

Exploring Roles for Radiation Safety Robots in Medical Facilities

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Abstract

Medical facilities around the world are seeing an increase in life-saving nuclear medicine procedures. The radioactive materials used in these procedures require careful monitoring and regulation to ensure that patients, staff, and the public are not unduly put at risk. At each facility, a team of radiation safety professionals is responsible for complying with radiation regulations through a combination of standard protocols and active decision-making. However, the number of experts in radiation safety has been declining in recent decades. Through facility tours, a questionnaire, and interviews with radiation safety professionals across North America, we explore the structure of radiation safety and highlight what differentiates medical radiation safety from other radiation safety contexts for which robots have been considered. We identify tasks of highest need in the medical context and present other insights for robotics development centered on the needs of medical radiation safety professionals to anticipate downstream effects of potential robot integration and guide upstream interventions to prioritize and support medical radiation safety experts.

CCS Concepts

• **Human-centered computing** → **Collaborative interaction; Participatory design**; • **Computer systems organization** → **Robotics**; • **Social and professional topics** → **Medical technologies**.

Keywords

Radiation safety, nuclear robotics, medical robotics, robotics

ACM Reference Format:

Claire Liang, Alex Cuellar, Naomi Schurr, and Julie A. Shah. 2026. Exploring Roles for Radiation Safety Robots in Medical Facilities. In *HRI '26: Robots for Care Workshop, 2026, Edinburgh, UK*. ACM, New York, NY, USA, 4 pages.

1 Introduction

Many professions require tasks that are “dull, dirty, and dangerous”—work that, if assigned to a robot teammate instead, could relieve people of repetitive or unsanitary labor, keep them safe, and enable the experts to spend their energies on more engaging aspects of the role.



Figure 1: Common tools used by radiation safety professionals, including those at medical facilities. Top: survey meters. Bottom-left: dosimeters. Bottom-right: wipes and envelopes.

Radiation safety is no exception—these professionals’ roles involve radiation exposure, repetitive work, and ergonomic challenges [3]. While the potential benefits have motivated significant work in bringing robots to perform radiation safety work in disaster sites, power plants, and decommissioning contexts [8], the medical sector has largely been overlooked. This gap has the potential to impact communities as our reliance on nuclear medicine increases; the demands on medical radiation safety professionals (RSPs) to support this care are increasing while they are experiencing the same waning workforce impacting radiological control all across North America [1, 7]. Although introducing robot teammates could potentially expand the reach of human RSP teams, it is important to note that radiation safety in the medical setting poses unique human-robot interaction (HRI) considerations not present in most domains involving radiation safety (e.g., industrial or disaster sites). Effectively supporting radiotherapy patients requires understanding where and how human relationships and patient care network structures impact radiological survey practices. Medical RSPs face dynamic, human-centered, and therapy-specific challenges—all compelling lines of investigation for HRI researchers.

In this work we present initial findings from our exploration of radiation safety across different industrial, research, and medical

sectors. We report on daily tasks that medical radiation safety professionals could envision a robot teammate performing in the future. This paper begins the conversation between roboticists and medical radiation safety experts as first steps to a participatory design structure and provides interested roboticists concrete articulations of tasks from experts' lived experiences.

2 Background

Since the beginnings of x-ray technology in 1895, the power of nuclear radiation has had major social, ethical, and organizational effects. Nuclear radiation provides the community with clean energy technology, powerful scientific techniques, and revolutionizing medical treatment through radiation therapy, but misuse can have dangerous outcomes. Careful adherence to regulations allows humankind to enjoy these benefits while mitigating the risks of handling radioactive materials.

Radiological control is expected in every facility that works with radioactivity. Relevant facilities include nuclear reactors, fission and fusion facilities, research labs, power plants, and medical facilities. Radiation regulation procedures must be put in place before the construction of a facility, and each facility must develop a policy for day-to-day operations that abides by mandatory thresholds and is approved by the Nuclear Regulatory Commission. The regulations protect both the population outside of the facility and the employees working within it.

A critical stakeholder in this field is the radiation safety professional (RSP). RSPs are responsible for safe handling of radioactive material to ensure that people receive minimal dose and risk, and that all radioactive materials are managed according to regulation. RSPs can be broadly divided into radiation safety technicians and health physicists. Radiation safety technicians typically require at least 6 months to a year of training and are the primary boots-on-the-ground staff performing regular surveys (e.g., using wipe tests or survey meters shown in Figure 1). Health physicists most often require a masters or doctoral degree in health physics, and are often responsible for regulatory compliance through protocol design and reporting.

To understand the role a robot can play to augment nuclear radiation procedures today, one must consider the impacts of upstream interventions and downstream effects of a robot's design and use.

3 Our Process

Our investigation had three stages: general understanding of radiation throughout history via literature review, gaining access to and building connections with radiation safety professionals at active facilities, and learning from experts one-on-one to anticipate potential downstream impacts from their perspectives.

3.1 Historical knowledge

We consulted books such as [4–6] for decommissioning case studies both nationally and internationally. To gain an understanding of nuclear safety protocols and requirements, we consulted MARSSIM [9], the primary guide for radiation surveying and site investigation. MARSSIM was first released in 1997 and is still considered the gold standard today.

ID	Years Experience	Title
P1	11	Alternate Radiation Safety Officer
P2	11	Clinical Health Physics Technologist
P3	33	Radiation Safety Officer
P4	24	Director of Radiation Safety
P5	28	Radiation Safety Officer
P6	9	<i>(title withheld by request)</i>

Table 1: Years of experience and titles of radiation safety professionals interviewed.

3.2 Facility tours

We conducted a set of tours at the Los Alamos National Laboratory, the Rhode Island Nuclear Reactor, the University of Massachusetts Lowell Nuclear Reactor, the Massachusetts Institute of Technology Reactor, and Massachusetts General Hospital. We learned from both 'boots on the ground' radiation professionals as well as experts in directorial positions.

From conversations with professionals across these facilities, we observed that the day-to-day for radiation safety professionals both within and between sectors (e.g., medical versus reactor) differed widely, despite sharing common standards and instruments. Factors such as facility type, team size, and organizational structure resulted in a wide variance on RSP experiences and interest in robotics. Factors such as ergonomics or workforce considerations resulted in different visions of the potential for robot teammates.

3.3 Expert Perspectives

We recruited radiological safety professionals both at the previously toured facilities as well as through the "Academic and Medical Radiation Safety Officer listserv" to complete a set of questionnaires with the option to follow up with an interview. We received fifteen responses across the United States and Canada. Five experts were from university reactors, nine from medical facilities, and one from a national laboratory.

We asked questionnaire participants to provide their own perspectives on their day to day roles and how they could envision a robot fitting in. There were twenty 5-point scale likert-style ratings and seven short-answer questions. The questionnaire covered topics such as interactions with other people, physical demands, and day to day decision-making. We also asked about the professionals' comfort level with robots assisting (trust calibration from questions [2]) and preferred or non-preferred tasks in the role.

We followed up with six experts (Table 1) with a semi-structured interview for a more nuanced and in-depth understanding of their roles and views on future robot use.

The study was registered with the institution's internal review board. Participants were compensated for the questionnaires and interviews.

4 Findings

Through our exploration, we identified particularly interesting HRI questions in medical radiation safety that call for nuanced consideration of potential downstream impacts and upstream interventions that can be considered now before system development.

4.1 Medical Radiation Safety

At medical facilities, RSP responsibilities include standard scans and wipe tests as used generally in radiation safety, but there are also responsibilities unique to the medical domain. This work focuses primarily on nuclear medicine and tasks associated with supporting patient care at these facilities.

The medical radioactive material: One unique quality of nuclear medicine is that the majority of radioactive material used has a short half-life (on the order of hours to days) while other types of facilities may operate around half-lives of years to tens of thousands of years. Therefore, a common method for managing radioactive waste that is both ubiquitous and unique to medical facilities is quarantining the material for several days and re-surveying it prior to release.

The patient: In medical facilities, patients treated with nuclear medicine become a source of radiation themselves. RSPs in medical facilities often need to operate in the same spaces as and interact with patients. Tasks involving patients may include performing wipe tests while a patient is in a room, monitoring procedures, responding to spills, measuring radiation levels of a patient treated with nuclear medicine, or providing instructions and information to patients about their care. RSPs also handle byproducts of patient care, such as unintentional contamination by radioactive human waste (e.g., urine splashes around a toilet, used tissues in trash cans), containers of urine stored as part of clinical trials, and radioactive packaging waste that needs to be defaced before disposal to comply with data privacy regulations. As patients are free-willed mobile radiation sources with minimal radiation safety training and stringent privacy requirements, they add complexity and dynamic elements to the radiation safety role.

The dynamics of human relationships and human spaces In medical facilities, the general public constantly flows in and out. A medical RSP's day-to-day often involves much more human interaction compared to their counterparts at reactor facilities. Due to the dynamic environment of the facility itself, obstacles often move, people travel, and adjusting to unexpected changes is a crucial component of the job. Furthermore, (as with other nuclear industries) larger health networks require their radiation safety teams to be responsible for more than one hospital building and even further satellite locations can fall under the same team's purview.

4.2 Medical radiation safety tasks with potential for robots

Radiological safety professionals in medical facilities were more likely to report ergonomically-challenging positions, challenges to complete their assigned work, and less confidence that they could satisfy the physical demands of their role for their entire careers compared to their non-medical counterparts.

4.3 RSPs' robot tasks

Here, we present tasks that medical radiation safety professionals suggested for robot involvement, as well as tasks they would reserve for human professionals.

Radiation Survey in Patient Room. RSPs use handheld radiation meters and swabs/wipes to survey for radioactive contamination.

This survey is typically done after a patient departs. Common contamination locations include high-touch surfaces, trash containing used tissues, or urine splashes in the restroom.

Decontaminate/Clean Patient Room. Decontamination involves removing loose radioactive matter such as by wiping up spills, and must follow procedures (e.g., wipe shape and direction) to minimize spread. Floor cleaning was a major ergonomic concern and deemed tedious.

Transport Non-Radioactive Material. Radiation safety professionals typically distribute and collect dosimeters (devices that measure accrued radiation exposure over time) from staff across entire facilities.

Transport of Radioactive Material. Transporting radioactive material typically requires heavy shielding and can demand payloads from 25 to 400 pounds. While RSPs generally agreed that automated transport could mitigate ergonomic risks, they had different ideas on necessary security measures.

Sealed Source Leak Testing. RSPs often perform routine sealed source leak testing weekly or quarterly and considered it useful to offload this task to a robot. However, some RSPs were concerned about robot entry to secure areas and if they had sufficient dexterity.

Waste Handling. RSPs are responsible for ensuring radiation does not exit the facility via waste streams. When waste is surveyed before it exits the building, any radioactive material above regulation limits must be removed. As a result, staff may need to manually go through trash, which was described as "dumpster diving."

Tasks reserved for RSPs. There were some tasks where RSPs did not want robots involved. RSPs preferred to handle tasks such as spill response during patient treatment administration, direct patient interaction, judgment calls based on individualized circumstances, interpersonal skills, and capabilities demanding high dexterity.

RSPs noted that at any level of robot autonomy the final responsibility falls upon RSPs verify a robot's results ("regulations...would require us to sign off on it anyways"). Therefore, an ability to certify the quality of the robot's work would be instrumental to overcoming regulatory hurdles.

5 Discussion and Conclusion

Although radiation safety robots' primary user group may be radiation safety professionals, robots still need to fit within the broader ecosystem of nuclear regulation, radiation safety teams, and patient care structures. Ultimately, various stakeholders (i.e., regulators, RSPs, and patients) require different considerations for successful robot deployments for medical radiation safety.

From our work with medical radiation safety professionals, we observed that tasks of highest interest for automation were overwhelmingly non-patient facing. RSPs were cautious in trusting robots to make safety-critical patient decisions when interacting (e.g., understanding a patient's ability to be safely discharged). In consideration of downstream impacts on patient care, upstream, it may be valuable to explicitly define the line between robot and human responsibilities in regards to patient proximity.

However, even if robots are not expected to take on explicitly social roles, medical spaces will never allow for completely ignoring the human in robot design. It is impossible to guarantee that patients and passers-by will never be present and there will be no downstream effects involving patients. We would suggest upstream interventions informed by inclusive participatory design with patients even if the intended user group is RSPs. The findings could help anticipate inevitable interactions and inform design language selections to avoid unnecessarily alarming patients and to encourage appropriate use and interaction beyond the primary RSP user group.

On the regulation side, RSPs we interviewed had differing expectations concerning how straightforward it would be to allow use of robots for certain tasks, such as radioactive materials transport and autonomous surveying. Nuclear safety regulations developed over the decades are not necessarily reflective of the current and rapidly advancing capabilities of robotics, which could cause downstream tensions for RSPs wanting to use robots with capabilities that push the status quo. An upstream recalibration of well-defined and well-informed regulations would guide ultimate robot use. Roboticists should work directly and continuously with regulators to anticipate and mitigate these downstream effects.

RSP interviews also noted the potential downstream impacts of robot adoption bringing long training times, learning curves, and responsibility changes that negatively affect RSPs ability to complete their work and job satisfaction. For example, if a robot were to manage dosimeter delivery, an RSP would also lose the benefits of exercise and sunshine that came with transiting between buildings. It will be valuable to create upstream policies that prioritize protection of RSPs' comfort and work fulfillment. These rules could ensure that RSPs workloads and conditions improve with robots rather than worsen.

Our next steps are to further our relationships with medical radiation professionals, and understand how human robot interaction must be handled in the near and long terms for welcome adoption by RSP teams.

Acknowledgments

Thank you to Los Alamos National Laboratory, the Rhode Island Nuclear Reactor, the University of Massachusetts Lowell Nuclear Reactor, the Massachusetts Institute of Technology Reactor, Massachusetts General Hospital, and all of the radiation safety professionals who shared their expertise with our team.

References

- [1] François Diaz-Maurin. 2023. Nuclear safety staffing in the United States: A crisis with no easy fix. <https://thebulletin.org/2023/07/nuclear-safety-staffing-in-the-united-states-a-crisis-with-no-easy-fix/>
- [2] M Lance Frazier, Paul D Johnson, and Stav Fainshmidt. 2013. Development and validation of a propensity to trust scale. *Journal of Trust Research* 3, 2 (2013), 76–97.
- [3] Jamshed Iqbal, Ahmad Mahmood Tahir, Raza ul Islam, et al. 2012. Robotics for nuclear power plants—challenges and future perspectives. In *2012 2nd International Conference on Applied Robotics for the Power Industry (CARPI)*. IEEE, 151–156.
- [4] Michele Laraia. 2012. *Nuclear decommissioning: Planning, execution and international experience*. Elsevier.
- [5] Michele Laraia. 2021. *Nuclear Decommissioning Case Studies: Policies, strategies, Planning and Knowledge Management*. Vol. 2. Academic Press.
- [6] Michele Laraia. 2022. *Nuclear Decommissioning Case Studies: The People Side*. Vol. 3. Academic Press.
- [7] Kathryn H Pryor. 2017. Membership trends in the health physics society: how did we get here and where are we going? *Health physics* 112, 2 (2017), 131–138.
- [8] Ioannis Tsitsimpelis, C. James Taylor, Barry Lennox, and Malcolm J. Joyce. 2019. A review of ground-based robotic systems for the characterization of nuclear environments. *Progress in Nuclear Energy* 111 (2019), 109–124. doi:10.1016/j.pnucene.2018.10.023
- [9] U.S. Nuclear Regulatory Commission, U.S. Environmental Protection Agency, U.S. Department of Defense, and U.S. Department of Energy. 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), Revision 1*. Technical Report NUREG-1575, EPA 402-R-97-016, DOE/EH-0624, DOD 4140.26-M. U.S. Nuclear Regulatory Commission, Washington, D.C. <https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1575/r1/index.html>