# Understanding Radiation Protection in Radioligand Therapy

## A Resource for Healthcare Professionals, Caregivers, Transport Operators and Family Members

PUBLICATION • Therapy Working Group • 2026

### About this guide

Radioligand therapy (RLT) is an established and growing cancer treatment across Europe. This guide provides factual, evidence-based information in accessible language for all professionals and family members who may encounter patients receiving RLT or radiopharmaceutical packages, grounded in current regulatory frameworks and published dosimetric data.

It covers three distinct situations:

- the **transport of patients and radiopharmaceutical shipments**,
- the administration of RLT by **healthcare professionals**,
- the care of patients at home by **family members and caregivers**.

With an estimated **25,000 to 28,000 patients currently receiving radioligand therapy annually across the EU**, and the therapeutic radiopharmaceutical segment growing at approximately 20% per year, the nurses, caregivers, transport operators, and family members who encounter patients receiving RLT and radiopharmaceutical shipments are a growing population with limited formal grounding in radiation protection.

Misconceptions about radiation risk are well documented and understandable. In this specific context, however, they have direct consequences: refusals to transport patients or shipments, unnecessary restriction of patient contact at home, and avoidable disruption to treatment delivery.

### Misconceptions and real consequences for patients

Patients receiving RLT travel during and between treatment cycles, and radiopharmaceutical shipments move daily across European borders. Both are subject to clear regulatory frameworks that explicitly permit their transport under defined conditions.

Yet transport refusals occur regularly, across multiple countries and transport modes. A patient who has recently received RLT may be stopped at an airport gate because a radiation detector has responded to their medical card (a document issued by the nuclear medicine department certifying the patient's treatment and expected radiation levels). Separately, a Type A package (a certified container designed to transport low to moderate activity radioactive materials safely) containing a radiopharmaceutical destined for a nuclear medicine centre may be offloaded from a cargo flight because a crew member has seen the radioactivity trefoil on the label. The shipment misses its slot. The radiopharmaceutical degrades. The patient's treatment cycle is delayed or cancelled. In both cases, the decision to refuse has no scientific or regulatory basis. In both cases, a patient loses access to treatment.

Among 57 organisations collectively responsible for tens of thousands of radioactive package movements per year, pilots have been documented to sometimes reject Class 7 cargo (radioactive materials under international transport classification) from the hold when live animals or biological samples are also being transported.[1] This practice is explicitly not required by any regulation. It is a refusal based on perception, not on law or science.

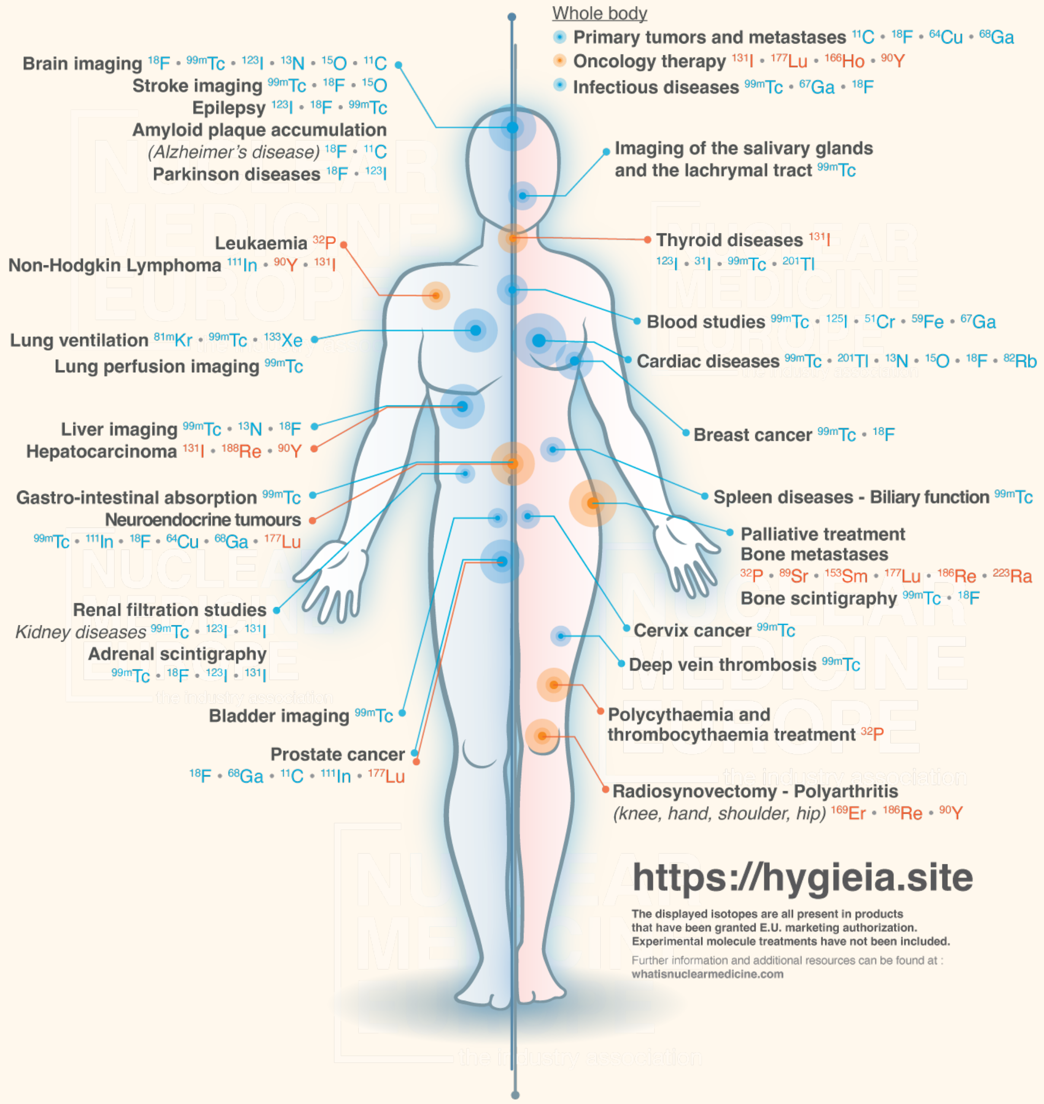
The IAEA has formally recognised the refusal to transport compliant radioactive medical shipments, known as Denial of Shipment (DoS), as a persistent and documented international problem since 2003. Between March and October 2020, El Salvador received no medical isotope deliveries due to airline refusals, leaving thousands of patients without access to cancer diagnostics and treatment that were available and ready to ship.

This guide provides the factual and regulatory basis for informed, proportionate decisions by all those who may encounter patients receiving RLT or radiopharmaceutical shipments - whether in a professional or personal capacity.

## Radioligand therapy and its clinical applications

Radioligand therapy is a targeted cancer treatment combining three components: a ligand, a molecule designed to seek out and bind to specific receptors expressed on tumour cells or on its immediate surroundings, a chelator and linker which enable the attachment of a radionuclide to the ligand and a radionuclide. Administered intravenously, the radioligand travels through the bloodstream, locates tumour cells wherever they are in the body, and delivers localised radiation directly to those cells or to its immediate surroundings. This includes metastases that external beam radiation therapy cannot reach, as it must be focused on a single anatomical location.

The clinical indications for currently approved RLT include metastatic castration-resistant prostate cancer, treated with $^{177}$Lu-PSMA-617, which has demonstrated significant improvement in progression-free and overall survival in patients who have already been treated with standard therapies; unresectable or metastatic, progressive, well-differentiated, somatostatin receptor-positive gastroenteropancreatic neuroendocrine tumours, treated with Lutetium-177 DOTATATE; and differentiated thyroid cancer, treated with Sodium Iodine-131, one of the longest-established forms of targeted radionuclide therapy.




*Several hundred clinical trials are currently underway globally, exploring new targets, tumour types, combination strategies, and earlier use in treatment pathways.*

## Understanding radiation

Radiation is energy that travels through space and matter. The ionising kind, which includes gamma rays, X-rays, beta and alpha particles, carries enough energy to interact with human tissue at the cellular level. At the low doses encountered in everyday life and in proximity to patients receiving RLT, the human body routinely manages and repairs these effects without lasting consequence.

In nuclear medicine, this property is deliberately exploited: diagnostic radiopharmaceuticals emit radiation that imaging equipment detects, while therapeutic radiopharmaceuticals deliver localised radiation directly to tumour cells or their immediate surroundings.

Radiation measurement uses three distinct units depending on what is being described :

- **The becquerel (Bq)** measures activity
  - how much radiation a source emits per second.
- **The gray (Gy)** measures absorbed dose
  - how much energy that radiation deposits in tissue.
- **The sievert (Sv)** measures effective dose
  - the biological effect of that radiation on human health, accounting for the type of radiation and the sensitivity of the tissues exposed.

It is this third unit, **the sievert**, that is most relevant when assessing health risk and occupational exposure. Because the doses encountered in everyday life and in proximity to patients receiving RLT are very small, they are expressed in millisieverts (mSv) or microsieverts (μSv): one millisievert equals 1,000 microsieverts. These are the units used throughout this guide and in the dose comparisons that follow.

## Common everyday sources of radiation

A banana contains potassium-40, a naturally occurring radioactive isotope. **Eating one banana exposes you to approximately 0.1 μSv of radiation**. This concept is sometimes used as a relatable unit: the “Banana Equivalent Dose” (BED). While not an official scientific unit, it helps illustrate that low-level radioactivity is simply part of eating fruit, vegetables, and most natural foods.

At cruise altitude (approximately 10,000 metres), the atmosphere provides far less shielding against cosmic radiation from space. **A transatlantic flight of around 8 hours exposes a passenger to approximately 40–80 μSv**. Pilots and cabin crew who fly professionally receive annual cosmic radiation doses estimated between 1,000 and 5,000 μSv per year, which is why aviation radiation exposure is monitored under EU regulations (Council Directive 2013/59/Euratom).This is well tolerated, and these professionals continue to work safely throughout long careers.

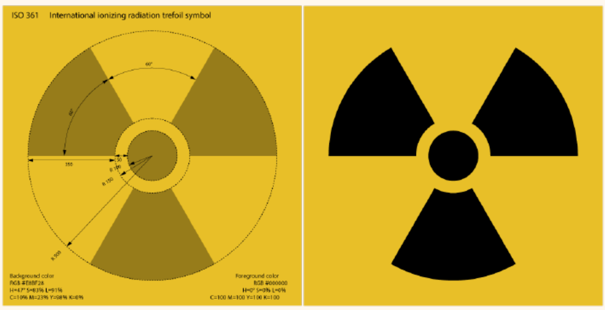
The least known everyday source: tobacco smoke. Cigarettes contain polonium-210 (Po-210) and lead-210 (Pb-210), naturally present in tobacco leaves from phosphate-based fertilisers and soil absorption. **A person smoking one pack per day receives an estimated internal radiation dose of approximately 3,600 μSv per year** to bronchial tissues from these isotopes alone, substantially more than any dose received from proximity to an RLT patient.

The global **average annual dose from all natural sources combined is approximately 2,400 µSv (2.4 mSv)**, with wide geographic variation. People living at higher altitudes or in areas with granite bedrock receive significantly higher doses. In some parts of Iran, India, and Brazil, natural background radiation exceeds 100 mSv per year, with no demonstrated adverse health effects in local populations.
The table below provides a more quantitative view of everyday doses alongside occupational limits and the doses associated with being near an RLT patient.

| Source of Exposure | Dose Received | Notes |
|---|---|---|
| Sleeping next to a partner (1 night) | 0.05 µSv | Natural body radioactivity |
| Eating 1 banana | 0.1 µSv | Natural potassium-40 |
| Max dose near RLT patient (1 h at 1 m) | ~5–20 µSv | Early post-injection |
| Chest X-ray | 20–100 µSv | Diagnostic imaging |
| Transatlantic flight (8 h) | 40–80 µSv | Cosmic rays at altitude |
| Standing 1 m from a Type A Lu-177 package for an entire transatlantic flight (8 h) | ≤ 800 µSv | In practice, passengers are always much further than 1m from any cargo |
| Regulatory public dose limit (annual) | 1,000 µSv | ICRP / EU Basic Safety Standards Directive |
| Annual natural background (EU avg) | 2,400 µSv | Cosmic, radon, food, ground |
| Smoking 1 pack/day (annual) | ~3,600 µSv | Polonium-210 in tobacco |
| CT scan abdomen | 5,000–8,000 µSv | Diagnostic imaging |

*Table 1. Comparative radiation doses from everyday activities and medical exposures. µSv = microsievert.*

## Transportation and the radioactivity symbol explained




The radioactivity symbol (a black and yellow trefoil) signals the presence of radioactive material and the need to follow established handling procedures. **It is not an indicator of danger to bystanders.**

A Type A package containing a clinical dose of Lu-177 (typically 7.4 GBq) emits a surface dose rate that, by regulatory requirement under IATA Dangerous Goods Regulations and IAEA Transport Regulations (SSR-6), must not exceed **2 mSv/h at the surface and 0.1 mSv/h at 1 metre**. In practice, well-shielded pharmaceutical packages present dose rates far below these limits.

The package, transported in the cargo hold with standard separation distances, delivers a dose to flight crew that is orders of magnitude below any occupational limit, and is often lower than the cosmic radiation dose from the flight itself.

Refusing to carry a compliant radiopharmaceutical shipment on radiation grounds has no scientific or regulatory justification and directly delays patient treatment.

## Radiation safety of patients receiving RLT treatment during transport

Immediately after injection, a patient treated with RLT does emit low levels of gamma radiation. However, the dose received by persons nearby, such as fellow passengers or crew, is very small and strictly regulated. Nuclear medicine guidelines from the European Association of Nuclear Medicine (EANM) and national radiation protection authorities provide specific instructions on minimum distances and timing of discharge.

In the case of Lutetium-177-based RLT, the dominant emission is a low-energy beta particle (which does not penetrate beyond a few millimetres of tissue) with a small gamma component. The dose rate at 1 metre from a patient shortly after a standard Lu-177 injection (7.4 GBq) is typically in the range of 15–30 μSv per hour, the cosmic radiation dose received during the flight itself.

For context, the total dose received by a person sitting 1 metre away from an RLT patient for an entire 8-hour transatlantic flight is approximately 40–120 μSv, equivalent to the cosmic radiation dose from the same flight. Both exposures are well within established safe limits for the general public and transport personnel alike. The patient presents no radiation hazard to others.

## Radiation Protection for Healthcare Professionals

Healthcare professionals involved at every stage of the RLT pathway - from radiopharmacists and technologists who prepare the dose to nurses who administer it and monitor the patient - are occupationally exposed to radiation. This exposure is systematically monitored, controlled, and kept well below regulatory limits through the application of three fundamental principles of radiation protection, known internationally as the ALARA principle (As Low As Reasonably Achievable).

**The three principles: Time, Distance, and Shielding**

1. **Time:** The less time spent near a radioactive source, the lower the dose received. Preparing injections efficiently and confidently minimises exposure time without compromising quality of care.
2. **Distance:** Radiation dose decreases with the square of the distance (the inverse square law). Doubling your distance from a source reduces your dose to one quarter. A nurse standing 1 metre from a

patient receives 4 times less dose than when standing 50 cm away. Simple measures, using long-handled forceps for vials, stepping back when not directly needed, make a meaningful difference.

3. **Shielding:** Appropriate shielding (lead syringe shields, lead aprons where indicated, and purpose-built preparation cabinets) significantly attenuates the gamma component of emissions. Facilities are designed to comply with EU Directive 2013/59/Euratom shielding requirements.

### Measured doses for nursing staff during RLT administration

Published data from EANM guidance and peer-reviewed dosimetry studies confirm that occupational doses for nuclear medicine nurses and technologists administering Lutetium-177-based RLT are consistently low when standard protocols are followed:

- Whole body dose per Lutetium-177-based RLT administration: approximately 1–5 µSv per procedure under standard conditions.
- Hand dose (extremity dose) per preparation and injection: typically, 20–100 µSv, depending on shielding and technique.
- Annual occupational dose for nurses administering 50 Lutetium-177-based RLT: estimated 50–250 µSv whole body, well below the occupational limit of 20,000 µSv (20 mSv) per year set by ICRP (International Commission on Radiological Protection) and EU Basic Safety Standards Directive (2013/59/Euratom).

These values confirm that routine RLT administration, when performed according to established protocols, does not pose an unacceptable radiation risk to nursing staff. Dosimetry badges (personal dosimeters) are worn to monitor individual exposure and ensure compliance with regulatory limits.

## Guidance for Family Members and Caregivers at Home

After discharge from the nuclear medicine unit, patients return home still carrying a low residual level of radioactivity. This is expected, managed, and safe, provided that simple, well-established precautions are followed for a short period.

Nuclear medicine physicians provide each patient with written instructions at discharge. These instructions are based on dosimetric calculations for the specific radiopharmaceutical and administered activity, and they are individualised where necessary. Family members should read and follow these instructions carefully. The guidance below reflects general principles applicable to most Lutetium-based RLT and Iodine-131-based therapies.

### Recommendations

The most important variable for family member exposure is distance and time spent in close proximity. General recommendations for the first few days after discharge typically include:

- Maintain a distance of at least 1 metre from the patient when sitting together in the same room.
- Avoid prolonged close contact (e.g. sitting side-by-side on a sofa for several hours). Brief contact for daily tasks, helping with meals, short conversations, is generally acceptable.
- Do not share a bed with the patient for the first 2–7 days (duration varies by radiopharmaceutical and activity administered).
- Children under 18 years of age and pregnant women should maintain greater distance (at least 2 metres) and minimise time spent near the patient for the duration specified in the discharge instructions.

These measures are precautionary. The calculated dose to family members who follow standard precautions is well below the public dose limit of 1 mSv per year and is often lower than the annual natural background radiation dose.

Radionuclides used in RLT are eliminated from the body primarily through the kidneys and urine. For this reason, urine is the main potential source of external contamination at home, particularly in the early days after treatment.

## The Need for Education Across All Sectors

Fear of radiation is one of the most common reasons for hesitation among caregivers, transport workers, and family members when encountering RLT patients. This fear is understandable, ionising radiation is invisible and associated in the public mind with catastrophic events such as nuclear accidents. However, this fear is often disproportionate to the actual risk presented by an RLT patient, and it can have serious consequences.

Refusal to transport a patient by air, ground, or rail on the basis of perceived radiation risk can delay or interrupt treatment, cause significant psychological distress to the patient, and in some cases compromise clinical outcomes. Education is therefore not merely desirable but clinically necessary.

## Recommendations by sector

### Transport operators and pilots

- Basic factual briefing: what RLT is, what dose rates are involved, and how these compare to cosmic radiation during flight.
- Awareness of the legal framework: EU Directive 2013/59/Euratom and IATA Dangerous Goods Regulations provide the regulatory basis for safe transport of patients and radiopharmaceutical packages.
- Clear documentation: patients discharged after RLT should carry a radiation release certificate issued by the nuclear medicine department, specifying the radiopharmaceutical administered, the date of treatment, and the estimated dose rate at a standard distance.

### Nurses

- Structured training in radiation protection principles (ALARA, inverse square law, half-life decay).
- Practical training in safe handling procedures and use of personal protective equipment (PPE).
- Access to real dosimetric data from their specific workplace.
- Clear institutional protocols for pregnant staff and those of reproductive age.

### Family members

- Clear, written discharge instructions in plain language.
- Specific guidance on duration of precautions, toilet hygiene, sleeping arrangements, and contact with children.
- A point of contact at the nuclear medicine department for questions that arise at home.

Comprehensive, targeted education across all stakeholder groups is essential to ensure that RLT, a therapy with proven medical benefits, can be delivered without unnecessary barriers at any point in the care pathway.

## Additional resources

Nuclear Medicine Europe develops and publishes a range of educational and policy resources on nuclear medicine, its clinical applications, and the regulatory environment in which it operates. Readers seeking broader context on the benefits of nuclear medicine for patients and healthcare systems are invited to consult the following:

> **Hygieia** - an interactive reference tool mapping radiopharmaceuticals to clinical applications, diseases, and body systems, designed for patients, healthcare professionals, and policymakers alike.
> https://hygieia.nuclearmedicineeurope.eu
>
> **What is Nuclear Medicine** - a public-facing educational resource explaining nuclear medicine diagnostics and therapies in accessible language.
> https://www.whatisnuclearmedicine.com
>
> **Publications and position papers** - Nuclear Medicine Europe's library of policy documents, position papers, and sector publications, including resources on dosimetry, radioligand therapy, the EU Biotech Act, and radiopharmaceutical regulation.
> https://nuclearmedicineeurope.eu/activities/publications/

## Glossary of Terms

| | |
|---|---|
| **ALARA** | As Low As Reasonably Achievable, the guiding principle of radiation protection practice |
| **GBq** | Gigabecquerel, unit of radioactivity (1 GBq = 1 billion nuclear disintegrations per second) |
| **ICRP** | International Commission on Radiological Protection |
| **mSv** | Millisievert, unit of radiation dose (1 mSv = 1,000 μSv) |
| **μSv** | Microsievert, very small unit of radiation dose |
| **RLT** | Radioligand Therapy, targeted cancer therapy using a radioactive molecule |
| **SPECT/CT** | Single Photon Emission Computed Tomography / Computed Tomography, nuclear medicine imaging |
| **tRP** | Therapeutic Radiopharmaceutical, a medicinal product containing a radionuclide used for treatment |
| **UNSCEAR** | United Nations Scientific Committee on the Effects of Atomic Radiation |

## References

https://www.iaea.org/newscenter/news/advances-in-nuclear-medicine-mean-patient-protection-needs-strengthening

Gorlin, S. (2021). Characterising the denial of shipment of radioactive material, and identifying potential remedial policies. Paper presented at the IAEA Technical Meeting on Denials of Shipment, 23–26 March 2021. World Nuclear Association (WNA). https://na.eventscloud.com/file_uploads/38e8d983b3084137605856b7e1e0d914_CharacterofDoSSolutionsGorlinIAEATMDOS_final_.pdf

Sartor O, de Bono J, Chi KN, et al. Lutetium-177–PSMA-617 for Metastatic Castration-Resistant Prostate Cancer. N Engl J Med. 2021;385(12):1091–1103.

Strosberg J, El-Haddad G, Wolin E, et al. Phase 3 Trial of 177Lu-Dotatate for Midgut Neuroendocrine Tumors. N Engl J Med. 2017;376(2):125–135.

Haugen BR, Alexander EK, Bible KC, et al. 2015 American Thyroid Association Management Guidelines for Adult Patients with Thyroid Nodules and Differentiated Thyroid Cancer. Thyroid. 2016;26(1):1–133.

Larson SM, Carrasquillo JA, Cheung NV, Press OW. Radioimmunotherapy of human tumours. Nat Rev Cancer. 2015;15(6):347–360.

International Commission on Radiological Protection (ICRP). The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann ICRP 2007;37(2–4).

Stabin MG. Radiation Protection and Dosimetry: An Introduction to Health Physics. Springer, 2007. [Banana Equivalent Dose and natural radioactivity in food]

Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation. Official Journal of the European Union, 2014.

National Council on Radiation Protection and Measurements (NCRP). Ionizing Radiation Exposure of the Population of the United States. NCRP Report No. 160. Bethesda, MD: NCRP, 2009. [Tobacco and polonium-210]

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Sources, Effects and Risks of Ionizing Radiation. UNSCEAR 2020/2021 Report. United Nations, New York.

Abubakar Sadiq Aliyu, Ahmad Termizi Ramli. The world's high background natural radiation areas (HBNRAs) revisited: A broad overview of the dosimetric, epidemiological and radiobiological issues. Radiation Measurements, Volume 73, 2015, Pages 51–59, ISSN 1350-4487. https://doi.org/10.1016/j.radmeas.2015.01.007.

Perko T. Radiation risk perception: A discrepancy between the experts and the general population. J Environ Radioact. 2011;102(6):519–521.

Konijnenberg M, Murray I, Rosenbaum-Krumme S, et al. EANM position paper on the role of quantitative SPECT/CT for the dosimetry of 177Lu-labelled PSMA- and SSTR-targeting radioligands. Eur J Nucl Med Mol Imaging. 2021;48(13):4141–4151.

Dauer LT, Williamson MJ, Germain J, et al. Radiation safety considerations for the use of 177Lu in the clinical setting. Health Phys. 2014;106(4):494–505.

International Air Transport Association (IATA). Dangerous Goods Regulations (DGR), 65th Edition. Montreal: IATA, 2024