# PRACTICAL RADIATION PROTECTION AND SAFETY ISSUES IN THERAPEUTIC NUCLEAR MEDICINE

LYDIA ANGELIKI ZOGLOPITOU

MEDICAL PHYSICIST, MSC, MPE, RPE

THEAGENIO CANCER HOSPITAL, THESSALONIKI, GREECE

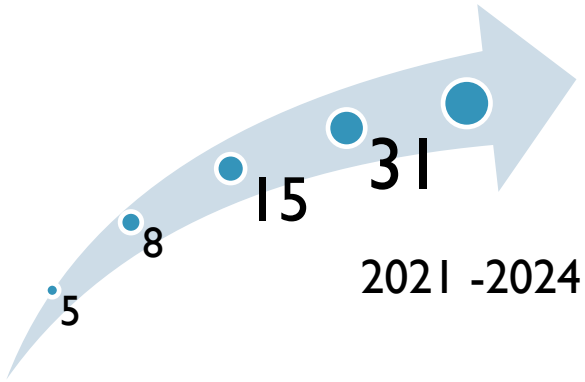
# OUTLINE

- Advancement of therapies
- Therapeutic Workflow
- Therapy Rooms
- Radioactive Waste
- Radiation Protection
- Challenges

# ADVANCEMENT OF THERAPIES IN RADIONUCLIDE THERAPY (RNT)

| Radionuclide | Application | Emission Type | Typical Dose Range |
|---|---|---|---|
| **I-131 (NaI)** | Benign thyroid disease | $\beta^-$, $\gamma$ | 150–1,500 MBq |
| | Malignant thyroid disease | $\beta^-$, $\gamma$ | 2–20,000 MBq |
| **I-131 (MIBG)** | Neuroendocrine tumors | $\beta^-$, $\gamma$ | 1.8–11,000 MBq |
| **Lu-177 (PSMA)** | Metastatic prostate cancer | $\beta^-$, $\gamma$ | 7,400 MBq |
| **Lu-177 (DOTA)** | Neuroendocrine tumors (NETs) | $\beta^-$, $\gamma$ | 7,400 MBq |
| **Y-90** | Liver cancer (microspheres) | $\beta^-$ | 0.2–10 GBq |

Theagenio Lu-177 (PSMA) Patients



# WHO DO WE NEED TO PROTECT

Patients

Staff

Public and care givers

Environment
Waste

Risk of unnecessary exposure to healthy tissues or caregivers.

Handling high-dose radiopharmaceuticals increases exposure risk.

Potential contamination from patient excreta or improper waste disposal.

# PRACTICAL FACTORS AFFECTING RADIATION SAFETY IN RNT

- **Radiopharmacy Safety**

  Ordering, storage, dispensing, waste management

- **Safe Administration**

  Patient ID, pregnancy checks, infusion protocols, extravasation prevention

- **Patient Preparation**

  Dose constraints, safe infusion practices

- **Therapy Patient Management**

  Nursing/visitor instructions, radiation monitoring, discharge, waste

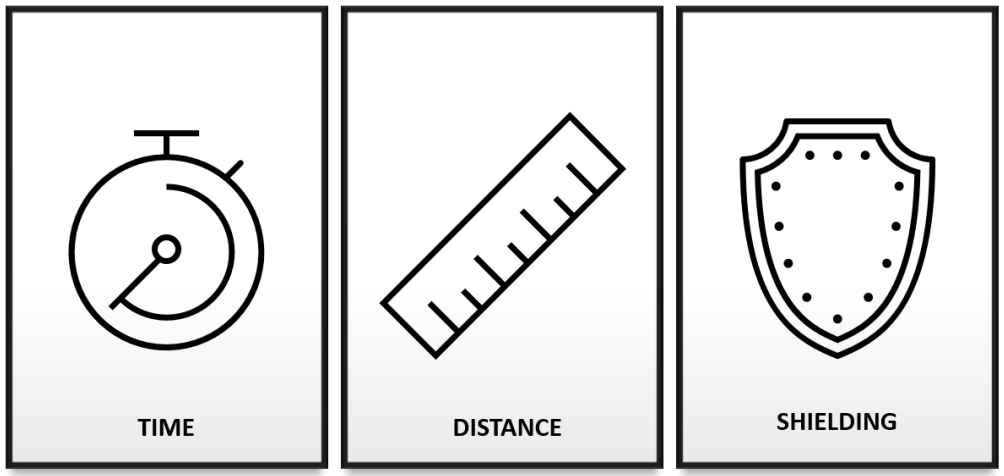
- **Emergency Procedures**

  Decontamination

- **Quality Management**

  Ensures safety, consistency, improved outcomes, and reduced wastage

# RADIATION PROTECTION




- **Justification**

  Benefits outweigh the risks

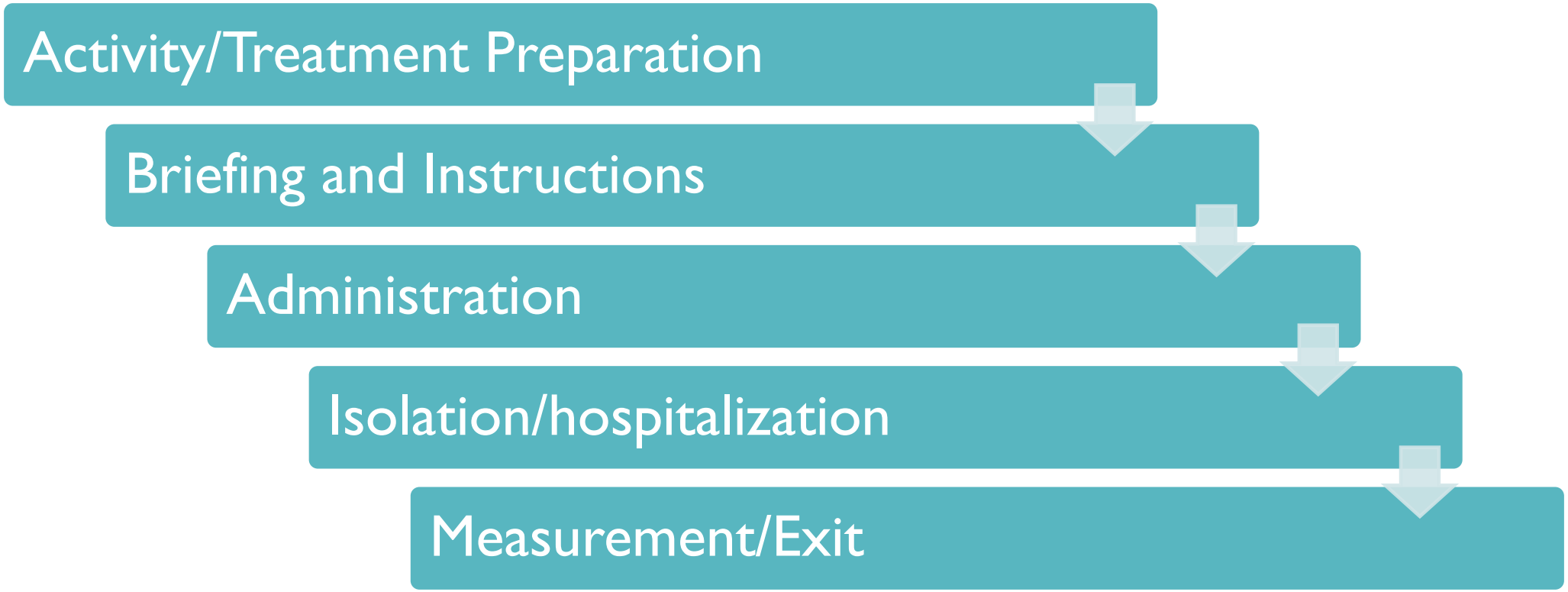
- **Optimization**

  As low as reasonably achievable (ALARA)

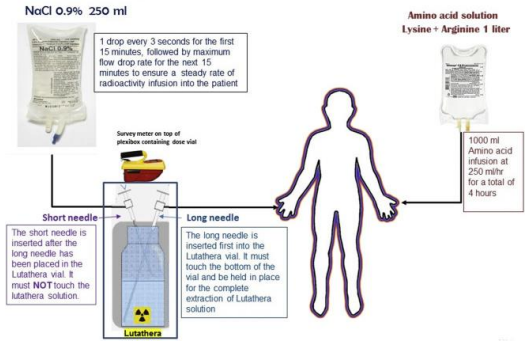
- **Limitation**

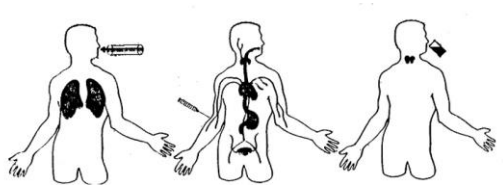
  **Staff and caregivers** must comply strictly with these limits using proper protective measures

# WORKFLOW OF RNT



# ADMINISTRATION



- Radiopharmaceutical is administered (IV, oral, or intra-arterial)

- Check with contamination meter after each procedure for potential contamination

# HOSPITALIZATION - THERAPY ROOMS

| Therapy | Typical Hospital Stay | Key Reasons for Admission |
|---|---|---|
| **I-131 (High Dose)** | 2-3 days | High gamma emissions (>1,000 MBq) |
| **Lu-177 (High Dose)** | 1 day ? | Monitoring and gamma emmisions? |
| **Y-90 Microspheres** | Overnight? | Post-embolization monitoring |
| **Ra-223 (Xofigo)** | Outpatient | Low gamma emissions |

- High-dose radiopharmaceuticals (e.g., I-131) require controlled isolation.
- Risks: External exposure (gamma/beta radiation), contamination, and public exposure.

# THERAPY ROOMS

**A. Recommended Placement**

- **Dedicated, isolated wing** (preferably ground floor)
- **Adjacent to but separate from** diagnostic nuclear medicine areas
- **Near patient access points**
- **Close to nursing stations**

**B. Prohibited Locations**

- ❌ **Near pediatric or maternity wards**
- ❌ **Next to PET-CT or gamma camera rooms**
- ❌ **High-traffic corridors**

# THERAPY ROOMS


**Room Design Features**

- **Self-contained ventilation**
- **Smooth, non-porous surfaces**, floors should **be curved to the wall**
- **Easy to decontaminate**
- **Dedicated bathroom**
- **Intercom/camera system**
- **Wall-mounted radiation survey monitor**
- **Waste bins**

# THERAPY ROOMS

- Only one patient in the room
- Easily cleanable surfaces
- Extra lead shields
- Door closed
- Warning signs outside the room
- Restriction for visitors
- Decontamination equipment

# INSTRUCTIONS DURING HOSPITALIZATION – ISOLATION PROTOCOL

Therapeutic doses  always require **strong protocols**

- Stay in the room
- Drink more than usual
- Use only the private toilet in the room
- Men should sit down on toilet to avoid splashing
- Wash hands well in soapy water after using the toilet
- Wear footwear when leaving the bed
- In event of vomiting or incontinence notify the nurse immediately
- Daily radiation surveys at 1m from patient

# RADIOACTIVE WASTE

- Patients treated with radionuclides become radiation sources
- Contamination risks: Clothing, medical devices (catheters, urine bags), diapers, and hospital items (dishes, bedding)
- Disposal: All contaminated items must be treated as radioactive waste
- Need for strong protocols

# RADIOACTIVE WASTE MANAGEMENT FOR COMMON RADIONUCLIDE THERAPIES

| WASTE TYPE | I-131 (IODINE-131) | LU-177 (LUTETIUM-177) | Y-90 (YTTRIUM-90) |
|---|---|---|---|
| **Patient Excreta** | - **High risk**: Urine/feces highly radioactive (1–3 days post-therapy).<br>- Use decay tanks or dilution (if permitted). | - **Moderate risk**: Urine radioactive.<br>- Storage or dilution. | - **Low risk**: Minimal excretion via urine.<br>- Standard sewage disposal typically safe. |
| **Contaminated Items** | - Bedding, clothing, diapers, utensils.<br>- Store as solid radioactive waste (decay ~10T1/2). | - Gloves, syringes, IV lines.<br>- Store as solid waste . | - Sharps, vials, PPE.<br>- Store as solid waste |
| **Medical Devices** | - Catheters, urine bags.<br>- Treat as liquid/solid waste; decay storage. | - IV tubing, injection kits.<br>- Short-term decay | - Microspheres, needles.<br>- Dispose as sharps waste. |
| **Notes** | - **Isolation**: Patients may need 2–3 days in controlled rooms.<br>- **Ventilation**: Avoid airborne exposure. | - **Shielding**: Low-energy β/γ; minimal shielding needed.<br>- **Hydration**: Flush residuals via urine. | - **Pure β-emitter**: No gamma shielding needed.<br>- **Institutional Review**: Confirm no particulate release. |

# MANAGING RADIOACTIVE WASTE

**Patient Excreta: Risks and Disposal Strategies**

- Urine/feces are radioactive waste

**Disposal methods:**

- Dilution: Direct sewage discharge
- Storage: Decay tanks for high-activity waste (common in nuclear medicine departments)
- Environmental caution: Avoid rapid discharge

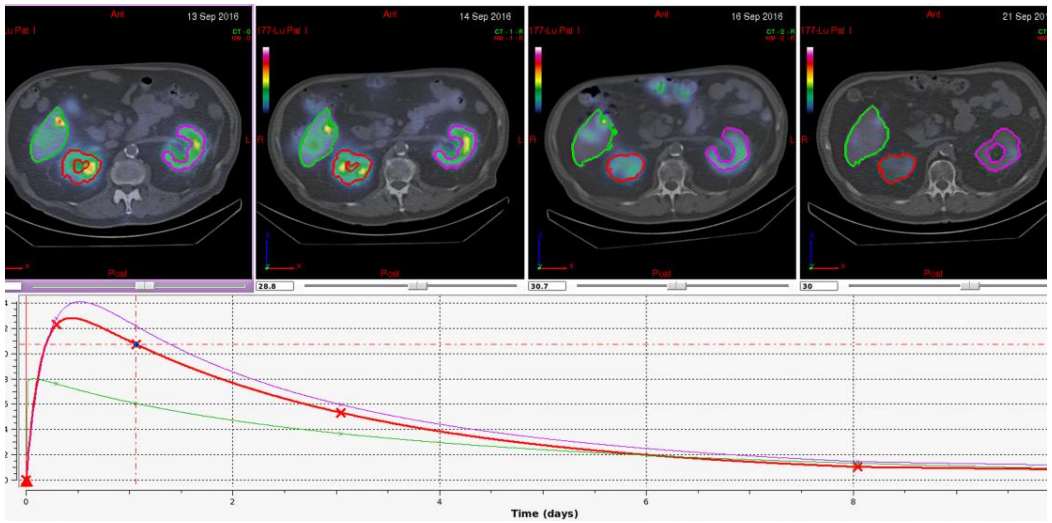
**Alternative: Filtered toilet systems**

- Pros: No tanks needed; easy installation
- Cons: Recurring costs for filter cartridges

# PATIENT RADIATION PROTECTION

- ✓ **Verify** patient **identity** & **pregnancy**/ **breastfeeding** status
- ✓ **Review** contraindications (e.g., renal/hepatic impairment)
- ✓ Assess **home/family situation** (e.g., young children, shared bathrooms).
- ✓ Educate on **radiation safety precautions** (e.g., flushing toilet twice, avoiding close contact).
- ✓ Obtain informed **consent** (radiation risks, isolation protocols)
- ✓ **Confirm** correct radionuclide, dose, and route

# PATIENT SPECIFIC DOSIMETRY




- Why Patient-Specific Dosimetry?
- 📉 Minimizes toxicity (e.g., bone marrow, kidneys)
- 🎯 Maximizes tumor dose (e.g., Lu-177 PSMA,)

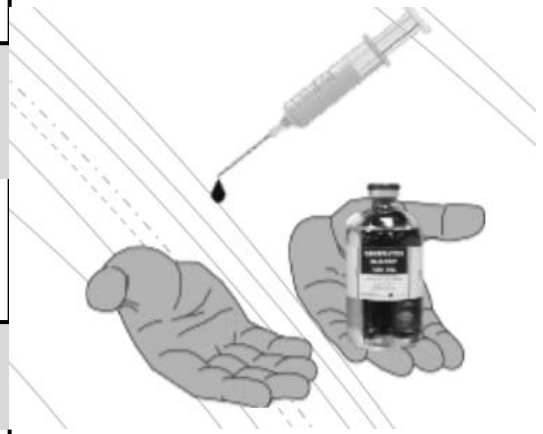
# OCCUPATIONAL EXPOSURE RISKS IN RADIONUCLIDE THERAPY

**Steps with Exposure Risks:**

- Receipt & Storage
- Handling radioactive shipments
- Storing radionuclides
- Preparation & Dispensing
- Drawing, diluting, or measuring radiopharmaceuticals
- Spills or leaks during vial manipulation
- Administration
- Direct handling during patient injection/infusion
- Proximity to the patient post-administration
- Waste Handling
- Disposing of contaminated materials
- Patient Care
- Close contact with high-activity patients

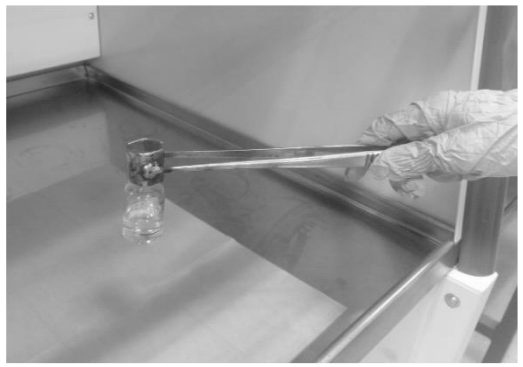
# OCCUPATIONAL EXPOSURE RISKS IN RADIONUCLIDE THERAPY

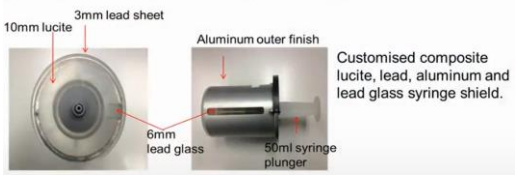
| Category | Occupational Limit | Public Limit | Therapy-Specific Risks | Safety Measures |
|---|---|---|---|---|
| **Effective Dose** | 20 mSv/year (5-yr avg) | 1 mSv/year | - | Follow ALARA principles |
| **Lens of the Eye** | 150 mSv/year | 15 mSv/year | - | Wear lead goggles if handling high-energy emitters (e.g., 90Y) |
| **Skin/Extremities** | 500 mSv/year | 50 mSv/year | **$^{177}$Lu**: Fingertip dose 1–44 µSv/GBq (radiolabeling highest risk) | Automated systems (↓ dose to 3 µSv/GBq); use tongs/shields |
| **Hands/Feet** | 500 mSv/year | – | **$^{131}$I (capsules)**: Negligible (patient self-administers) | Minimal PPE required |
| **N/A** | – | – | **SIRT (resin/glass)**: No significant worker exposure | Standard PPE sufficient |



*ICRP, 2007, Sgouros et al., 2022, Zanzonico et al., 2018*

# PROTECTIVE MEASURES TO MINIMIZE EXPOSURE






- **Time**
  - Minimize time spent near radioactive sources
  - Use quick, well-practiced procedures
- **Distance**
  - Use tongs and long-handled tools
  - Maintain maximum feasible distance from sources
- **Shielding**
  - Shields for vials and syringes
  - Portable barriers for high-dose preparations

# PROTECTIVE MEASURES TO MINIMIZE EXPOSURE

- **Contamination Control**
  - Work in fume hoods for volatile radionuclides
  - Use absorbent pads and spill kits
- **PPE**
  - Gloves, lab coats, goggles
  - Disposable shoe covers in contamination zones

# SAFETY PRACTICES

**For All Staff:**

- Wear **dosimeters** (TLD/OSL badges) for exposure tracking.
- Regular **training** on emergency protocols (spills, accidental exposure)
- Work not fast but accurate

- **ALARA Principle (As Low As Reasonably Achievable)** must guide all actions

# CARERS & COMFORTERS

- Patients with mobility issues require special handling
- Their companions may stay in the isolation rooms
- A planned exposure assessment is conducted to permit their entry
- Radiation protection instructions and real-time personal dosimeters are provided

- Planned exposure limit: 3000 μSv

# PRACTICAL MEASUREMENTS

- **Staff**

| | Ρυθμός δόσης έκθεσης (μSv/h) | Χρόνος έκθεσης (min) | Δόση έκθεσης ανά ασθενή (μSv) | Ασθενείς ανά μήνα | Μηνιαία Δόση (μSv) | Μηνιαία Δόση (mSv) | Ετήσια Δόση (mSv) |
|---|---|---|---|---|---|---|---|
| **Γιατρός @ 0,5m** | 109 | 1 | **1,8** | 15 | **27,1** | **0,027** | **0,32** |
| **Φυσικός @ 0,5m** | 109 | 2 | **3,6** | 15 | **54,3** | **0,054** | **0,65** |
| **Νοσηλευτής @ 0,5m** | 109 | 2 | **3,6** | 15 | **54,3** | **0,054** | **0,65** |
| **Καθαριστής @ επαφή** | 22 | 1 | **0,4** | 15 | **5,5** | **0,006** | **0,07** |
| | | | | | | | |
| **Τεχνολόγος @ 0,5m** | 96 | 2 | **3,2** | 15 | 46 | 0,046 | 1η λήψη |
| | 48 | 2 | **1,6** | 15 | 23 | 0,023 | 2η λήψη |
| | 26 | 2 | **0,9** | 15 | 12,5 | 0,013 | 3η λήψη |
| | 16 | 2 | **0,5** | 15 | 9 | 0,009 | 4η λήψη |
| | | | **6,2** | | **60,3** | **0,06** | **0,72** |

*Courtesy of A. Vatalis*

- **Carers**

## ΔΟΣΗ ΣΥΝΟΔΩΝ ΑΣΘΕΝΩΝ ΣΤΑ ΔΩΜΑΤΙΑ

- **Μετρήθηκε η δόση έκθεσης σε διάφορα σημεία με τον ασθενή στο δωμάτιο**
- **Όριο σχεδιασμένης έκθεσης 3000 μSv**

| | Συνοδός στο κρεβάτι |
|---|---|
| **Ασθενής στο κρεβάτι** | <0,5 μSv/h |
| **Ασθενής στο τραπέζι** | 5-9 μSv/h |
| | |
| **Ασθενής @ 0,5 m** | 104 μSv/h |

| **Σενάρια** | **Χρόνος (h)** | **Real Δόση (μSv)** |
|---|---|---|
| **Ύπνος Συνοδού** | 8 | 4 |
| **Συνοδός Κρεβάτι-Ασθενής Τραπέζι** | 1 | 8 |
| **Συνοδός Κρεβάτι-Ασθενής κρεβάτι** | 4,5 | 2,25 |
| **Επαφή** | 0,5 (0,1 – 1) | 52 (10 – 104) |
| **Συνοδός εκτός δωματίου** | 6 | - |
| **Σύνολο** | **20** | **67 (20 – 120)** |

| **Συνοδός** | **Θεωρητική δόση (μSv)** | **Μετρούμενη δόση (μSv)** |
|---|---|---|
| **1** | 67 | 22 |
| **2** | 67 | 25 |
| **3** | 67 | 21 |
| **4** | 67 | 30 |
| **5** | 67 | 26 |
| **Μέση τιμή** | **67 (20 – 120)** | **24,8** |

24,8μSv

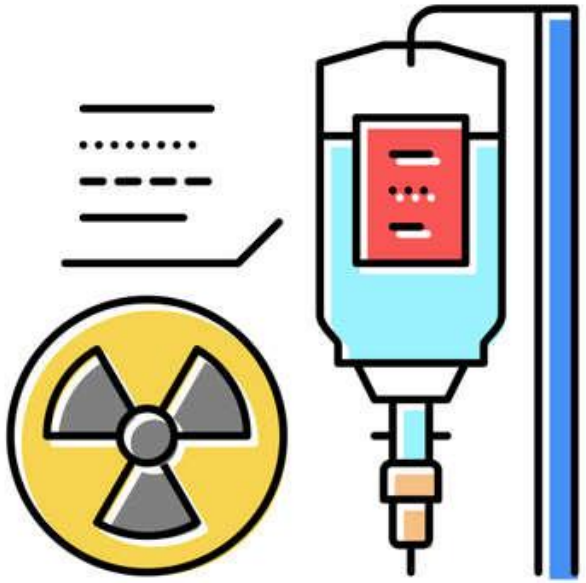
# CHALLENGES

- Time constraints in busy clinics leading to rushed procedures
- Lack of standardized protocols across centers
- Need for harmonized guidelines and continuous training

# CONCLUSION & KEY TAKEAWAYS

- Patient safety requires strict protocols
- Staff must optimize protection with training & tools
- Waste management must be proactive and compliant
- Future therapies demand updated safety frameworks
- Call to action: Need for collaboration, training, and research in RP

- **Final message: Radiation protection is a shared responsibility—integrate safety into every step**



# THANK YOU

# FOR YOUR ATTENTION