# Radiation Safety Considerations and Clinical Advantages of α-Emitting Therapy Radionuclides

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α-emitting radionuclides provide an effective means of delivering large radiation doses to targeted treatment locations. $^{223}RaCl_2$ is Food and Drug Administration–approved for treatment of metastatic castration-resistant prostate cancer, and $^{225}Ac$ ($^{225}Ac$-lintuzumab) radiolabeled antibodies have been shown to be beneficial for patients with acute myeloid leukemia. In recent years, there has been increasing use of α-emitters in theranostic agents with both small- and large-molecule constructs. The proper precautionary means for their use and surveying documentation of these isotopes in a clinical setting are an essential accompaniment to these treatments. **Methods:** Patient treatment data collected over a 3-y period, as well as regulatory requirements and safety practices, are described. Commonly used radiation instruments were evaluated for their ability to identify potential radioactive material spills and contamination events during a clinical administration of $^{225}Ac$. These instruments were placed at 0.32 cm from a 1.0-cm $^{225}Ac$ disk source for measurement purposes. Radiation background values, efficiencies, and minimal detectable activities were measured and calculated for each type of detector. **Results:** The median external measured dose rate from $^{223}RaCl_2$ patients ($n$ = 611) was 2.5 μSv $h^{-1}$ on contact and 0.2 μSv $h^{-1}$ at 1 m immediately after administration. Similarly, $^{225}Ac$-lintuzumab ($n$ = 19) patients had median external dose rates of 2.0 μSv $h^{-1}$ on contact and 0.3 μSv $h^{-1}$ at 1 m. For the measurement of $^{225}Ac$ samples, a liquid scintillation counter was found to have the highest overall efficiency (97%), whereas a ZnS α-probe offered the lowest minimal detectable activity at 3 counts per minute. **Conclusion:** In this article, we report data from 630 patients who were undergoing treatment with the α-emitting isotopes $^{223}Ra$ and $^{225}Ac$. Although α-emitters have the ability to deliver a higher internal radiation dose to the exposed tissues than can other unsealed radionuclides, they typically present minimal concerns about external dose rate. Additionally, α-radiation can be efficiently detected with appropriate radiation instrumentation, such as a liquid scintillation counter or ZnS probe, which should be prioritized when surveying for spills of α-emitters.

**Key Words:** α-emitters; actinium; radium; nuclear medicine; radiation efficiency

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Radionuclides that are α-emitters offer a unique and effective way of treating various types of cancer by delivering a high–linear-energy-transfer focal radiation deposition to a treatment site. The physical characteristics of high particle energy, often 5–9 MeV, and a short (<100 μm) particle range in tissue make α-emitting radionuclides attractive sources to deliver large radiation doses to targeted tissues (*1*). α-particles create dense ionization tracks that can produce multiple damages to the DNA, resulting in less repairable double-strand break damage (*2,3*). This ability allows radiopharmaceutical carriers of α-emitting radionuclides to produce efficient cell death in targeted tumor cells while sparing untargeted normal healthy tissues beyond the range of the α-emissions (*4,5*).

Certain α-emitting radionuclides, such as $^{223}Ra$, $^{225}Ac$, and $^{227}Th$, are part of a radioactive decay chain with multiple α-particle emissions that result in a total emission energy per decay that is typically 2 orders of magnitude higher than for conventional β-particle theranostics. This characteristic provides an advantage for clinical applications because the necessary administered activities for effective therapy are hundreds of times less than their β-particle or photon-emitting counterparts (*6*). Therefore, the radiation exposure rates due to particle and photon emissions from an α-emitting radionuclide's progeny pose little to no external concern and are not a safety-limiting factor at the submillicurie quantities used in clinical practice. This ability to deliver smaller activities, with minimal radiation exposure concern, allows α-emitting radionuclides to be advantageous for radiation safety considerations, encompassing both occupational staff exposure and adherence to patient release criteria at the federal and state levels.

Initially used in 1912 for the treatment of ankylosing spondylitis, $^{224}Ra$ was the first α-emitting radionuclide to

be used in a clinical application (*7*). However, it was not until much later, in 2013, that $^{223}RaCl_2$, now produced by Bayer Pharmaceuticals under the name Xofigo, became the first Food and Drug Administration–approved α-emitting radionuclide therapy for the treatment of prostate cancer with metastatic bone lesions (*8*). More recently, other α-emitters, such as $^{225}Ac$ and $^{227}Th$, have begun to see expanded use in clinical trials. $^{227}Th$ is produced by the decay of the long-lived parent isotope $^{227}Ac$ through the same processes already used for its decay product, $^{223}Ra$ (*9*). Found naturally in the neptunium decay series seen in Figure 1, the current supply of $^{225}Ac$ comes from fissile $^{233}U$ and its decay product $^{229}Th$, which were first produced during investigation into nuclear weapons and reactors (*10*). $^{225}Ac$ can be separated and purified from $^{229}Th$ through a combination of ion exchange and extraction chromatographic methods (*11*). Alternative methods to produce $^{225}Ac$ have been explored, the most promising being a $^{226}Ra(p,2n)^{225}Ac$ reaction, which has not been widely used but is being further explored (*12*).

Three α-emitting radionuclides currently in use at Memorial Sloan Kettering Cancer Center under specific institutional protocols will be addressed in this paper; these include $^{223}RaCl_2$ for metastatic castration-resistant prostate cancer, $^{225}Ac$ monoclonal antibody lintuzumab for acute myeloid leukemia, and the recently initiated $^{227}Th$-labeled antibody–chelator conjugate BAY 2701439 (Bayer) for targeting tumors expressing human epidermal growth factor receptor 2. $^{223}RaCl_2$ has been used for treatment of symptomatic patients with metastatic castration-resistant prostate cancer, and its use has resulted in an overall improvement in quality of life and increased length of overall survival (*13,14*). Although the therapeutic efficacy of $^{225}Ac$, with a half-life of 10 d, is still in the early research stages, $^{213}Bi$, the final radioactive daughter product in the decay chain, has been used in clinical trials and shown to be safe and therapeutically efficacious in patients with acute myeloid leukemia (*15*).

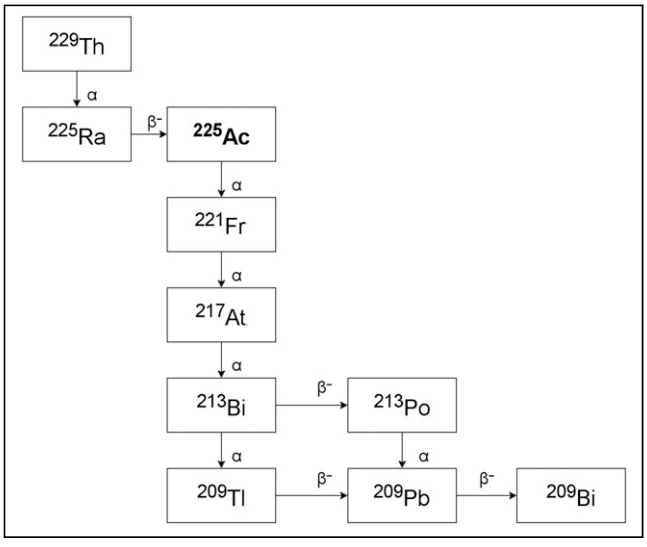



**FIGURE 1.** Decay of $^{225}Ac$ via neptunium series.

Here, we provide an overview of our experience using α-emitting radionuclides in current and recently completed clinical trials, with a focus on the preparation, administrative procedures, radiation safety precautions, and regulatory requirements that must be met to safely administer α-emitting radionuclides in a clinical setting. In addition, radiation detection equipment is evaluated to see the varying effectiveness for monitoring the α-emitter $^{225}Ac$ in the clinical setting, to help guide individuals on the proper selection of survey equipment.

## MATERIALS AND METHODS

### Regulatory Framework

When preparing to administer α-emitting radionuclides, an institution must first fulfil regulatory requirements. The U.S. Nuclear Regulatory Commission offers guidance documents on the types of precautions and instrumentation that must be present for proper administration of α-emitting radionuclides. These documents will be addressed alongside perspectives from groups such as the International Commission on Radiation Protection, the National Council on Radiation Protection and Measurements, and the National Research Council.

Many general broad-scope radioactive material licenses for medical use include only "any byproduct material with atomic numbers 1 through 83" as designated by regulation 1,556, volume 11, of the U.S. Nuclear Regulatory Commission (*16*). Most α-emitting radionuclides, including all those discussed in this paper, have an atomic number greater than 83 and must be specifically documented on a radioactive material license. The maximum possession amount should be estimated from the proposed patient load, estimated activity needed per patient, and waste storage capabilities.

Training required by the Nuclear Regulatory Commission for an authorized user to administer unsealed byproduct material can be found in title 10, part 35, subpart E, of the *Code of Federal Regulations*; included are items related to education, training and experience, and board certification (*17*). For individuals to become authorized users, they must also be approved by an institution's internal radiation safety committee. In addition to approving authorized users for the administration of radioactive materials, the most important part of the radiation safety committee's job is to instill a proper safety culture in staff members' daily routine and make safety the top priority (*18*). This task can be accomplished through a plethora of means, such as a robust radiation safety training program, proper workflow processes, and widespread monitoring and self-auditing practices.

### Overview of α-Emitting Radionuclide Therapy

In a review of applicable α-emitting radionuclide protocols at Memorial Sloan Kettering Cancer Center, all radionuclides were administered according to vendor or internal protocol recommendations. $^{223}RaCl_2$ was administered as a slow bolus intravenous injection over 3–5 min, whereas $^{225}Ac$- and $^{227}Th$-labeled antibodies were administered over a 15- to 30-min infusion. All 3 protocols have completed, or plan to complete, a dose escalation or expansion study to determine dose-limiting patient toxicity levels. The results of the completed dose escalation studies are shown in Table 1. As shown, $^{223}RaCl_2$ and $^{225}Ac$ treatment activities were based on patient weight, whereas planned $^{227}Th$ doses were based strictly on fixed activity levels.

## Treatment Preparation

The requirements for the administration of radioactive materials will vary widely depending on the type of radioactive material being administered. For staff directly handling these radionuclides, procedures such as the use of long-handled tools or shielded syringes may be applied to help minimize extremity radiation exposure but are often unnecessary for the lower activities being used. Before treatment, α-emitting radionuclides should be stored such that both the β-radiation and the photon radiation are reasonably shielded. The α-emitters are stored in either Plexiglas or lead, depending on the isotope. $^{223}$Ra Xofigo is shipped (and stored) as unit dose syringes in a self-made container (Xofigo Plastic Pig [XPP]; Cardinal Health), remaining in the container until the syringe is removed by the nuclear medicine physician for treatment. $^{225}$Ac and $^{227}$Th are shipped (and stored) in a small lead container from the vendors. The isotopes are diluted in-house and are placed in a plastic syringe. Once in the syringe, they are placed under 1/8″ lead sheet until administered by the physician.

Because of minimal external dose-rate readings, patients may be treated in locations without lead shielding or other radiation-limiting interventions. Most treatments using α-emitting radionuclides involve either an injection or an infusion of radioactive material through a syringe, allowing for a closed system that delivers radioactive materials directly into the bloodstream to limit the risk of contamination events or radiation exposure to staff members. Since α-particles are of great concern for inhalation and ingestion, proper care should be taken to mitigate the risk of these intake pathways. Proper personal protective equipment, such as gloves (double preferred) and laboratory coats, should always be worn by staff administering α-emitting radionuclides. Absorbent pads should be placed around the injection or infusion site to mitigate the risk of spreading contamination in the event of a spill.

## Special Considerations

Needle sticks and skin contamination during treatments are considered special events and must be treated promptly and properly because of possible intake of radioactive material. Rapid cleaning of the area and continual monitoring must be performed. Methods for evaluating radioactive material intake (i.e., bioassay) and the need for further investigation are described in Nuclear Regulatory Commission regulatory guide 8.9. In special monitoring situations, suspected intake of material must be evaluated with a scope commensurate with the potential risk (*19*).

If radioactive material intake is suspected, a bioassay test is the preferred method for estimating the amount of material ingested or inhaled. A single 24-h biospecimen sample may be sufficient, but regular daily measurements could be needed for higher intakes. For α-emitting radionuclides, including all 3 of those reviewed here, fecal bioassays are preferred since feces contain a larger percentage of the excreta than does urine (*20*). Intake retention functions can be used to estimate the total intake of radioactive material, which can then determine the cumulative total internal dose (committed effective dose equivalent) to a staff member. This is done using the values from title 10, part 20, appendix B, of the *Code of Federal Regulations* for the appropriate annual limits on intake value for each isotope, as well as any necessary tissue weighting factors from International Commission on Radiological Protection publication 103 (*21,22*). The committed effective dose equivalent, added to any external occupational exposure, is called the total effective dose equivalent for an individual and carries a limit of 5,000 mrem annually in the United States. Equation 1 calculates the occupational dose from internal exposures (committed effective dose equivalent). The annual limit on intake values is the amount of radioactive material that would need to be inhaled or ingested to reach the annual occupational

**TABLE 1**
Memorial Sloan Kettering Cancer Center α-Emitting Radionuclide Dose Escalation and Expansion Clinical Protocols

| Radionuclide | Activity administered (kBq kg$^{-1}$) | Total treatment cycles | Period between cycles (wk) |
|---|---|---|---|
| $^{223}$Ra | | | |
| Phase 1.1 | 50 | 1 | NA |
| Phase 1.2 | 100 | 1 | NA |
| Phase 1.3 | 200 | 1 | NA |
| Phase 2 | 50 | 6 | 4 |
| Phase 3 | 50 | 6 | 4 |
| NIST-adjusted Xofigo | 55 | 6 | 4 |
| $^{225}$Ac | | | |
| Phase 1.1 | 18.5 | 1 | NA |
| Phase 1.2 | 37 | 1 | NA |
| Phase 1.3 | 74 | 1 | NA |
| Phase 1.4 | 148* | 1 | NA |
| Phase 1.5 | 111 | 1 | NA |
| $^{227}$Th (in progress) | | | |
| Phase 1.1 | 1,500 kBq† | 4 | 6 |
| Phase 1.2 | 2,500 kBq† | 4 | 6 |
| Phase 1.3 | 3,500 kBq† | 4 | 6 |
| Phase 1.4 | 4,500 kB† | 4 | 6 |
| Phase 1.5 | 6,000 kBq† | 2 | 6 |
| | Additional 25% increase | 2 | 6 |

*Dose-limiting toxicity seen at phase 1.4.
†Patients receiving $^{227}$Th receive fixed dose values instead of weight-based doses.
NA = not applicable; NIST = National Institute of Standards and Technology.

dose limit for a radiation worker without any other exposure, with examples shown in Table 2.

$$\text{Committed effective dose equivalent} = \text{intake} \times \frac{\text{occupational dose limit}}{\text{appropriate annual limits on intake}} \times \text{tissue weighting factor.} \quad \text{Eq. 1}$$

### Contamination Survey Instrumentation

Regular surveying practices, proper radiation instrumentation, and methods for decontamination should always be present during radioactive material administration. An α-probe, such as a ZnS scintillation detector or a similar device, may be preferable to a standard Geiger–Müller (GM) detector for the detection of α-emitting radionuclides. α-probes can filter out the measurement of β-particles or photons, allowing them to have lower background levels of radiation and a subsequently lower minimal detectable activity (MDA). In addition, the mica film on the outside of a standard GM detector makes direct measurement of α-particles difficult and inefficient but still possible if the film is less than approximately 7 mg $cm^{-2}$ (*23*). Such a film filters out most low-energy α-particles and leads to a lower efficiency for those that can be measured. Coupled with a higher background reading, such filtering increases the difficulty of detecting small amounts of α-emitting radionuclides with a standard GM detector. Instead, GM detectors focus on measuring the associated β-particle and photon emissions from daughter nuclei. Although GM detector efficiency can reach about 33% for high-energy β-particles, photon efficiencies are generally poor and often less than 1% for low-energy photons such as those produced by $^{99m}$Tc or $^{125}$I (*24*). A low MDA, and reasonable efficiency, are crucial for measuring the low levels of surface contamination needed to meet regulatory requirements such as the 1,000 disintegrations/(min * 100 $cm^2$) combined activity for most α-emitters (*25*).

### Radiation Instrumentation Statistics

$^{223}$Ra efficiencies, MDA levels, dose rates, and decay pathways were previously examined, in detail, by Dauer et al. (*26*). The decay pathway for $^{223}$Ra via the actinium decay series can be seen in Figure 2. $^{225}$Ac has a decay pathway similar to that of $^{223}$Ra, which contains a mixture of different decay modalities, including both α- and β-decay (*27*). A net value of 4 primary α-particle decays, 2 primary β-particles, and numerous γ-ray emissions is present in the decay process between radioactive $^{225}$Ac and stable $^{209}$Bi. The effectiveness of various radiation detection equipment for $^{225}$Ac was measured experimentally by dissolving solid actinium nitrate in a 0.1 M HCl solution. The solution was then diluted and pipetted onto a 1.0-cm-diameter filter disk. Before application, the $^{225}$Ac used in this process was decayed in storage to ensure secular equilibrium with daughter products, a process that takes approximately 24 h (*28*). Portable instrumentation was placed in a repeatable geometry in which the detector face was 0.32 cm from the filter disk. These radiation detectors were connected to an integrating scaler configured to accumulate counts for 1 min, and the measurement was repeated 10 times for both background and source counts. Stand-alone instrumentation, such as that used for wipe tests, was adjusted to count for 10 min for both sample and background counts. Efficiencies for each instrument were calculated by the measured count rates divided by the dose-calibrated activity. MDA was subsequently calculated using Equation 2 with the empirically determined conversion factor from dpm to other desired activity unit, if applicable (*C*), efficiencies (*E*), background count rates ($R_b$), source count times ($t_s$), background count times ($t_b$), and constant value, $k_1$, of 1.645 representing a 1-sided 95% CI (*29*).

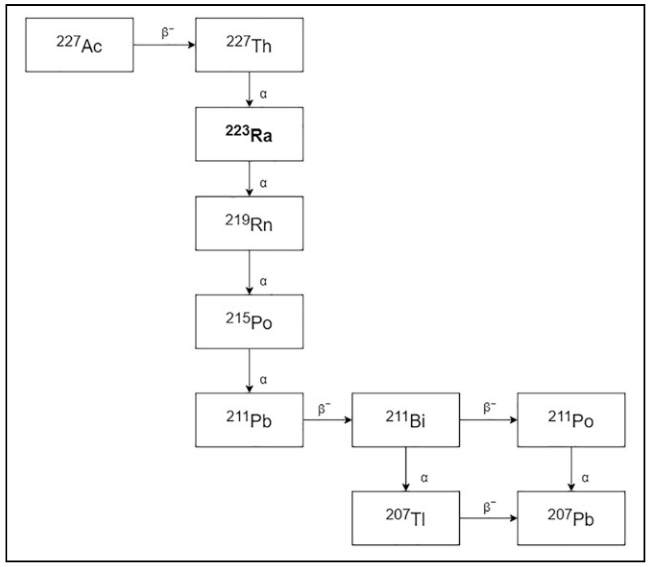



**FIGURE 2.** Decay of $^{223}$Ra via actinium series.

$$\text{MDA} = \frac{k_1{}^2 + 2k_1\sqrt{R_b t_s\left(1+\frac{t_s}{t_b}\right)}}{t_s \text{ E C}}. \quad \text{Eq. 2}$$

The portable survey detectors used for efficiency and MDA testing were a ZnS α-probe (model 43-2; Ludlum), a thin windowed GM probe (model 44-9; Ludlum), and an NaI low-energy γ-probe (model 44-3; Ludlum). These portable detectors are used for real-time measurements and personnel surveys at the site of use. Stand-alone ionizing-radiation spectrometers such as a liquid scintillation counter (model TriCarb 2900TR; Perkin Elmer) and a γ-counter (Wizard2; Perkin Elmer) were also tested. These stand-alone detectors are often used for quantifying removable contamination survey results for documentation purposes. $^{225}$Ac, used for efficiency measurements, was supplied by the U.S. Department of Energy, Oak Ridge National Laboratory. Values for the efficiencies of various radiation instrumentation, and their associated MDAs, for $^{225}$Ac are examined in more detail in Table 3.

**TABLE 2**
Restrictive Annual Limit on Intake Values for Select α-Emitting Radionuclides and Radionuclides in Common Medical Use

| Radionuclide | Decay mode | Restrictive annual limit on intake (MBq) |
|---|---|---|
| $^{18}$F | β | 1,850 |
| $^{99m}$Tc | IT | 2,960 |
| $^{131}$I | β | 1.11 |
| $^{223}$Ra | α | 0.026 |
| $^{225}$Ac | α | 0.011 |
| $^{227}$Th | α | 0.011 |

**TABLE 3**
Removable Contamination Efficiencies and MDAs for Commonly Used Radiation Detection Equipment Integrated over 1-Minute Count Time for $^{225}$Ac

| Instrument | Background (cpm) | Efficiency (cpm/dpm) | MDA | |
|---|---|---|---|---|
| | | | dpm | Bq |
| Portable survey meters | | | | |
| α-probe (ZnS) | 0 | 0.07 | 3 | 0.05 |
| Thin window β-/γ-probe (GM) | 33 | 0.18 | 147 | 2.47 |
| Low-energy γ-probe (NaI) | 234 | 0.06 | 1,128 | 18.82 |
| Radiometric detectors | | | | |
| Liquid scintillation counter | 36 | 0.97 | 13 | 0.22 |
| γ-counter | 288 | 0.13 | 547 | 9.13 |

cpm = counts per minute; dpm = disintegrations per minute.

## RESULTS

### Treatment Data and Precautions

Administrations of $^{223}RaCl_2$ ($n = 611$) and $^{225}$Ac-lintuzumab ($n = 19$) to patients were reviewed for various safety considerations. The median age of $^{223}RaCl_2$ patients was 72.26 y ± 8.93 y (range, 46.53–92.94 y), with administered activities of 4.81 ± 0.95 MBq. The median age of $^{225}$Ac-lintuzumab patients was 77.90 y ± 9.72 y (range, 56.35–87.60 y), with administered activities of 3.00 ± 1.68 Bq. Radiation doses to members of the staff and the public from patients receiving either $^{223}RaCl_2$ or $^{225}$Ac-lintuzumab were considered minimal. $^{223}RaCl_2$ dose-rate readings were minimal, with a median of 2.5 ± 0.07 μSv $h^{-1}$ on contact (i.e., on the external surface of the patient's body; external dose-rate readings for these patients were taken near the heart due to intravenous injections and infusions yielding the highest results there). Likewise, $^{225}$Ac-lintuzumab had similar readings of 1.7 ± 1.2 μSv $h^{-1}$ on contact. All activity and dose-rate readings were taken with ionization chambers immediately after the therapy.

### Radiation Detector Measurements

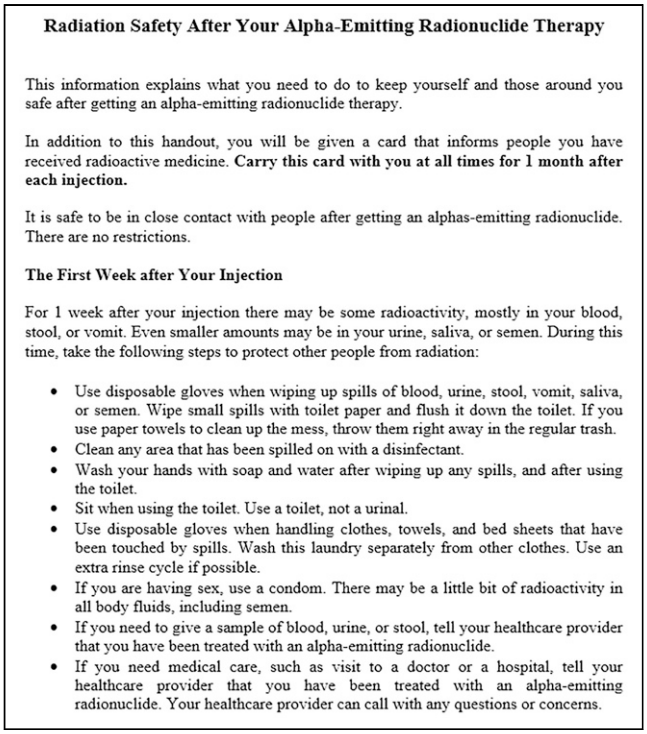
Radiation detection equipment was evaluated to determine detector efficiency, MDAs, and the feasibility of use during administrations of $^{225}$Ac. The data for an unshielded radioactive source of $^{225}$Ac are summarized in Table 3. MDAs were calculated with a $k_1$ value of 1.645, representative of the 95% CI. Efficiency levels were calculated and rounded to the nearest whole percentage point.

## DISCUSSION

External exposure rates for patients receiving α-emitting radionuclides were found to be low, as expected. With median dose rates of less than 0.5 μSv $h^{-1}$ at a 1-m distance, patients may return to their regular lifestyle immediately after treatment, without radiation precautions. This advantage allows for effective treatment while avoiding some common precautions needed for other types of radiopharmaceutical treatments. Low external dose rates also allow for better patient care by staff members by removing the constraints and limitations of occupational radiation exposure. Specimens containing bodily fluids should continue to be handled with care by staff members to avoid accidental intake of the radioactive material.

Because of low external dose rates, no patient—under reasonable assumptions—will subject a member of the public to 1 mSv of radiation exposure, the necessary requirement for the release of patients administered radioactive materials as designated by Regulatory Guide 8.39 of the U.S. Nuclear Regulatory Commission (*30*). Instructions for the proper control of bodily fluids were given to minimize the risk—to the public or members of the household—of receiving a dose from accidental ingestion of material after patient release, as seen in Figure 3. The instructions include sitting while urinating or defecating, properly washing the hands after encountering any bodily fluids, promptly cleaning any vomitus or bodily fluid spills, and using a condom during sexual intercourse. The instructions are given for 1 wk after therapy, though data suggest that most excretion of radioactive material occurs within the first 72 h (*31*). Beyond this point, the amount of radioactive material remaining is inconsequential to the overall dose received by the public.

From a radiation detection standpoint, as shown in Table 3, there are advantages and disadvantages to different radiation detectors. α-probes offer the best mix of efficiency, low background, and low MDA for surveillance purposes—because of the sulfide's ability to filter out non–α-radiation—which allows for a near-zero background. The extremely low background allows even the smallest amount of radioactive material to be detected by the scintillator, as is helpful in slight-contamination events. Liquid scintillation counters also offer desirable results but not necessarily the rapid results needed during regular administrations and surveys; they also come with both a higher initial cost and higher upkeep expenses. The data show that a GM detector offers higher efficiency than a ZnS α-probe but also a higher MDA



**Radiation Safety After Your Alpha-Emitting Radionuclide Therapy**

This information explains what you need to do to keep yourself and those around you safe after getting an alpha-emitting radionuclide therapy.

In addition to this handout, you will be given a card that informs people you have received radioactive medicine. **Carry this card with you at all times for 1 month after each injection.**

It is safe to be in close contact with people after getting an alphas-emitting radionuclide. There are no restrictions.

**The First Week after Your Injection**

For 1 week after your injection there may be some radioactivity, mostly in your blood, stool, or vomit. Even smaller amounts may be in your urine, saliva, or semen. During this time, take the following steps to protect other people from radiation:

- Use disposable gloves when wiping up spills of blood, urine, stool, vomit, saliva, or semen. Wipe small spills with toilet paper and flush it down the toilet. If you use paper towels to clean up the mess, throw them right away in the regular trash.
- Clean any area that has been spilled on with a disinfectant.
- Wash your hands with soap and water after wiping up any spills, and after using the toilet.
- Sit when using the toilet. Use a toilet, not a urinal.
- Use disposable gloves when handling clothes, towels, and bed sheets that have been touched by spills. Wash this laundry separately from other clothes. Use an extra rinse cycle if possible.
- If you are having sex, use a condom. There may be a little bit of radioactivity in all body fluids, including semen.
- If you need to give a sample of blood, urine, or stool, tell your healthcare provider that you have been treated with an alpha-emitting radionuclide.
- If you need medical care, such as visit to a doctor or a hospital, tell your healthcare provider that you have been treated with an alpha-emitting radionuclide. Your healthcare provider can call with any questions or concerns.

**FIGURE 3.** Example of radiation safety precautions for patients receiving α-emitting therapies.

because of higher background radiation levels. With MDAs below those used for regulatory purposes for most α-emitters, a GM detector may be a suitable alternative for a program because of cost and availability. Larger survey areas and longer count times can always be implemented to help lower a detector's MDA when needed. Low-energy scintillation probes and γ-counters should not be used to measure for α-emitting radionuclides since their MDA may be near or above the surface contamination levels that require remediation under normal circumstances.

## CONCLUSION

There has been a growth of interest in, and use of, α-emitting radionuclides in the treatment of cancer because of their higher radiotoxicity per unit of administered activity relative to radionuclides emitting β-, γ-, or x-rays. With robust administrative and engineering controls, α-emitting radionuclides can be handled and administered safely for clinical use. Proper personal protective equipment, training techniques, and radiation detection instrumentation are crucial for reducing contamination events and protecting the clinical staff and the public. Patient release instructions for α-emitters can be limited to only hygiene precautions to prevent the accidental inhalation or ingestion of radioactive material by another individual. This policy allows patients to resume their everyday lives free of the external radiation restrictions that may accompany other radionuclide therapies. With all their advantages, α-emitting radionuclides continue to be a leading option in radionuclide therapy and can be safely administered.

## DISCLOSURE

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## KEY POINTS

**QUESTION:** Are current patient precautions and radiation survey equipment sufficient for safe and compliant radionuclide therapies containing α-emitting radionuclides?

**PERTINENT FINDINGS:** External dose-rate readings from patients receiving radioactive materials continue to be low in clinical trials and Food and Drug Administration–approved treatments. Radiation detection equipment such as ZnS detectors and liquid scintillation detectors are preferable to the more commonly used GM counter.

**IMPLICATIONS FOR PATIENT CARE:** Radiation safety precautions for patients receiving α-emitting radionuclide therapy can continue to include only hygiene-related precautions for $^{225}$Ac and $^{227}$Th while maintaining compliance with federal guidance and regulations.

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