Releasing Nuclear Medicine Patients to the Public: Dose Calculations and Discharge Instructions

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Educational Objectives

• Introduce participants to the medical conditions that are treated with radioiodine.
• Review the regulatory considerations regarding inpatient and outpatient radioiodine procedures.
• Review ways in which the regulatory requirements may be satisfied, including “public” radiation dose computations, content of post-discharge instructions and addressing the concerns of patients and their families.
• Introduce Web-based methods to facilitate documentation of outpatient treatment.

Medically Useful Iodine Isotopes

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Half-life</th>
<th>Primary Emissions</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-123</td>
<td>13.3 hours</td>
<td>γ (0.158 MeV)</td>
<td>Diagnosis</td>
</tr>
<tr>
<td>I-124</td>
<td>4.2 days</td>
<td>β⁺ and γ (0.511 MeV +)</td>
<td>Diagnosis, Therapy(?)</td>
</tr>
<tr>
<td>I-125</td>
<td>59.4 days</td>
<td>γ (0.035 MeV)</td>
<td>Brachytherapy</td>
</tr>
<tr>
<td>I-131</td>
<td>8.0 days</td>
<td>β⁻ (0.606 MeV), γ (0.364 MeV)</td>
<td>Diagnosis, Therapy</td>
</tr>
</tbody>
</table>

Treatment of Toxic Goiter

• Surgery (not done, except for very large thyroid, low iodine uptake, cancer or pregnancy)
• Drugs (propylthiouracil) and beta blockers (short-term)
• Ablation with radioactive iodine

Radioiodine Treatment

• I-131 sodium iodide solution, orally
• 8 – 15 millicuries for diffuse toxic goiter
• 15 – 40 millicuries for toxic multinodular goiter
• Must know the % uptake at 24 hours to compute administered activity and clearance rates

Thyroid Carcinoma

• Incidence: about 3 per 100,000 per year
• Females > Males (2:1)
• About 80% papillary type; remainder follicular or medullary types.
• Medullary thyroid carcinoma does not take up radioiodine.
Diagnosis of Thyroid Carcinoma

- Usually asymptomatic except for a painless neck mass.
- "Cold" nodule on Tc-99m pertechnetate scintigraphy.
- Non-cystic mass on ultrasound.
- Fine needle aspiration of nodule.

Treatment of Thyroid Carcinoma

- Surgical removal of thyroid gland and dissection of local lymph nodes.
- Total body diagnostic I-131 scan after withdrawal of thyroid hormone to detect metastatic disease.
- I-131 sodium iodide, 150 – 200 millicuries administered orally to ablate remaining thyroid and metastases.

"Neuroendocrine" Tumors

- Carcinoid Tumors
- Pheochromocytoma
- Neuroblastoma (mainly children)
- Medullary Thyroid Carcinoma

Carcinoid Tumors

- Incidence: About 25 / million / year
- Most arise somewhere in the GI tract (75%) or lungs (25%).
- Usually small and do not cause symptoms (benign).
- Malignant ones can metastasize to liver, bone and lung.

Treatment of Carcinoid Syndrome

- Surgery
- Embolization of liver metastases
- I-131 MIBG
- Yttrium-90 Octreotide

Non-Hodgkin’s Lymphoma

- Incidence: About 200 / 100,000 per year in U.S (7 – 8 times more common than Hodgkin’s Disease)
- Average age at diagnosis: 60
- Diffuse disease involving lymph nodes and bone marrow
- B-cell and T-cell types
Treatment of Non-Hodgkin’s Lymphoma

- External beam irradiation of mantle field and/or pelvic lymph nodes
- Chemotherapy
- Immunotherapy with monoclonal antibodies against B-cells (MAB)
- Radioimmunotherapy: I-131 MAB or Y-90 MAB

Treatment with I-131 MAB

- Serial images with I-131 MAB (5 mCi) to determine total body clearance half-time.
- Titrate administered therapy activity based on clearance half-time.
- Precede I-131 MAB with infusion of non-labeled MAB.
- Administer 80 – 120 mCi via slow intravenous infusion.

The Reasons We Have Release Regulations Are...

- To ensure that radiation exposure to the public is ALARA.
- To reassure concerned members of the public that the “risk” from radiation patients is manageable and under authoritative control.

I-131 Patient Release: History

- Prior to 1997, criteria for release were based strictly upon activity or dose-rate.
- OK to Release if: < 30 millicuries, or < 5 mrem per hour at one meter.
- After 1997, criteria based upon expected radiation dose to a “member of the public” being < 500 millirem.

Current Regulatory Criteria

- Criteria are “risk-based” rather than “rules-based”.
- Can be adapted to other therapeutic radionuclides, not just I-131.
- Flexible approach to determination of expected dose to public.

Current Regulatory Requirements

- Written Instructions on minimizing exposure to others must be provided to patient if a member of the public could receive > 100 mrem.
- Patient may be released if “public dose”, as demonstrated by “default criteria” or by licensee’s computation, is < 500 mrem.
**Current Regulatory Requirements**

- **Written Documentation** of release is required if licensee’s computation is based on assumptions other than those underlying the “default criteria”.
- Documentation must be maintained by the licensee for three years.

**Where to Find Regulations and Regulatory Guidance**

- **10 CFR 35.75**, “Release of Individuals Containing Unsealed Byproduct Material or Implants Containing Byproduct Material”.
  - [www.nrc.gov > Electronic Reading Room > Regulations (10 CFR)]
- **NUREG 1556, Vol. 9, Appendix U** (formerly Regulatory Guide 8.39)
  - [www.nrc.gov > Electronic Reading Room > Document Collections > NUREG-Series Publications]

**“Default” I-131 Release Criteria**

- < 33 millicuries administered, or < 7 mrem/hr at one meter → FREE TO GO. Need only written instructions (generic; provided by Nuclear Medicine).
- Based on: patient is an unshielded point source, and only elimination is by physical decay (conservative).

**“Default” I-131 Release Criteria**

\[
D = 1.44 \times T_{1/2} \times O \times R
\]

\(D=\) “Public” dose
\(T_{1/2} =\) physical half-life (hr)
\(O =\) Occupancy factor at one meter
\(R =\) Dose rate at one meter (mrem/hr)

For \(T_{1/2} = 196\) hr, \(O = .25\) and \(R = 7\) mrem/hr, \(D = 500\) mrem.

**Licensee’s Computation**

- May assume non-point source geometry.
- May assume tissue shielding.
- May take biological clearance into account.
- May assume occupancy factor different than 0.25 at one meter.

**Licensee’s Computation**

\[
D = O \int_{0}^{\infty} R(t) \, dt
\]

\(R(t)\) at 1 m

**I-131 MIBG Clearance**

<table>
<thead>
<tr>
<th>Fraction</th>
<th>0.0</th>
<th>0.5</th>
<th>1.0</th>
</tr>
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<tbody>
<tr>
<td>Hours Post-administration</td>
<td>104.5</td>
<td>209</td>
<td>313.5</td>
</tr>
</tbody>
</table>

- **I-131 MBG/Clearance**

\[
I-131 \text{ MBG/Clearance} = \frac{I_{131}}{C_{\text{clearance}}}
\]
**External Dose From a Thyroid Cancer Patient**

\[ D = O \left( 1.44 \cdot T_{1/2} \cdot R_0 \right) \]

- **D** = “Public” dose
- **T_{1/2}** = effective half-life (hr)
- **O** = Occupancy factor at one meter
- **R_0** = Dose rate at one meter (mrem/hr)

For \( T_{1/2} = 18 \) hr, \( O = 0.25 \) and \( R = 12 \) mrem/hr, \( D = 97 \) mrem.

**What About Internal Irradiation?**

- Radioiodine from therapy patients may be excreted in their urine, perspiration and saliva.
- These body fluids can contaminate household surfaces.
- Family members might ingest this contamination through hand-to-mouth contact.

**Instructions Should Address...**

- Public transportation.
- Children, pregnant women and nursing mothers.
- Spouse or spousal equivalent.
- Visitors and co-workers.
- Time-Distance considerations.
- Length of time to limit interaction.

**What About Internal Irradiation?**

- Assume one part in 100,000 of the radioactivity administered to patient (AA) is ingested by a family member.
- Compute effective dose to family member from ingestion: \( D = 10^{-5} \) (AA) (53 rem/mCi)
- If greater than 10% of computed external dose, must include it in total dose computation.

**For Example...**

- Avoid airplanes and buses at first.
- Limit interactions with others.
- Stay six feet or more away from children and pregnant women.
- Spouse sleeps in a separate bed.
- Use separate bathroom.
- Shower / brush teeth frequently.

**How Long Should Patients Limit Interaction?**

- The higher the computed “general public” dose, the longer the time certain activities should be avoided.
- Times to avoid certain activities can be calculated based on the estimated “public dose”.

**For Example...**

- Avoid airplanes and buses at first.
- Limit interactions with others.
- Stay six feet or more away from children and pregnant women.
- Spouse sleeps in a separate bed.
- Use separate bathroom.
- Shower / brush teeth frequently.
Maintaining Release Records

- No record required if patient released according to default criteria (< 33 mCi or 7 mrem/hr at one meter).
- Otherwise, release must be documented, and the documentation maintained for three years.
- Specific information regarding the release must be included.

Release Record Must Include...

- Patient identifier (NOT Name).
- Release activity and dose rate at one meter.
- Survey instrument used.
- Estimated “public” dose (mrem).
- Effective half-life used in computation of dose.
- Method used to compute dose.
- Times to limit certain activities.

Duke’s Implementation of Release Regulations

- Uses initial dose rate at one meter.
- Uses Duke population clearance curves for different treatments.
- Data for a patient is entered into a Web site.
- Web site calculates expected “general public” dose and creates a set of instructions and documentation.

The Radiation Safety Tech...

- Interviews the patient to determine home situation, transportation, work, visitors and capacity for self-care.
- Obtains dose rate measurement at one meter from patient.
- Uses Web site to create “customized” instructions and release documentation.
- Maintains documentation for three years.

Alternative to Web Site

- Interview patient, obtain effective half-life and measure dose rate.
- Look up “public dose” in pre-computed tables and release patient if < 500 millirem.
- Look up length of time instructions are to be followed in tables.
- Fill in pre-printed instruction form.

What About Homeland Security?

- Extremely sensitive radiation detectors are deployed in train stations, airports, tunnels, etc.
- I-131 patients may set off alarms up to 95 days following a procedure.*
- Society of Nuclear Medicine recommends giving patients letter containing radionuclide and hospital contact information.