.R. Malisan • 44
Warning Signs

Radiation sign posted on door and on Patient Chart

King Faisal Specialist Hospital and Research Center, Riyadh

Radiation Protection in Radionuclide Therapy

M.R. Malisan 45
Patient Instructions

• Stay in the room.
• Drink as much as possible.
• Eat lemon slices.
• Use only the private toilet and flush 3 times. (Men should sit down to avoid splashing.)
• Wash hands well in soapy water after using toilet.
• Wear footwear when leaving the bed.
• In event of vomiting or incontinence notify the nurse immediately.
Instructions to Nursing Staff

• Consistent with patient safety and good quality medical care, reduce time spent with patient by planning ahead and working efficiently.

• Work as far from patient as possible.

• Practice preventative measures against contamination.
  - wear impermeable protection gloves
  - wear shoe covers
  - wear a protective gown

• Remove protection clothing before leaving the room.

• At exit, check personal contamination with hand-foot-clothing monitor.
Monitoring of Staff Internal Contamination

- Hand-Foot-Clothing Contamination
- Monitor
- Set calibration for various isotopes (Bq/cm² per cps)
- Set appropriate thresholds and alarms

<table>
<thead>
<tr>
<th>Background</th>
<th>Calibration</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 - 10 cps</td>
<td>0.74</td>
<td>100 cps</td>
</tr>
</tbody>
</table>

- Background Calibration Threshold
  - 9 - 10 cps: 0.74 Bq/cm²/cps
  - Threshold: 100 cps

- Radiation Protection in Radionuclide Therapy
Discharge of Patient

Typical Graph Showing the Percentage of I-131 that is Retained in the Body of a Patient Administered with 5.5 GBq

Abdalla Al-Haj
Decontamination of a general use room

The RPO should supervise the removal of contaminated waste, the decontamination of the room and equipment and should make a documented final survey of the room.

Monitoring and decontamination must be done prior to entry of nursing and housekeeping staff to prepare the room for the next patient.

When survey and decontamination procedures are complete, the RPO will remove the radiation warning sign and notify the nursing and housekeeping staff that the room is now clear for general use.
A “Radiation Safe” sign is posted at the door after decontamination and clearing of room.
Contamination Monitoring

Furniture and telephone sets are surveyed.

 Areas suspected to be contaminated are surveyed.

I-131 Derived Limit: 3 Bq/cm²

• Assay of removable contamination on potentially contaminated surfaces shall be performed at regular intervals and whenever contamination is suspected, using a «wipe test».

• Results shall be recorded and maintained for periods established by regulatory authorities.

King Faisal Specialist Hospital and Research Center, Riyadh
Nursing Instructions for Handling Laboratory Specimens
Taken from Patients Receiving Radionuclide Therapy

1. Any lab specimen taken from a patient receiving radionuclide therapy must first be labeled with the appropriate patient identification. In addition to that a radiation warning label must also be attached to the specimen container and to the lab requisition. A copy of the lab instructions must also be attached to the requisition. Finally, the specimen container must be placed in a zip-lock type plastic bag for transport to the laboratory. CALL THE RECEIVING LABORATORY TO ALERT THEM THAT A RADIOACTIVE SPECIMEN IS COMING. A RUNNER MUST TAKE THE SPECIMEN DIRECTLY TO THE LABORATORY.

2. Radiation warning labels, lab instructions, and zip-lock bags may be found in the LAB KIT placed in the patient's room by the technologist handling the therapy dose administration. THIS KIT MUST STAY IN THE PATIENT'S ROOM AT ALL TIMES!!!!
Radioactive Waste

- **Solid waste.**
  Cover papers, gloves, empty vials and syringes. Items used by hospitalized patients after radionuclide therapy.

- **Liquid waste.**
  Patient excreta.

- **Gaseous waste.**
  Exhausted gas from treated patients
Radioactive Waste

Shall be collected, segregated and disposed of according to national regulations and local rules.
Radioactive Waste

- Faeces, urine and other liquids should be disposed of via the toilet.

- Contaminated clothing, linen, food items etc which can not go into the toilet should be stored in a separate plastic bag labeled 'RADIOACTIVE', and should be removed daily to the designated radioactive waste storage facility.

- Disposable cutlery and dishes should be used. If not, they should be washed in the patient’s room and reused by the patient.
Radioactive Waste

All patient radioactive wastes are placed in a plastic bag and the bag is properly tagged.
Storage of radioactive waste

A room for interim storage of radioactive waste should be available. The room should be locked, properly marked and if necessary ventilated.

Each type of waste should be kept in separate containers properly labeled to supply information about the radionuclide, activity concentration etc. Flammable goods should be kept apart.

Records should be kept where the origin of the waste can be identified.

Short-lived radionuclides such as I-131, Sm-153, Sr-89 etc. should, after segregation, be stored for decay during a period of time established locally by the RPO, taking into account all applicable national regulations.
Storage of radioactive waste

- Patient wastes generated from radionuclide therapies may need to be stored for decay for periods from 1 week to several months depending on the activity and radionuclide used.
- Wastes should be stored until a survey indicates that only background levels of activity are present.
PATIENT EXCRETA

Therapy patients

Different policies in different countries:

• Use separate toilets equipped with delay tanks or an active treatment system, or

• Allow the excreta to be released directly into the sewer system.

The Regulatory Authority should define the principles taking the environmental impact into consideration
I-131 LIQUID DISCHARGES

in University Hospital in Udine (Italy)

- \(~100\) pts/year
- \(~5.55\) GBq/pt
- Annual limit of discharge: 70 MBq (\(~0.01\%\) of administered activity)
- Limit for discharge into public sewage: 1 Bq/l
I-131 LIQUID DISCHARGE

Sewer system for decay storage in University Hospital in Udine (Italy)

15 m³
Staff Monitoring: External monitoring

• Personal monitoring for external exposure shall be performed for all occupationally-exposed individuals, according to RSO classification.

• Extremity dosimeters shall be worn when an individual’s extremities are expected to be closer to the source than the body.
Monitoring of Staff Internal Contamination

- Bioassay is used to determine the activity present in an individual.
- The optimal type of bioassay procedure to use depends on:
  - Chemical and physical form of the radioactive material
  - Radiation emissions; Mode of intake
  - Biodistribution and half-lives in the body.
- By application of appropriate biological models, bioassay measurements are converted to body or organ activity burdens and, finally, to absorbed doses.
- Personnel who prepare or administer therapeutic amounts of radioiodine should be monitored due to the volatilization and inhalation of the radioiodine as a gas.
- Thyroid burden should be measured with a thyroid uptake probe within 1-3 days after the administration.
Monitoring of Staff Internal Contamination

• Routine Monitoring and Special Monitoring after accidental contamination.

• Procedures for bioassay and estimates of doses should be a part of the institution’s policy and procedure manual.
Monitoring of Staff Internal Contamination

ICRP 78

INDIVIDUAL MONITORING FOR INTERNAL EXPOSURE OF WORKERS

Iodine-131 (half-life = 8.0 d)

Table A.6.15. Emissions

<table>
<thead>
<tr>
<th>Radiation</th>
<th>Energy (MeV)</th>
<th>Intensity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta^-$</td>
<td>0.19&lt;sup&gt;a&lt;/sup&gt;</td>
<td>89</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.36</td>
<td>81</td>
</tr>
</tbody>
</table>

<sup>a</sup>Average energy

Table A.6.16. Measurement techniques

<table>
<thead>
<tr>
<th>Method of measurement</th>
<th>Typical detection limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma$-ray spectrometry in vivo</td>
<td>Thyroid</td>
</tr>
<tr>
<td>$\gamma$-ray spectrometry on biological samples</td>
<td>Urine</td>
</tr>
</tbody>
</table>
I-131 Special Monitoring

- Monitoring carried out in actual or suspected abnormal conditions.
- Necessary to know the time of possible intake.

Iodine-131 presents no detection problems. The urinary excretion rate decreases rapidly with time following intake and so thyroid monitoring is to be preferred unless the actual time of intake is known. Monitoring by urinary excretion would be required if thyroid uptake had been blocked.

ICRP 78 Table A.6.17. Special monitoring: predicted values (Bq per Bq intake) for inhalation of $^{131}$I

<table>
<thead>
<tr>
<th>Time after intake (d)</th>
<th>Type F</th>
<th></th>
<th>Vapour</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thyroid</td>
<td>Daily urinary excretion</td>
<td>Thyroid</td>
<td>Daily urinary excretion</td>
</tr>
<tr>
<td>1</td>
<td>1.2E-01</td>
<td>2.8E-01</td>
<td>2.3E-01</td>
<td>5.3E-01</td>
</tr>
<tr>
<td>2</td>
<td>1.2E-01</td>
<td>2.3E-02</td>
<td>2.2E-01</td>
<td>4.3E-02</td>
</tr>
<tr>
<td>3</td>
<td>1.1E-01</td>
<td>1.4E-03</td>
<td>2.0E-01</td>
<td>2.5E-03</td>
</tr>
<tr>
<td>4</td>
<td>9.9E-02</td>
<td>1.5E-04</td>
<td>1.9E-01</td>
<td>2.7E-04</td>
</tr>
<tr>
<td>5</td>
<td>9.0E-02</td>
<td>8.9E-05</td>
<td>1.7E-01</td>
<td>1.7E-04</td>
</tr>
<tr>
<td>6</td>
<td>8.2E-02</td>
<td>9.6E-05</td>
<td>1.5E-01</td>
<td>1.8E-04</td>
</tr>
<tr>
<td>7</td>
<td>7.4E-02</td>
<td>1.0E-04</td>
<td>1.4E-01</td>
<td>1.9E-04</td>
</tr>
<tr>
<td>8</td>
<td>6.8E-02</td>
<td>1.1E-04</td>
<td>1.3E-01</td>
<td>2.0E-04</td>
</tr>
<tr>
<td>9</td>
<td>6.2E-02</td>
<td>1.1E-04</td>
<td>1.2E-01</td>
<td>2.1E-04</td>
</tr>
<tr>
<td>10</td>
<td>5.6E-02</td>
<td>1.1E-04</td>
<td>1.1E-01</td>
<td>2.1E-04</td>
</tr>
</tbody>
</table>
I-131 Routine Monitoring

- Routine monitoring involves regular measurements on individual workers.
- It is only required in conditions of essentially continuous risk of contamination of the workplace as a result of normal operations.
- Necessary to assume a pattern of intake in order to interpret the measurements, usually at the mid-point of the monitoring interval.

ICRP 78

INDIVIDUAL MONITORING FOR INTERNAL EXPOSURE OF WORKERS

Table A.6.19. Routine monitoring: predicted values (Bq per Bq intake) for inhalation of $^{131}$I

<table>
<thead>
<tr>
<th>Monitoring interval (d)</th>
<th>Thyroid</th>
<th>Daily urinary excretion</th>
<th>Vapour</th>
<th>Daily urinary excretion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type F</td>
<td></td>
<td>Vapour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thyroid</td>
<td>Daily urinary excretion</td>
<td>Thyroid</td>
<td>Daily urinary excretion</td>
</tr>
<tr>
<td>30</td>
<td>(3.5E–02)</td>
<td>9.8E–05</td>
<td>(6.6E–02)</td>
<td>1.8E–04</td>
</tr>
<tr>
<td>14</td>
<td>7.4E–02</td>
<td>1.0E–04</td>
<td>1.4E–01</td>
<td>1.9E–04</td>
</tr>
<tr>
<td>7</td>
<td>9.9E–02</td>
<td>1.5E–04</td>
<td>1.9E–01</td>
<td>2.7E–04</td>
</tr>
</tbody>
</table>

*Values in brackets do not satisfy the requirements set out in Section 6
HELP!
A safety assessment will reveal the possible situations where emergency actions have to be taken:

- Loss or damage of radioactive material
- Spillage of radioactive material
- Fire
- Medical emergencies
- ...

A detailed contingency plan covering actions to be taken in any foreseeable accident should be available.
Cardiac or Respiratory Arrest

- Lifesaving efforts shall take precedence over consideration of radiation exposure received by medical personnel.

- These procedures may result in contamination of the hands, gloves and clothing of involved medical personnel.

- Decontamination of these personnel and of the location where the medical emergency has taken place should be undertaken by radiation safety staff once the medical emergency has been resolved.

NCRP Report n. 155
Emergency surgery

• Consideration of radiation exposure should not deter the surgery from proceeding.

• If possible, **consult the RSO**. If not possible, and the situation is life-threatening, the surgery should proceed and the necessary information should be conveyed to the surgical team a.s.a.p.

• Standard precautions always used in surgical settings will minimize the spread of radioactive contamination and the risk of internal contamination to OR personnel.

• Tools and other equipment from the surgery should be monitored and decontaminated as necessary, or stored for decay or reated as radioactive waste.

NCRP Report n. 155

• Radiation Protection in Radionuclide Therapy

M.R. Malisan 72
Patient on Dialysis

- These pts will not clear radioactive materials as quickly as other pts, and the clearance will generally not take place until the patient undergoes a dialysis session.
- So the administered activity should be based on a trial administration, to observe the elimination rate.
- The largest amount of activity will usually be eliminated during the 1st dialysis session.
- Before, consult the RSO to assess the radiation exposures likely to be received by medical personnel.
- The materials, tubing, filters and waste containers used in the dialysis session should be checked and stored for decay.
- The volume of fluids used during dialysis should be sufficient to dilute the radioactive concentration below regulatory limits for sewer discharge.

NCRP Report n. 155
Death of Patient

In the event of death of a patient who has recently received a therapeutic dose of a radionuclide, care has to be taken to ensure that personnel receive as low a dose as possible at all stages prior to the burial or cremation.

Table 10: Maximum activities proposed for autopsy, embalming, burial or cremation of the body of a patient who has died during treatment with unsealed radioactive substances (IAEA 2007)

<table>
<thead>
<tr>
<th></th>
<th>Half life (days)</th>
<th>Indicative maximum activity administered (MBq)</th>
<th>Autopsy/Embalming (MBq)</th>
<th>Burial (MBq)</th>
<th>Cremation (MBq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{32}\text{P}$</td>
<td>14.3</td>
<td>200</td>
<td>100</td>
<td>2 000</td>
<td>30</td>
</tr>
<tr>
<td>$^{89}\text{Sr}$</td>
<td>50.7</td>
<td>200</td>
<td>50</td>
<td>2 000</td>
<td>20</td>
</tr>
<tr>
<td>$^{90}\text{Y}$</td>
<td>2.7</td>
<td>2 000</td>
<td>200</td>
<td>2 000</td>
<td>70</td>
</tr>
<tr>
<td>$^{131}\text{I}$</td>
<td>8.0</td>
<td>10 000</td>
<td>10</td>
<td>400</td>
<td>400</td>
</tr>
</tbody>
</table>

Note: Samarium-153, an alternative to strontium-89 for the palliation of malignant bone disease, is not included in Table 10 as the short half life of 1.95 days allows significant reduction in residual activity after a few days delay.
Death of Patient

Precautions that should be given are depending on the residual activity and the expert advice provided by the RPO and may involve the following:

- preparation for burial or cremation should be controlled by a competent person,
- relatives should be prevented from coming into close contact with the body,
- people should not be allowed to linger in the presence of the coffin,
- all personnel involved in handling the corpse should be instructed by the RPO and monitored if appropriate,
- all objects, clothes, documents etc that might have been in contact with the deceased must be tested for contamination,
- it may be expedient to wrap the cadaver in waterproof material immediately after death to prevent spread of contaminated body fluids,
- embalming of cadavers should, if possible, be avoided,
- autopsy of highly radioactive cadavers should be restricted to the absolute minimum
Thank you for listening!