Advisory Committee on the Medical Use of Isotopes (ACMUI)
Patient Release Subcommittee Report

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Charge: To evaluate patient release/human research subject release issues; to objectively review and analyze data, which may include state regulations and guidance as well as recommendations in international guidance documents; to provide a statement on the issues, including patient release to other than private residences and an annual rather than per-release limit on radiation doses to others from released individuals; and, if appropriate, to provide recommendations for improvements to existing NRC rules and guidance.

Summary Statements and Recommendations

1. The medical use of radioactive materials provides important diagnostic and therapeutic tools that have well-recognized health benefits[1,2,3,4]. Use of radionuclides in medicine and patient access to radionuclide medical procedures, with associated public doses at or below typical environmental background levels, should not be burdened by excessive regulatory controls, including controls that may lead some practitioners to avoid their use or to deliver sub-optimal care (such as multiple lower-administered activity treatments) simply to comply with regulatory dose limits. The Subcommittee affirms that radiation doses to other individuals from radioactivity in released patients[5] can be safely controlled by:

- the current 10 CFR 35.75 patient release criteria[6],
- licensees' use of scientifically developed dose-based release calculation methods, and patient release instructions based on individual patient circumstances, and
- patients' and caregivers' understanding of and adherence to the patient release instructions.

[1] NCRP Commentary No. 11, "Dose Limits for Individuals Who Receive Exposure from Radionuclide Therapy Patients", National Council on Radiation Protection and Measurements, February 1995.
[2] ICRP Publication 94, "Release of Patients after Therapy with Unsealed Radionuclides", International Commission on Radiological Protection, March 2004.
[3] NCRP Report No. 155, "Management of Radionuclide Therapy Patients", National Council on Radiation Protection and Measurements, December 2006.
[4] IAEA Safety Reports Series No. 63, "Release of Patients after Radionuclide Therapy", International Atomic Energy Agency, 2009.
[5] Use of the term "patient" in this report is intended to also include human research subject.
[6] NRC Regulation 10 CFR 35.75, "Release of individuals containing unsealed byproduct material or implants containing byproduct material", Nuclear Regulatory Commission.

Relevant regulations should not be overly prescriptive because the licensee is best qualified to assess the suitability of individual patients for release post-treatment and to provide personalized guidance to patients to assure compliance with the applicable release criteria.

2. Current 10 CFR 35.75 patient release criteria, along with NRC RIS 2003-04[7], appropriately balance public safety with patient access to medical treatment.

- Based on NRC conclusions documented in the final rulemaking[8] and lack of further rulemaking changes to these criteria, the current patient release criteria should continue to be considered as per-release dose limits until modified by future rulemaking.
- National and international scientific recommendations on patient release are consistent, in principle and practice, with NRC patient release regulations and guidance.
- The NRC per-release 5 mSv (500-mrem) dose limit for any individual is consistent with ICRP and IAEA recommendations for caregivers and other members of the patient's household.
- For all other members of the general public, NRC requires the licensee to provide written instructions to the patient on ways to keep radiation dose as low as reasonably achievable, or less than 1 mSv (100 mrem). Specifically, these instructions further protect children, pregnant women, and non-caregivers.

3. Current NRC guidance on patient release calculations[9] overestimates caregiver and public doses because the guidance assumes unrealistically conservative assumptions. The Subcommittee recommends that:

- NRC guidance and assumptions should be updated, with assistance from experts, and should include current information on actual radiopharmaceutical biokinetics and calculated or measured patient dose rates.
- Updated scientifically-based tools should be developed to assist licensees in determining and documenting compliance with the patient release criteria.
- Reasonable assumptions should be employed for calculating realistic doses to people from a released patient.
- In addition to private residences, release scenarios should address patient release to other locations (such as hotels, public transport, public events).

4. Current NRC instructions for patient release[9] should be updated, in conjunction with release calculation methods and assumptions, and the NRC should support research efforts to advance understanding and communication of circumstances that impact patient release decisions, instructions and perceptions.

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[7] NRC Regulatory Issue Summary 2003-04 "Use of the Effective Dose Equivalent in Place of the Deep Dose Equivalent in Dose Assessments" (February 13, 2003).

[8] 62 FR 4120: "Criteria for the Release of Individuals Administered Radioactive Material-Final Rule", NRC Docket No. RIN 3150-AE41, January 29, 1997.

[9] NRC Regulatory Guide 8.39, "Release of Patients Administered Radioactive Materials", Nuclear Regulatory Commission, April 1997.

Scientific Evaluation of Patient/Human Research Subject Release Issues

Experts in radiation protection[10,11] apply three fundamental principles to the use of radioactive materials:

- The Principle of Justification: Any decision that alters the radiation exposure situation should do more good than harm.
- The Principle of Optimization of Protection: The likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable (ALARA), taking into account economic and societal as well as medical factors.
- The Principle of Application of Dose Limits: The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits specified.

The appropriate use of radioactive materials in medicine is accepted as doing more good than harm. Exposure to the patient is intentional for the direct medical benefit of the patient. Radiation protection experts oppose dose limits for patients because doing so may compromise the effectiveness of the patient's diagnosis or treatment, and thus do more harm than good. Experts emphasize the physician's informed medical justification for a patient's medical procedure while maintaining the patient's radiation dose as low as reasonably achievable, again taking into account economic and societal as well as medical factors.

<u>Exposure to Other Individuals from Patients Released from Licensee Control</u>

Patients undergoing therapeutic medical procedures using radioactive materials become a radiation source that may expose other individuals, and therefore warrant appropriate precautions for limiting doses to those individuals. Patients undergoing diagnostic radiopharmaceutical procedures may also expose other individuals to radiation fields. The likely dose to others from nuclear medicine or implant procedures is low, but not necessarily zero[12,13]. Individuals most likely to be exposed to a released patient are the patient's family members, or other person caring for or comforting the patient (caregiver), who will be in physical proximity of the patient in the initial days following release. Reducing the need for hospital stays also provide patients, their families and caregivers psychological and emotional benefits of having the patient with them and of lowering their health care costs[13,14]. This also provides societal benefits by reducing the direct economic costs, and commitment, of medical resources required to retain the patient in a hospital,

[10] NCRP Report No. 116, "Limitation of Exposure to Ionizing Radiation", National Council on Radiation Protection and Measurements, March 1993.
[11] ICRP Publication 103, "The 2007 Recommendations of the International Commission on Radiation Protection", March 2007.
[12] ICRP Publication 94, "Release of Patients after Therapy with Unsealed Radionuclides", International Commission on Radiological Protection, March 2004.
[13] NRC NUREG-1492, "Regulatory Analysis on Criteria for the Release of Patients Administered Radioactive Materials, Final Report", by Stewart Schneider and Stephen A. McGuire, Nuclear Regulatory Commission, April 1996.
[14] 62 FR 4120: "Criteria for the Release of Individuals Administered Radioactive Material-Final Rule", NRC Docket No. RIN 3150-AE41, January 29, 1997.

and the indirect costs of a patient's or their employer's lost work time[15]. Exposures to other individuals can be effectively managed by the educated patient (or parent or guardian) after release if that patient follows the instructions provided by the licensee. These instructions help the patient to maintain doses to levels comparable to or less than variations in natural background radiation doses. Given the balance of personal and societal benefits gained, and the ability to maintain doses to others as low as reasonably achievable levels, the NRC concluded in its final rulemaking that the benefits outweigh the potential of small increased risks associated with the release of patients administered radioactive materials[16,17].

Scientific Development of Current NRC Patient Release Criteria

In the early 1990s, the NRC received three petitions for rule making[18,19,20] concerning the 10 CFR 35.75 patient release criteria, which at that time included an activity-based limit and 10 CFR 20.1301 public dose limits. In response to these petitions, the NRC initiated rulemaking to change patient release criteria to dose rate-based limits[21]. The NRC evaluated patient release criteria which appropriately applied the three fundamental principles previously discussed. The NRC considered three alternatives in its cost-benefit analysis[15] of the controlling criteria for determining when a patient may be released from the licensee's control:

Alternative 1 – 1 mSv (100 mrem) per year dose limit in 10 CFR 20.1301

Alternative 2 – less than 1,110 MBq (30 mCi) or less than 0.05 mSv/h (5 mrem/h) at 1 meter per the activity-based, which was the 1996 version of 10 CFR 35.75 [22]

Alternative 3 – 5 mSv (500 mrem) dose limit

NRC concluded that **Alternative 3** best served the interest of patients and society[16] for the following reasons:

1. All of the alternatives were compatible with generally accepted radiation protection principles.
2. **Alternative 1** was dismissed due to its excessive economic costs and adverse psychological impact on patients and their families due to the required patient isolation.

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[15] NRC NUREG-1492, "Regulatory Analysis on Criteria for the Release of Patients Administered Radioactive Materials, Final Report", by Stewart Schneider and Stephen A. McGuire, Nuclear Regulatory Commission, April 1996.
[16] NRC SECY 96-100: "Final Amendments to 10 CFR Parts 20 and 35 on Criteria for the Release of Individuals Administered Radioactive Material", Nuclear Regulatory Commission, May 8, 1996.
[17] 62 FR 4120: "Criteria for the Release of Individuals Administered Radioactive Material-Final Rule", NRC Docket No. RIN 3150-AE41, January 29, 1997.
[18] 56 FR 26945: "Carol S. Marcus; Filing of Petition for Rulemaking", NRC Docket No. PRM-20-20, June 12, 1991.
[19] 57 FR 8282: "American College of Nuclear Medicine; Receipt of Petition for Rulemaking", NRC Docket No. PRM-35-10, March 9, 1992; and 57 FR 21043: "American College of Nuclear Medicine; Receipt of Amended Petition for Rulemaking", NRC Docket No. PRM-35-10A, May 18, 1992.
[20] 59 FR 37950: "American Medical Association; Petition for Rulemaking", NRC Docket No. PRM-35-11, July 26, 1994.
[21] 59 FR 30724: "Criteria for the Release of Patient Administered Radioactive Material, Proposed Rule", NRC Docket No. RIN 3150-AE41, June 15, 1994.
[22] Also referred to as the "30-mCi rule"

3. **Alternative 3** was preferred over **Alternative 2** because of its more favorable cost-effectiveness and more positive psychological impact on patients and their families.
4. Basing patient release criteria on the dose to individuals exposed to a patient provided the consistent, scientific basis of dose for such decisions that treats all radionuclides on a risk-equivalent basis. The 30-mCi limit (**Alternative 2**), which may have been appropriate for iodine-131 under some circumstances, was excessive for some patients and clinical situations using certain other radionuclides (projected doses would be well below the dose limit), but inadequate for other situations and radionuclides (projected doses exceed the dose limit).
5. **Alternative 3** allowed physicians flexibility to *not* have to fractionate therapy doses, leading to improved effectiveness of treatment for the patient while avoiding unnecessary hospitalization associated with the 30-mCi rule[23].
6. Reduction of medically unwarranted hospital stays provided emotional benefits to patients and their families. Allowing earlier reunion of families could improve the patient's state of mind, which in itself improved the outcome of the treatment and led to the delivery of more effective health care. At the same time, the opportunity to personally care for a seriously ill family member was comforting to many individuals.

Today, the Subcommittee affirms the thorough analysis found in NUREG-1492 and its rational evaluation of the three alternatives. The NRC's final decision to implement **Alternative 3** as the patient release criteria found in 10 CFR 35.75 appropriately balanced the three fundamental radiation protection principles for use of radioactive materials in medicine.

Current National and International Recommendations Regarding Released Patients

The National Council on Radiation Protection and Measurements (NCRP) recommendations[24] specific to release criteria for radionuclide therapy patients in place at the time NRC established the current 10 CFR 35.75 release criteria were as follows:

Other Individual	**NCRP[24] Recommended Dose Limit**
Public	1 mSv/y, but 5 mSv/y may be used for infrequent exposures
Patient's Family, Adults	5 mSv/y, 50 mSv/y with special training
Patient's Family, Children and Pregnant Women	1 mSv/y

The NCRP also concluded in this commentary that "a contamination incident that could lead to a significant intake of radioactive material is very unlikely"[25]. The most recent NCRP Report on the subject maintains those same limits[26].

[23] In locations where the 30-mCi rule is in effect, some physicians treat thyroid cancer with multiple administrations of 29.9 mCi of I-131 for no reason other than to avoid hospitalization of patients, thereby treating the patient in a protracted, less therapeutically-effective manner, which can compromise the treatment and, ultimately, the well-being of the patient. When physicians choose to treat thyroid cancer with one administration greater than 30 mCi of I-131, patients can be denied treatment, some for many months, until a private hospital bed is available.

[24] NCRP Commentary No. 11, "Dose Limits for Individuals Who Receive Exposure from Radionuclide Therapy Patients", National Council on Radiation Protection and Measurements, February 1995.

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The International Commission on Radiation Protection (ICRP) recently updated its recommendations on limiting dose to other individuals from the release of patients after therapy with unsealed radionuclides[27]. The ICRP recommendations incorporate the concept of dose constraint, rather than a dose limit, as follows:

Other Individual	**ICRP[27] Recommendations**
Public	1 mSv/y (limit)
Relatives, Visitors, and Caregivers	A few mSv/episode (constraint)
Infants, Young Children, and Casual Visitor	1 mSv/y (limit)

The International Atomic Energy Agency (IAEA) also recently published a safety series report on the release of radionuclide therapy patients[28]. The IAEA endorsed the ICRP recommendations and further clarified its criteria in a recent position statement[29].

All three of the above authoritative national and international advisory bodies agreed that the decision to hospitalize or release a patient should be determined on an individual basis and should be based on dose criteria rather than on residual-activity criteria (as with the previous 30-mCi rule).

The physician's decision should also take into account the patient's wishes and medical condition, his or her physical and mental capacity to understand and follow instructions, occupational and public exposures, family considerations (including the presence of children and pregnant women in the household), cost, and environmental factors. These advisory bodies' recommendations incorporated the concept of maintaining the dose to other individuals as low as reasonably achievable, and recognized the need for flexibility in the regulatory authority's practical application of limits and constraints so that patient physical and psychological factors, as well as economic and societal factors, are properly considered.

The ICRP noted that determination of the overall costs associated with various methodologies related to release of patients after therapy with unsealed radionuclides had generally not been attempted[27]. The ICRP stated:

> "Ideally, 'costs' should include psychological and adverse health consequences, as well as monetary costs. Cost-benefit analysis for a specific issue may vary substantially from country to country, but it does provide a tool that may help the optimization process."

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[25] NCRP Commentary No. 11, "Dose Limits for Individuals Who Receive Exposure from Radionuclide Therapy Patients", National Council on Radiation Protection and Measurements, February 1995.

[26] NCRP Report 155, "Management of Radionuclide Therapy Patients." National Council on Radiation Protection and Measurements, December 2006.

[27] ICRP Publication 94, "Release of Patients after Therapy with Unsealed Radionuclides", International Commission on Radiological Protection, March 2004.

[28] IAEA Safety Reports Series No. 63, "Release of Patients after Radionuclide Therapy", International Atomic Energy Agency, 2009.

[29] IAEA Position Statement, "Release of Patients after Radionuclide Therapy", International Atomic Energy Agency, February 23, 2010.

The ICRP cited the NRC's NUREG-1492 cost-benefit analysis as a scientifically appropriate example.

The Subcommittee finds the current 10 CFR 35.75 release criteria to be consistent with the practical application of nationally and internationally recommended dose constraints and limits, and to be in harmony with public safety, humane patient care, and cost-effective delivery of medical treatment.

<u>Control of Dose to Other Individuals from Released Patients</u>

In contrast to diagnostic nuclear medicine procedures, doses to the public, patients' relatives, and others may need to be limited after some therapeutic procedures. The preponderance of peer-reviewed scientific data demonstrate that the radiation dose from internal contamination of other individuals from released patients is far less significant than that from external exposure[30,31,32,33]. Because of its physical properties and the extent of its use, I-131 is the most likely therapeutic radionuclide having potential to cause radiation dose to medical staff, the public and family members. Therefore, the Subcommittee has focused its review on circumstances associated with I-131 therapy patients.

Prior to patient release, the licensee has responsibilities established by NRC regulations and license conditions for controlling dose to other individuals exposed to an I-131 therapy patient. These controls incorporate well-established and straightforward concepts of limiting exposure: minimizing time, maximizing distance from the source (i.e., the patient), and, to the extent practical, using shielding. Controls include measures to prevent or at least minimize radioactive contamination; a medical facility's use of universal precautions[34,35] and infection controls[36,37] effectively achieve this. The licensee has responsibility to evaluate the circumstances of the planned patient release to ensure compliance with 10 CFR 35.75[38] , which permits a licensee to "authorize the release from its control any individual who has been administered unsealed byproduct material or implants containing byproduct material if the total effective dose equivalent to any other individual from exposure to the released individual will not likely exceed 5 mSv (0.5

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[30] NCRP Commentary No. 11, "Dose Limits for Individuals Who Receive Exposure from Radionuclide Therapy Patients", National Council on Radiation Protection and Measurements, February 1995.
[31] NRC NUREG-1492, "Regulatory Analysis on Criteria for the Release of Patients Administered Radioactive Materials, Final Report", by Stewart Schneider and Stephen A. McGuire, Nuclear Regulatory Commission, April 1996.
[32] ICRP Publication 94, "Release of Patients after Therapy with Unsealed Radionuclides", International Commission on Radiological Protection, March 2004.
[33] IAEA Safety Reports Series No. 63, "Release of Patients after Radionuclide Therapy", International Atomic Energy Agency, 2009.
[34] OSHA Regulation 29 CFR 1910.1030, "Bloodborne Pathogens", Occupational Safety & Health Administration, Department of Labor.
[35] CDC Fact Sheet, "Universal Precautions for Prevention of Transmission of HIV and Other Bloodborne Infections", Centers for Disease and Control Prevention, Department of Health and Human Services, 1996 update.
[36] CDC, "Guidelines for Environmental Infection Control in Health-Care Facilities", Centers for Disease and Control Prevention, Department of Health and Human Services, 2003.
[37] CDC, "2007 Guidelines for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings", Centers for Disease and Control Prevention, Department of Health and Human Services, 2007.
[38] NRC Regulation 10 CFR 35.75, "Release of individuals containing unsealed byproduct material or implants containing byproduct material", Nuclear Regulatory Commission.

rem)". The licensee is also required to "provide the released individual, or the individual's parent or guardian, with instructions, including written instructions, on actions recommended to maintain doses to other individuals as low as is reasonably achievable if the total effective dose equivalent to any other individual is likely to exceed 1 mSv (0.1 rem)". This regulatory language characterizes the responsibility of the licensee as ensuring that the dose to an individual from a released patient is not *likely* to exceed the specified dose limit, rather than as certitude that the dose limit will not be exceeded.

In the case of an orally administered therapeutic radionuclide (such as I-131 sodium iodide), vomiting shortly after its administration is a contamination concern. The NRC concluded in its final rulemaking for the current 10 CFR 35.75[39]:

> "Vomiting is seldom an important elimination route for radiopharmaceuticals after the patient has left the medical facility since orally administered radiopharmaceuticals such as iodine-131 are rapidly absorbed, within a half hour, by the gastrointestinal system."

Vomiting is a rare event, and can often be prevented by giving antiemetics to the patient prior to administration of the radionuclide. The risk of vomiting in public can be further mitigated by having the patient remain in a designated monitored area at the facility for a short period of time post-administration, when vomiting is most likely.

Once an I-131 therapy patient is released, NRC's regulatory control, and thus the licensee's responsibilities[40], ends[39]. At this point, the patient, parent or guardian assumes responsibility for managing radiation exposure to other individuals based on instructions provided by the licensee. These instructions should be straightforward and easy to follow so that the patient will understand how to minimize radiation doses to other individuals as low as reasonably achievable. Instructions include maintaining distance from other people, minimizing time in public places, measures to reduce the spread of radioactive contamination, and the length of time the patient should follow each such precaution[41]. As part of the implementation of the current 10 CFR 35.75 release criteria, the NRC worked with the Society of Nuclear Medicine (SNM) to prepare a pamphlet that provides practical information for patients receiving treatment with radioiodine[42]. The NRC noted in final rulemaking for the current 10 CFR 35.75[39] that "American medical practice routinely depends on patients following instructions, such as instructions on when and how to take medications".

As a licensee reviews the I-131 therapy patient's post-release living and traveling circumstances, certain precautions may be emphasized or lengths of time adjusted for special circumstances, such as those involving potential exposure of children or pregnant women or the need to use public transportation to return home or to stay in a hotel or other non-private residence

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[39] 62 FR 4120: "Criteria for the Release of Individuals Administered Radioactive Material-Final Rule" (NRC Docket No. RIN 3150-AE41), January 29, 1997.

[40] The term "licensee's responsibilities" refers only to the control of radioactive material under NRC regulations, and does not include the physician's continuing responsibilities for medical care of the patient.

[41] NRC Regulatory Guide 8.39, "Release of Patients Administered Radioactive Materials", Nuclear Regulatory Commission, April 1997.

[42] SNM Pamphlet, "Guidelines for Patients Receiving Radioiodine Treatment," Society of Nuclear Medicine, 1997. This pamphlet may be obtained from the Society of Nuclear Medicine, 1850 Samuel Morse Drive, Reston, VA 20190-5316.

prior to returning home. As the IAEA noted[43], "The success of a patient release program is critically dependent on the quality and specificity of the information provided to the patient, the skill with which it is communicated, and whether or not the patient believes the information provided." The IAEA also advised that the precautions "should be based upon realistic models of behavior, including realistic occupancy factors, and should not be over-cautious"[44].

The NRC adopted a dose-based limit in its final rulemaking because it "better expresses the NRC's primary concern for the public's health and safety"[45]. Scientists[46,47] have measured doses to other individuals, primarily family members and other caregivers, from released I-131 therapy patients, and the actual doses received by these individuals are significantly less than those conservatively projected by the licensee as the basis for the patient release.

<u>Use and Misuse of Conservative Assumptions in Estimating Dose to Other Individuals</u>

With implementation of the current 10 CFR 35.75 release criteria, the NRC issued guidance[48] to assist licensees with determining when a patient could be released, when instructions to patients were required, and what records must be generated and maintained. NRC guidance on calculating dose to other individuals was primarily based on release of an I-131 therapy patient using what is now judged to be very conservative assumptions[49,50]. As noted, the IAEA advised that these dose calculations should be realistic and not overly-cautious[44]. Although NRC's 1997 guidance was conservative, the NRC practice of establishing risk-informed and performance-based regulations[51] allowed licensees the practical flexibility to use more reasonable guidance and realistic calculations in determining compliance with the current 10 CFR 35.75 release criteria[45].

As previously discussed, licensees must evaluate an I-131 therapy patient's post-release living circumstances in order to choose reasonable specific calculation assumptions and to provide appropriate instructions specific for that patient. On the other hand, when performing such analyses for a generalized patient population, more conservative assumptions may be chosen to account for a greater range of living or traveling circumstances. And, experts may assume activities, distances, occupancy factors, and so forth, that far exceed values likely to be encountered in practice to

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[43] IAEA Safety Reports Series No. 63, "Release of Patients after Radionuclide Therapy", International Atomic Energy Agency, 2009.
[44] IAEA Position Statement, "Release of Patients after Radionuclide Therapy", International Atomic Energy Agency, February 23, 2010.
[45] 62 FR 4120: "Criteria for the Release of Individuals Administered Radioactive Material-Final Rule", NRC Docket No. RIN 3150-AE41, January 29, 1997.
[46] Grigsby PW, Siegel BA, Baker S, & Eichling, JO. "Radiation exposure from outpatient radioactive iodine (I-131) therapy for Thyroid Carcinoma". JAMA. 2000;283:2272–2274.
[47] Rutar FJ, Augustine SC, Colcher D, et al. "Outpatient treatment with 131I-anti-B1 antibody: radiation exposure to family members". J Nucl Med. 2001;42:907–915.
[48] NRC Regulatory Guide 8.39, "Release of Patients Administered Radioactive Materials", Nuclear Regulatory Commission, April 1997.
[49] Siegel JA, Marcus CS, Stabin MG, "Licensee Over-Reliance on Conservatisms in NRC Guidance Regarding the Release of Patient Treated with I-131", Health Physics (93:667-677), December 2007.
[50] ICRP Publication 94, "Release of Patients after Therapy with Unsealed Radionuclides", International Commission on Radiological Protection, March 2004.
[51] NRC "The Risk-Informed and Performance-Based Plan (RPP)", http://www.nrc.gov/about-nrc/regulatory/risk-informed/rpp.html.

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thereby demonstrate that if such highly improbable scenarios are compatible with release criteria, then more realistic dose projections could be expected to be much lower. However, some may misuse the end result from such extreme calculations uncritically, that is, without consideration of how unrealistic the underlying assumptions are, and thus precipitate unnecessary public safety concerns and alarm.

An example of such a calculation is found in the latest ICRP recommendations[52]. The ICRP made this calculation to demonstrate the importance of an I-131 therapy patient taking precautions to reduce or prevent internal contamination of children and infants. The ICRP's concluding statements accompanying this calculation are as follows:

> "Contamination of infants and young children with saliva from a treated patient during the first few days after radioiodine therapy could result in significant doses to the child's thyroid, and potentially raise the risk of subsequent radiation-induced thyroid cancer".
>
> "Thyroid cancer as a result of contamination (particularly with saliva) may be a significant risk for those under 20 years of age."

As described in Paragraphs (68) and (69) of the ICRP report[52], the following unrealistic assumptions were used:

- The I-131 therapy patient (parent) does not follow the precautions given in their oral and written instructions to minimize contact with their own infants and children;
- The I-131 therapy patient (parent) transfers 1 milliliter (e.g., approximately ¼ teaspoon) of saliva (55,500 Bq = 1.5 μCi) by kissing the child in the first day after therapy; and,
- The thyroid cancer incidence from this child's calculated thyroid dose is estimated based on preliminary data of cancer incidence being studied in children who ingested larger amounts of radioactive iodine and other radionuclides in milk and vegetables contaminated from the Chernobyl accident[53].

The ICRP report stated that actual measurements from children when parents followed appropriate precautions resulted in lower thyroid doses than those indicated by this calculation. In one study[54], iodine activity was detected in only 25 of 89 children; even though some of these parents did not receive, understand, or follow the precautions. So even without proper instruction, 64 of the 89 children had no detectable iodine activity.

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[52] ICRP Publication 94, "Release of Patients after Therapy with Unsealed Radionuclides", International Commission on Radiological Protection, March 2004.

[53] Another study of children administered diagnostic amounts (5 to 15 μCi) of I-131 found no incidence of cancer – Dickman PW, et. al., "Thyroid Cancer Risk After Thyroid Examination with I-131: a Population-Based Cohort Study in Sweden", Int. J. Cancer: 106, 580-587 (2003).

[54] Barrington, S.F., O'Doherty, M.J., Kettle, A.G., et al. "Radiation Exposure of Families of Outpatients Treated with Radioactive Iodine (iodine-131) for Hyperthyroidism", Eur. J. Nucl. Med. 26, 686–692 (1999).

The Subcommittee agrees that a released I-131 therapy patient should be instructed to take special precautions to minimize dose to children and pregnant women. The 1997 SNM pamphlet[55] that many licensees provide to their I-131 therapy patients instructs the patient to avoid kissing the first few days following treatment, and to avoid prolonged physical contact, especially with children and pregnant women, explaining that the thyroid glands of children and fetuses are more sensitive to the effects of I-131 than those of adults.

The NRC issued a Regulatory Issue Summary (RIS)[56] in 2008, which included the first ICRP concluding statement listed above, but provided no details regarding the assumptions. The RIS also stated:

> "However, as described in the Background section of this RIS, for some I-131 therapies, such as oral administration of sodium iodide I-131, the ICRP cautions that the internal dose to infants and young children who may come in contact with a released patient could be significant."

> "The guidance recommends that licensees consider not releasing patients, administered I-131, whose living conditions may result in unnecessary exposure of infants and young children."

The intent of this RIS was to remind licensees of precautions (established in 1997 with the current 10 CFR 35.75 release criteria) that should be discussed with their I-131 therapy patients. The Subcommittee recommends that these types of caution statements should be fully explained, and that future documents of this type should include a statement for patients to consult their physician for additional information specific to their medical procedure.

Release of I-131 Therapy Patients to Locations other than a Private Residence

The NRC asked the ACMUI to review a draft RIS being developed to address the release of I-131 therapy patients to locations other than a private residence. As part of the ACMUI's analysis, the ACMUI Subcommittee calculated the radiation dose to other individuals from release of an I-131 therapy patient to a hotel. Despite the possibility of misunderstanding or misuse of the resulting calculation and conclusions, the Subcommittee used overly conservative assumptions and parameters, along with reasonable ones, to demonstrate that even highly unlikely dose projections do not exceed the release criteria and that reasonable doses are comparable to variations in background radiation doses.

The example calculations, assumptions used in each case, and the results of this analysis are presented in the Report Appendix[57]. The Subcommittee concluded that when a licensee assesses the I-131 therapy patient's planned living situation upon release, provides the patient with simple

[55] SNM Pamphlet, "Guidelines for Patients Receiving Radioiodine Treatment," Society of Nuclear Medicine, 1997. This pamphlet may be obtained from the Society of Nuclear Medicine, 1850 Samuel Morse Drive, Reston, VA 20190-5316.

[56] NRC RIS 2008-11, "NRC Regulatory Issue Summary 2008-11: Precautions to Protect Children Who May Come in Contact with Patients Released After Therapeutic Administration of Iodine-131", Nuclear Regulatory Commission, May 2008.

[57] See Report Appendix, "Radiation Dose Calculations for I-131 Therapy Patients Released to a Hotel"

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and easily understood oral and written instructions, and judges that the patient, or the patient's parent or guardian, understands the instructions and is capable of complying with the recommended precaution actions, then the dose to any other individual exposed to the I-131 therapy patient is likely not to exceed 1 mSv even when released to a location other than a private residence.

The ICRP[58] suggested that a patient could "stay at a nonhospital living facility, such as a hotel, for several days" when the patient's home situation would put the patient in close contact with children due to physical or social constraints, because this "is less expensive than staying in a hospital". Initial research survey results conducted with voluntary respondents from the Thyroid Cancer Survivors' Association indicated that most released patients in the U.S. go to a private residence (approximately 94%) and only a few (approximately 5%) go to hotels[59]. The Subcommittee agrees that I-131 therapy patient release to a private residence should be encouraged, and that licensees should carefully evaluate patient release to other locations and communicate to the patient additional radiation safety precautions that may be appropriate for such locations.

The Subcommittee discussed management of dose to other individuals exposed to multiple released patients as might occur with workers in a hotel near a major medical facility or workers in a nursing home. The NRC's final rulemaking states that its medical experts "concluded that no common nuclear medicine practice, be it diagnostic, therapeutic, or a combination of the two, results in multiple large administrations that would be likely to cause the 5-millisievert (0.5-rem) dose limit to be exceeded because of multiple administrations in a year"[60]. The Subcommittee extensively discussed patient release to hotels in regard to whether:

- dose management is adequate with current patient release instructions,
- additional guidance and patient instructions are needed,
- there should be added regulatory criteria, and
- this dose management would be effectively accomplished by focusing only on I-131 therapy patient release rather than trying to sum small doses from all radioactive material released patients.

One Subcommittee member felt that no patients should be released to hotels or other similar locations, and one Subcommittee member felt uneasy about allowing this release. Two Subcommittee members felt that patients should be allowed to go a hotel, but that a licensee should, by NRC guidance, track and control the number of released I-131 therapy patients planning to go to specific hotels. Four Subcommittee members felt release to hotels was an acceptable option, and there was no need to track or control release to specific hotels because the realistic projected dose to others is small[61]. The different perspectives of the Subcommittee members on how best to assure compliance with the applicable dose limits led us to conclude that the NRC should support a wider discussion on this topic with the medical community and the public.

[58] ICRP Publication 94, "Release of Patients after Therapy with Unsealed Radionuclides", International Commission on Radiological Protection, March 2004 – see paragraph (106), item (v).
[59] Vetter R, Van Nostrand D, Khorjekar G, et al, Presentation on "Use of a Patient Survey to Evaluate Compliance with and Quality of Instructions Given to Patients Treated with Radioiodine", Annual Meeting of the Health Physics Society, Salt Lake City, Utah, June 27-July 1, 2010.
[60] 62 FR 4120: "Criteria for the Release of Individuals Administered Radioactive Material-Final Rule", NRC Docket No. RIN 3150-AE41, January 29, 1997.
[61] See Report Appendix, "Radiation Dose Calculations for I-131 Therapy Patients Released to a Hotel"

Annual Dose Limits versus Per-Release Dose Limits

The current 10 CFR 35.75 release criteria were developed in accordance with the NRC's stated practice of implementing risk-informed performance-based regulations for licensees. The NRC appropriately recognized that licensees would only be able to judge "likely" doses to other individuals based on knowledge shared by patients of their post-release living circumstances and on the patients' ability to follow instructions in maintaining these doses as low as reasonably achievable. Once the patient is released, the licensee no longer controls the patients' actions, and patients are not accountable to NRC regulations. As stated in the final rulemaking for 10 CFR 35.75[62]:

> "The NRC is establishing a dose limit of 5 millisieverts (0.5 rem) total effective dose equivalent to an individual from exposure to the released patient for each patient release."

The ICRP recommended dose constraint of a few mSv/episode "has often been inappropriately interpreted as a rigid annual dose limit"[63]. The Subcommittee considered the consequences of changes to the current 10 CFR 35.75 release criteria, which apply to all diagnostic and therapeutic radioactive materials administered to patients and human research subjects, from a per-release limit to a rigid annual dose limit. The primary difficulty identified was the practicality of licensees tracking all doses to other individuals on an annual basis, potentially including those from multiple therapy administrations to the same patient in a single calendar year. The NRC concluded in their final rulemaking that the level of recordkeeping, even when limited to patient releases likely to exceed 0.1 mSv, was "an unnecessary burden", and NRC clearly stated[62]:

> "Each patient release is to be treated as a separate event, and licensee knowledge of previous administrations is unnecessary."

The NRC published a regulatory issue summary in 2008 which stated its intent to pursue rulemaking to change the 10 CFR 35.75 patient release criteria from dose limits to dose per year limits because the "presumption that patients receive single administrations of therapeutic doses in a given year, which is the basis used in developing the wording for the dose limit in 10 CFR 35.75, is no longer valid"[64]. The RIS states NRC's view of how licensees should manage patient release involving multiple administrations or applications in a single year. While the NRC explained that it would follow normal rulemaking procedures, including opportunity for public comment, this RIS created confusion as to whether the current 10 CFR 35.75 patient release criteria are per-release or annual dose limits[65].

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[62] 62 FR 4120: "Criteria for the Release of Individuals Administered Radioactive Material-Final Rule", NRC Docket No. RIN 3150-AE41, January 29, 1997.

[63] ICRP Publication 94, "Release of Patients after Therapy with Unsealed Radionuclides", International Commission on Radiological Protection, March 2004.

[64] NRC Regulatory Issue Summary 2008-07: "Dose Limit for Patient Release Under 10 CFR 35.75", March 27, 2008.

[65] Prior to review of the 10 CFR 35.75 rulemaking notices in the Federal Register, polling of the Subcommittee members indicated that half of the members believed current release criteria were per-release dose limits and half believed the criteria were annual limits.

The Subcommittee reviewed and compared the Federal Register proposed rulemaking[66] and the final rulemaking[67] which established the current 10 CRF 35.75 patient release criteria. The NRC clearly stated in its proposed rulemaking that the patient release criteria would be annual dose limits. However, in the final rulemaking, the NRC changed the patient release criteria by dropping the annual limits and instead making the limits apply to each patient release. In regard to this change, the NRC stated[67],

> "Upon reconsideration, based on public comments and consultation with the ACMUI, an NRC medical consultant, and the NRC Visiting Medical Fellow, the NRC has decided to delete this requirement. A review of medical treatment practices revealed no common practice that would result in doses exceeding the 5 millisievert (0.5 rem) limit because of multiple administrations in the same year to the same patient. Without the need to account for the dose from multiple administrations, maintaining records for the many tens of thousands of patients released when their dose to an individual is likely to exceed 1 millisievert (0.1 millisievert) becomes an unnecessary burden. The requirement to retain these records has therefore been deleted. Each patient release is to be treated as a separate event, and licensee knowledge of previous administrations is unnecessary."

There has been significant growth in the use of radioactive material medical procedures in the past 20 years[68], and a few medical procedures, including a few I-131 therapy procedures, are administered to patients more than one time within a calendar year. However, exposure from multiple patients undergoing diagnostic procedures continues to be low in doses to other individuals. Exposure to a patient undergoing multiple I-131 therapies (2 to 3) in one year is likely to be a low dose to other individuals because of the patient following simple instructions for their release. Moreover if one applies the theory of linear no threshold radiation risk, there would be no difference in theoretical risk of radiation dose from exposure to an I-131 therapy patient receiving two therapies in one calendar year versus exposure to an I-131 therapy patient receiving a therapy per year in two calendar years.

Based on the NRC conclusions documented in its final rulemaking[67] and lack of further rulemaking changes to the current 10 CFR 35.75 patient release criteria, the Subcommittee recommends the current patient release criteria should continue to be considered as per-release dose limits until modified by future rulemaking. Seven Subcommittee members believe that a new requirement for annualized dose limits could severely limit patients' access to appropriate medical care at reasonable costs[69]. These Subcommittee members conclude that the most effective and practical way to control the dose to other individuals from the release of patients administered radioactive materials is to support development of new guidance and other tools to assist: (a)

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[66] 59 FR 30724: "Criteria for the Release of Patient Administered Radioactive Material, Proposed Rule", NRC Docket No. RIN 3150-AE41, June 15, 1994.

[67] 62 FR 4120: "Criteria for the Release of Individuals Administered Radioactive Material-Final Rule", NRC Docket No. RIN 3150-AE41, January 29, 1997.

[68] NCRP Report 160, "Ionizing Radiation Exposure of the Population of the United States", National Council on Radiation Protection and Measurements, March 2009.

[69] One Subcommittee member believed that a dose limit would not be a true limit without an associated time frame. The remaining Subcommittee members believed strict adherence to an annual dose limit would severely limit access to medical care, and that the type and typical number of radioactive material medical procedures for a given patient do not result in excessive dose to other individuals in a calendar year.

licensees in assessing, carrying out, and documenting patient release; and (b) patients in understanding and taking appropriate precautions for their specific living circumstances.

One Subcommittee member felt that the inconsistency and confusion over the per-release and annual limit was due to the regulatory nature of the regulation. A per-event limit without an annual limit allows an individual to receive multiple exposures. Although highly unlikely, this situation would be allowable. Furthermore, an annual limit that is the same as a per-release limit is duplicative, since the per-release limit would then be unnecessary. This one Subcommittee member believes the simple solution would be to increase the annual limit for a caregiver who is exposed more than once in a calendar year.

<u>Petition to Return to Pre-1997 Release Criteria</u>

The NRC was petitioned[70] to replace the current dose-based release criteria and to re-instate the 1986 10 CFR 35.75 release criteria[71], widely known as the "30-mCi" rule. The NRC has also received other requests to return to this old rule[72]. The Subcommittee finds no scientific merit in returning to such activity-based release criteria, which have no identifiable scientific basis[73]. The Subcommittee maintains that dose-based release criteria are more scientifically rigorous than activity-based criteria and better protect the public by basing patient releasability on the quantity, dose, *directly* related to potential radiation hazard rather than on a quantity, activity, *indirectly* related to this potential hazard. In the case of I-131 treatment of thyroid cancer, for example, the administered I-131 is rapidly excreted (assuming a whole-body biological half-time of only about 2 days or less). In treating hyperthyroidism, however, 25 to 50% or more of the radioiodine localizes in the thyroid, and that activity is cleared from the gland (and, in turn, the body) much more slowly, with half-times of about 20 days or longer. Accordingly, the retained activity from the much higher activity (typically greater than 100 mCi) administered to the thyroid cancer patient is rapidly reduced to a lower activity than that retained by hyperthyroid patients (who typically receive about 10 mCi)[71]. Thus, higher dose-rate irradiation of individuals persists longer for lower-activity treatment of hyperthyroidism than for higher-activity treatment of thyroid cancer, illustrating the fallacy of an idea that activity-based release criteria (i.e. the "30-mCi" rule) is more protective of public safety[74,75,76].

In fact, the 30-mCi rule is a special case of the 1997 release criteria, based on I-131 with the following conditions:

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[70] 70 FR 75752, "Peter G. Crane; Receipt for Rulemaking", NRC Docket No. PRM-35-18, December 21, 2005.
[71] 51 FR 36932, "Medical Use of Radioactive Material-Final Rule", Nuclear Regulatory Commission, October 16, 1986.
[72] "Radioactive Roulette: How the Nuclear Regulatory Commission's Cancer Patient Radiation Rules Gamble with Public Health and Safety", A report by the Staff of Edward J. Markey (D-MA), Chairman, Subcommittee on Energy and Environment, Energy and Commerce Committee, U.S. House of Representatives, March 18, 2010.
[73] Siegel JA, "Tracking the Origin of the NRC 30-mCi Rule", J Nucl Med. 2000;41:10-16N.
[74] ICRP Publication 94, "Release of Patients after Therapy with Unsealed Radionuclides", International Commission on Radiological Protection, March 2004.
[75] IAEA Safety Reports Series No. 63, "Release of Patients after Radionuclide Therapy", International Atomic Energy Agency, 2009.
[76] See Report Appendix, "Radiation Dose Calculations for I-131 Therapy Patients Released to a Hotel".

- Using the physical half-life instead of the effective half-life, ignoring biological elimination of the radionuclide;
- Ignoring the attenuation of the radiation by the patient;
- Using the default occupancy of 0.25 rather than a value based on actual patient behavior information.

The 30-mCi rule also represented a "per-release" limit. Returning to the old rule simply would ignore physical principles as well as consideration of actual patient behavior in different living circumstances. Change from the 30-mCi rule to the current 10 CFR 35.75 patient release criteria in no way weakened the NRC rules.

NRC policy was not intended to intrude on the practice of medicine[77], yet evidence exists that prior to adopting the 1997 risk based release criteria, the former activity-based release criteria adversely impacted the practice of medicine and patient care by limiting patients to only 30-mCi administered activities simply to allow immediate patient release. This practice essentially fractionates the patient's therapy dose and reduced the effectiveness of therapy. In some countries where activity-based release criteria are still used, patients are effectively denied therapy for as long as one year because of lack of hospital rooms for overnight accommodation. The Subcommittee commends the NRC for adopting the current-risk-based criteria.

Developing Updated Guidance in Support of Patient Release Dose Controls

The NRC guidance to licensees on patient release criteria[78] was based on dose calculation methods and assumptions that are overly conservative and outdated. The Subcommittee recommends that the NRC, with assistance from experts, update the patient release guidance using reasonable assumptions based on an expanded list of radionuclides used in medicine, current radiopharmaceutical biokinetics information, and reported dose measurements from patients. Computer-based modes of communications, data gathering, and data processing should be used to develop tools and accrue data for guidance of licensees in:

- assessing various living situations, including patient release to other locations (such as hotels, public transport, public events),
- calculating realistic radiation dose to others,
- choosing realistic precautions for patients to take,
- instructing patients on these precautions and specific applications, and
- documenting compliance with the patient release criteria.

During this review, the Subcommittee found many scholarly efforts which have advanced understanding and communication of real-world situations that impact patient release decisions and perceptions. The NRC should support research activities to better identify what aspects of patient release have realistic impact on doses to other individuals. As examples, the following efforts provide insights into various aspects of patient release.

[77] 65 FR 47654, "Medical Use of Byproduct Material; Policy Statement, Revision", Nuclear Regulatory Commission, August 3, 2000.
[78] NRC Regulatory Guide 8.39, "Release of Patients Administered Radioactive Materials", Nuclear Regulatory Commission, April 1997.

- Measurements of radiation exposure to household members from released patients[79]
- Surveys of patients and caregivers to determine understanding of and adherence to patient release instructions[80]
- Communication tools to help convey personalized instructions to patients[81]
- Credible websites providing objective, scientific information about radiation[82]
- Medical protocol enhancements for patient release[83]

Patients want access to the best health care. And while release of the I-131 therapy patient is most often the focus of evaluating the potential hazard to others, the I-131 patient should not be treated unfairly by virtue of need for I-131 therapy. Well-informed patients are self-motivated and sensitive to the fact that they are radioactive for a period of time, excreting radioactivity, and will typically do as much as possible to reduce potential exposures to family, caregivers, and other members of the general public. They need to be reassured that their medical procedure with radioactive material is safe for themselves, their family members and their caregivers, and that they do not represent a source of harmful radiation exposure to members of the public. Any new NRC guidance should be developed with the assistance of experts involved with patient release[84], and focus on improved patient counseling rather than excessive controlling or monitoring of the patient.

Subcommittee Conclusions on Patient/Human Research Subject Release Issues

The Subcommittee commends the NRC for its leadership role in developing and implementing practical regulatory control of the use of radioactive materials in patients which appropriately applies the three fundamental radiation protection principles of justification, optimization and limits. Benefits from medical use of radioactive materials are many and well-recognized, improving the health and lives of millions of people in the U.S. These benefits far exceed the small theoretical risks associated with exposure from released patients.

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[79] Grigsby PW, Siegel BA, Baker S, & Eichling, JO. “Radiation exposure from outpatient radioactive iodine (I-131) therapy for Thyroid Carcinoma”. JAMA. 2000;283:2272–2274.

[80] Vetter R, Van Nostrand D, Khorjekar G, et al, Presentation on “Use of a Patient Survey to Evaluate Compliance with and Quality of Instructions Given to Patients Treated with Radioiodine”, Annual Meeting of the Health Physics Society, Salt Lake City, Utah, June 27-July 1, 2010.

[81] Freidman MI, Ghesani M, “Interactive Software Automates Personalized Radiation Safety Plans for $Na^{131}I$ Therapy”, Health Physics (83 Supplement 5:S71-S84), November 2002.

[82] “Radiation Answers: Answers to Questions About Radiation and You”, www.radiationanswers.org , supported by the Health Physics Society.

[83] Khorjekar G, Van Nostrand D, Vetter R, et al, Poster on “The Relationship of Several Factors and Vomiting After Outpatient I-131 Therapy in Patients with Well-Differentiated Thyroid Cancer”, Society of Nuclear Medicine Annual Meeting, Salt Lake City, Utah, June 5-9, 2010.

[84] The Subcommittee members differed in their opinions on methods needed to best counsel multiple patients in managing release to the same location, but agreed that it is essential for the NRC to work with the medical community and the public to develop reasonable and effectual guidance which minimizes impacts on patient access to these medical procedures.

The Health Physics Society[85] recently updated their position statement regarding radiation risk[86], and stated:

> "In accordance with current knowledge of radiation health risks, the Health Physics Society recommends against quantitative estimation of health risks below an individual dose of 5 rem in one year or a lifetime dose of 10 rem above that received from natural sources. Doses from natural background radiation in the United States average about 0.3 rem per year. A dose of 5 rem will be accumulated in the first 17 years of life and about 25 rem in a lifetime of 80 years. Estimation of health risk associated with radiation doses that are of similar magnitude as those received from natural sources should be strictly qualitative and encompass a range of hypothetical health outcomes, including the possibility of no adverse health effects at such low levels.
>
> There is substantial and convincing scientific evidence for health risks following high-dose exposures. However, below 5–10 rem (which includes occupational and environmental exposures), risks of health effects are either too small to be observed or are nonexistent."

Ongoing research efforts are exploring the effects of low-dose radiation exposures[87,88] and examining whether health impacts exist in populations exposed to low levels of radiation[89,90,91,92].

Regulatory decision-making is ultimately a politically based national policy discussion[93] which is shaped by opinions sometimes based on the perception rather than the reality of risk[94]. The NRC remains an important leader in this national discourse [95]. In light of limited health care resources, it is increasingly important that regulations serve not only to protect society from *real* hazards, but

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[85] The Health Physics Society is a nonprofit scientific professional organization whose mission is excellence in the science and practice of radiation safety. Since its formation in 1956, the Society has grown to approximately 6,000 scientists, physicians, engineers, lawyers, and other professionals representing academia, industry, government, national laboratories, the Department of Defense, and other organizations. Society activities include encouraging research in radiation science, developing standards, and disseminating radiation safety information. Society members are involved in understanding, evaluating, and controlling the potential risks from radiation relative to the benefits.

[86] HPS PS010-2, "Radiation Risk in Perspective", Position Statement of the Health Physics Society, revised July 2010.

[87] Brooks AL, "Developing a Scientific Basis for Radiation Risk Estimates: Goal of the DOE Low Research Program", Health Physics (85:85-93), July 2003.

[88] Averbeck D, "Does Scientific Evidence Support a Change from the LNT Model for Low-Dose Radiation Risk Extrapolation?", Health Physics (97:493-504), November 2009.

[89] Shore RE, "Low-Dose Radiation Epidemiology Studies: Status and Issues", Health Physics (97:481-486), November 2009.

[90] Dickman PW, et. al., "Thyroid Cancer Risk After Thyroid Examination with I-131: a Population-Based Cohort Study in Sweden", Int. J. Cancer: 106, 580-587 (2003).

[91] Ghiassi-nejad M, et al, "Very High Background Radiation Areas of Ramsar, Iran: Preliminary Biological Studies", Health Physics (82:87-93), January 2002.

[92] Nair RRK, et al, "Background Radiation and Cancer Incidence in Kerala, India-Karunagappally Cohort Study", Health Physics (96:55-66), January 2009.

[93] Locke P, "Incorporating Information from the U.S. Department of Energy Low-Dose Program into Regulatory Decision-Making: Three Policy Integration Challenges", Health Physics (97:510-515), November 2009.

[94] Jenkins-Smith HC, Silva CL, Murray C, "Beliefs about Radiation: Scientists, the Public and Public Policy", Health Physics (97:519-527), November 2009.

[95] Tenforde TS, Brooks AL, "Perspectives of U.S. Government Agencies on the Potential Role of Greater Scientific Understanding of Low-Dose Radiation Effects in Establishing Regulatory Health Protection Guidance", Health Physics (97:516-518), November 2009.

that they also be based on realistic projections of the severity and likelihood, and on consideration of the actual costs, financial and otherwise, from overly cautious and potentially intrusive regulations. For radionuclide therapy that has been shown to be a safe, effective, and financially viable treatment for certain cancers and other serious diseases, patient release criteria and relevant regulations based on realistic dose projections are both conducive to public safety and promote access to and affordability of such therapy. The Subcommittee affirms that the current dose-based release criteria 10 CFR 35.75 meet these essential benchmarks.

The Subcommittee therefore concludes that the current 10 CFR 35.75 release criteria appropriately balance public safety with patient access to efficacious and cost-effective medical treatment. The Subcommittee recommends that the NRC gather scientific data on patient behavior and understanding of instructions to determine the most effective instructions to enhance licensee communication and documentation of patient release, and to promote patient understanding. The Subcommittee further recommends that the NRC update patient release guidance, with assistance from experts, to include current information on actual radiopharmaceutical biokinetics and calculated or measured patient dose rates, and provide guidance for release scenarios to other locations other than private residences (such as hotels, public transport, public events).

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Appendix[96] – Radiation Dose Calculations for I-131 Therapy Patients Released to a Hotel

The Subcommittee conducted a scientific analysis of radiation doses that might be received by hotel workers in the event that an iodine-131 (I-131) therapy patient, appropriately released from a medical institution, chose to stay in a hotel immediately following the release. We show for four scenarios what the radiation doses to hotel workers and other guests could be under different sets of parameters. The four scenarios are labeled *unrealistic* (representing an improbable, worst-case scenario), *highly unlikely* (representing a doubtful scenario, rarely occurring), *conservative* (representing a possible scenario, not likely to occur), and *realistic* (representing a more likely scenario for a typical patient). The four scenarios involve release to a hotel of (1) an I-131 cancer therapy patient (Table 1), and (2) an I-131 hyperthyroid therapy patient (Table 2). The assumptions and parameters used for each scenario are described in each table.

Published scientific literature indicates that radiation doses to non-patients from iodine-131 patients released after therapy may consist of two components: (1) external radiation exposure received by standing in close proximity to the patient, and (2) the intake of I-131 contamination from I-131 that leaves the patient in excreta or sweat. The literature shows that an individual's radiation dose from the uptake of I-131 contamination is far less significant (less than 10%) than the radiation dose received from external exposure to the patient [97,98,99,100]. Radiation measurements have shown that internal contamination of family members from radioactive patients may only be something on the order of one-millionth of the activity administered to the patient. Therefore, the potential radiation dose to a family member or hotel worker from internalized contamination left by a released I-131 patient can only be far below that which is possible from external doses[101,102,103,104,105,106] (also see Table 3). In addition, the likelihood of

[96] Appendix to the Advisory Committee on the Medical Use of Isotopes (ACMUI) Patient Release Subcommittee Report, December 6, 2010 draft.

[97] NCRP Commentary No. 11, "Dose Limits for Individuals Who Receive Exposure from Radionuclide Therapy Patients", National Council on Radiation Protection and Measurements, February 1995.

[98] NRC NUREG-1492, "Regulatory Analysis on Criteria for the Release of Patients Administered Radioactive Materials, Final Report", by Stewart Schneider and Stephen A. McGuire, Nuclear Regulatory Commission, April 1996.

[99] ICRP Publication 94, "Release of Patients after Therapy with Unsealed Radionuclides", International Commission on Radiological Protection, March 2004.

[100] IAEA Safety Reports Series No. 63, "Release of Patients after Radionuclide Therapy", International Atomic Energy Agency, 2009.

[101] Buchan RCT, Brindle JM. "Radioiodine therapy to outpatients—the contamination hazard". Br J Radiol 43:479–482; 1970.

[102] Hammond N, Jacobson A. An effective method to reduce the exposure to families of radioiodine therapy patients. *Health Phys*. 1982;43:89-172.

[103] Jacobson AP, Plato PA, Toeroek D. "Contamination of the home environment by patients treated with iodine-131: initial results". Am J Public Health 68:230–235; 1978.

[104] Plato P, Jacobson A, Homann S. "In vivo thyroid monitoring for iodine-131 in the environment". *Inter J Applied Radiat Isotopes*. 1976;27:539-545.

[105] Toeroek D, Jacobson A, Plato P. "Radiation protection of families of radioactive patients". *Health Phys*. 1978;35:911-912.

[106] Chandra R, Marshall C. "Radioiodine therapy to out-patients - The contamination hazard (Letter)". *Br J Radiol*. 1971;44:557.

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an intake following intermittent exposure to I-131 contamination of toilets and bedding is very small for both immediate family members and for hotel guests or workers[107]. Even if a hotel worker were *not* to wear gloves while cleaning a released I-131 therapy patient's room, the risk of internalization of I-131 radioactivity remains low – as indicated by the data in the references in Footnote 101 and Table 3.

Despite the use of these overly-cautious assumptions and parameters used in Tables 1 and 2, the highest projected dose to a hotel housekeeper from a released cancer therapy patient is less than 100 mrem. For the case of a released hyperthyroid patient treated for immediate release under the 30-mCi rule, where the amount of I-131 administered is 17% of the amount administered to the cancer therapy patient (Table 2), the three-day projected doses to a hotel housekeeper are 67% of that from the released cancer therapy patient.

The realistic projected doses to hotel workers are very low. To give a perspective of how safe these projected doses are, the average U.S. dose from natural background radiation is 310 mrem per year[108], or 0.85 mrem per day. The highest realistic hotel worker dose of 1.2 mrem would be equivalent to an extra 1.4 days of natural background radiation. The highest realistic guest dose of 22 mrem would be equivalent to an extra 26 days of natural background radiation.

Use of patient-specific parameters in conjunction with realistic assumptions of behavior by the patient, hotel workers and other guests should be used when calculating a particular patient release.

[107] Personal correspondence from M.G. Stabin, Ph.D., CHP.
[108] NCRP Report No. 160, "Ionizing Radiation Exposure of the Population of the United States", National Council on Radiation Protection and Measurements, March 2009.

TABLE 1 –Radiation Dose Calculations to Hotel Workers and Guests from an I-131 Cancer Therapy Patient

- **175 mCi ^{131}I-iodide administered to a post-thyroidectomy thyroid cancer patient**
- **Doses calculated assuming point source*: patient self-shielding** (0.13 mrem-m^2/h-mCi); laundry no shielding (0.22 mrem-m^2/h-mCi)**
- **Total-body effective time-activity function*: $0.95\ e^{(0.693/0.32\ day)\ t} + 0.05\ e^{(-0.693/7.3\ day)\ t}$**
- **Mean distance from patient to guest in adjoining room is 2.2 m (based on mid-point of 80 inch long beds + 6 inch wall), assuming no shielding provided by walls between rooms, and assuming head to head exposure equals mid-body to mid-body exposure**
- **Dose contribution of possible internal radioactive contamination is considered minor and not included**

Assumptions and Parameters* **	**Unrealistic**			**Highly Unlikely**			**Conservative**			**Realistic**		
	Time (in days) Patient Remained in Hotel											
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Cohort	**Radiation Dose to Cohort (in mrem)**											
Hotel Housekeeper	**69**	**83**	**91**	**35**	**43**	**47**	**14**	**17**	**18**	**0.90**	**1.1**	**1.2**
Hotel Laundry Worker	**39**	**47**	**52**	**16**	**19**	**21**	**3.9**	**4.7**	**5.2**	**0.078**	**0.095**	**0.10**
Non-Housekeeping/Non-Laundry Hotel Worker or Hotel Guest in Non-Adjoining Room	**30**	**36**	**39**	**20**	**24**	**26**	**10**	**12**	**13**	**0.83**	**0.99**	**1.1**
Hotel Guest in Room Adjoining that of Patient	**54**	**65**	**71**	**40**	**48**	**53**	**26**	**32**	**34**	**17**	**21**	**22**
Parameters												
Remaining activity in patient excreted into bed linens at midpoint of each day	50% per day			20% per day			5% per day			0.1% per day (bath linens & cleaning only)		
Time hotel housekeeper and laundry worker each hold contaminated linens (0.3 m away)	30 minutes per day			20 minutes per day			10 minutes per day			10 minutes per day		
Time hotel housekeeper, other workers (except laundry), and other guests are 1 meter from patient	3 hours per day			2 hours per day			1 hour per day			5 minutes per day		
Additional time patient and other hotel guest in adjoining room are both in their respective beds	12 hours per day			10 hours per day			8 hours per day			8 hours per day		

* Values used are from NRC Regulatory Guide 8.39

** Patient self-shielding value from SPARKS, R.B., SIEGEL, J.A. and WAHL, R.L. (1998). “The need for better methods to determine release criteria for patients administered radioactive material,” Health Phys. **75**(4), 385–388.

***These assumptions and parameters should be adjusted for patient-specific situations, considering patient release instructions, to calculate realistic doses.

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TABLE 2 – Radiation Dose Calculations to Hotel Workers and Guests from an I-131 Hyperthyroid Patient

- **29.9 mCi ^{131}I-iodide administered to a hyperthyroid patient**
- **Doses calculated assuming point source*: patient self-shielding** (0.13 mrem-m^2/h-mCi); laundry no shielding (0.22 mrem-m^2/h-mCi)**
- **Total-body effective time-activity function*: $0.20\ e^{(0.693/0.32\ \text{day})\ t} + 0.80\ e^{(-0.693/5.2\ \text{day})\ t}$**
- **Mean distance from patient to guest in adjoining room is 2.2 m (based on mid-point of 80 inch long beds + 6 inch wall), assuming no shielding provided by walls between rooms, and assuming head to head exposure equals mid-body to mid-body exposure**
- **Dose contribution of possible internal radioactive contamination is considered minor and not included**

Assumptions and Parameters***	Unrealistic			Highly Unlikely			Conservative			Realistic		
	Time (in days) Patient Remained in Hotel											
	1	2	3	1	2	3	1	2	3	1	2	3
Cohort	Radiation Dose to Cohort (in mrem)											
Hotel Housekeeper	25	44	61	12	22	31	4.7	8.5	12	0.30	0.54	0.74
Hotel Laundry Worker	15	27	37	5.9	11	15	1.5	2.7	3.7	0.029	0.053	0.074
Non-Housekeeping/Non-Laundry Hotel Worker or Hotel Guest in Non-Adjoining Room	10	17	24	6.4	12	16	3.2	5.8	8.0	0.27	0.48	0.67
Hotel Guest in Room Adjoining that of Patient	18	32	44	13	24	33	8.5	15	21	5.6	10	14
Parameters												
Remaining activity in patient excreted into bed linens at midpoint of each day	50% per day			20% per day			5% per day			0.1% per day (bath linens & cleaning only)		
Time hotel housekeeper and laundry worker each hold contaminated linens (0.3 m away)	30 minutes per day			20 minutes per day			10 minutes per day			10 minutes per day		
Time hotel housekeeper, other workers (except laundry), and other guests are 1 meter from patient	3 hours per day			2 hours per day			1 hour per day			5 minutes per day		
Additional time patient and other hotel guest in adjoining room are both in their respective beds	12 hours per day			10 hours per day			8 hours per day			8 hours per day		

* Values used are from NRC Regulatory Guide 8.39

** Patient self-shielding value from SPARKS, R.B., SIEGEL, J.A. and WAHL, R.L. (1998). "The need for better methods to determine release criteria for patients administered radioactive material," Health Phys. **75**(4), 385–388.

***These assumptions and parameters should be adjusted for patient-specific situations, considering patient release instructions, to calculate realistic doses.

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Table 3 – Summary Table of Family Doses from Buchan Reference in Footnote 101

Summary of Radiation Dosimetry for Family Members of I131-Treated Thyroid Patients

Disease Treated	Exposed Cohort	Maximum Recommended Annual Effective Dose µSv	Maximum Recommended Annual Effective Dose mrem	Radiation Precautions		Equivalent Dose per Unit Patient Total Body Activity at Discharge: Total Body (Non-Thyroid) µSv/MBq	Total Body (Non-Thyroid) mrem/mCi	Thyroid: Thyroid-to-Thyroid µSv/MBq	Thyroid-to-Thyroid mrem/mCi	Thyroid: Total µSv/MBq	Thyroid: Total mrem/mCi	Effective Dose per Unit Activity at Discharge: Total Body (non-Thyroid) Contribution µSv/MBq	Total Body (non-Thyroid) Contribution mrem/mCi	Thyroid Contribution µSv/MBq	Thyroid Contribution mrem/mCi	Total µSv/MBq	Total mrem/mCi		Patient Activity at Discharge for Maximum Recommended Effective Dose MBq	mCi
Hyperthyroidism	Children	1,000	100	None / Minimal[a]	*Minimum*	0.398	1.47	*0.0789*	*0.292*	0.477	1.76	0.378	1.40	0.0238	0.0881	0.402	1.48	*Best case*	2,490	67.4
					Maximum	0.920	3.42	*55.1*	*204*	56.0	207	0.874	3.25	2.80	10.4	3.68	13.6	*Worst case*	272	7.34
					Median	0.733	2.71	*0.47*	*1.74*	1.20	4.45	0.696	2.57	0.0602	0.223	0.757	2.80	*Median*	1,320	35.8
				Minimize contact for up to 25 days	*Minimum*	0.0811	0.300	0.0789	0.292	0.160	0.592	0.0770	0.285	0.00800	0.0296	0.0850	0.315	*Best case*	11,800	318
					Maximum	10.5	38.8	55.1	204	65.6	243	9.98	36.9	3.28	12.1	13.3	49.0	*Worst case*	76	2.04
					Median	1.99	7.35	0.47	1.74	2.46	9.09	1.89	6.98	0.123	0.455	2.01	7.44	*Median*	498	13.4
	Adults / Spouses	5,000	500	None / Minimal	*Minimum*	0.241	0.89	3	1.11	3.24	2.00	0.229	0.85	0.162	0.100	0.391	0.946	*Best case*	19,600	529
					Maximum	22.2	82.2	11.7	43.3	33.9	126	21.09	78.09	1.70	6.28	22.8	84.4	*Worst case*	219	5.93
					Median	4.83	17.9	1.88	7.00	6.71	24.9	4.59	17.01	0.336	1.25	4.92	18.3	*Median*	1,010	27.4
				Sleep apart for up to 25 days	*Minimum*	1.43	5.28	0.478	1.77	1.91	7.05	1.36	5.016	0.0954	0.353	1.45	5.37	*Best case*	3,450	93.1
					Maximum	13.1	48.3	10.2	37.6	23.3	85.9	12.44500	45.9	1.17	4.30	13.6	50.2	*Worst case*	369	10.0
					Median	1.79	6.64	2.03	7.52	3.82	14.2	1.70	6.31	0.191	0.708	1.89	7.02	*Median*	2,640	71.3
Thyroid Cancer	Children	1,000	100	None / Minimal[b]	*Minimum*	0	0.00	*0.135*	*0.500*	0.135	0.500	0.00	0.00	0.00675	0.0250	0.00675	0.0250	*Best case*	148,000	4,000
					Maximum	1.38	5.36	*0.252*	*0.933*	1.63	6.29	1.31	5.09	0.0816	0.315	1.39	5.41	*Worst case*	684	18.5
					Median	0.816	3.02	*0.194*	*0.717*	1.01	3.74	0.775	2.87	0.0505	0.187	0.826	3.06	*Median*	1,210	33
				Minimize contact for up to 8 days[c]	*Minimum*	NA	NA	0.135	0.500	NA	NA	NA	NA	NA	NA	NA	NA	*Best case*	NA	NA
					Maximum	0.0274	0.100	0.252	0.933	0.279	1.03	0.0260	0.0950	0.0140	0.0517	0.0400	0.147	*Worst case*	126,000	3,410
					Median	NA	NA	0.194	0.717	NA	NA	NA	NA	NA	NA	NA	NA	*Median*	NA	NA
	Adults / Spouses	5,000	500	None / Minimal[d]	*Minimum*	0.0137	0.0507	*0.108*	*0.400*	0.122	0.451	0.0130	0.0482	0.00609	0.0225	0.0191	0.0707	*Best case*	262,000	7,070
					Maximum	0.258	0.955	*0.108*	*0.400*	0.366	1.36	0.245	0.907	0.0183	0.0678	0.263	0.975	*Worst case*	19,000	513
					Median	0.0855	0.316	*0.108*	*0.400*	0.194	0.716	0.0812	0.300	0.00968	0.0358	0.0909	0.336	*Median*	55,100	1,490
				Sleep apart for up to 25 days[d]	*Minimum*	0	0	*0.108*	*0.400*	0.108	0.400	0.00	0.00	0.00540	0.0200	0.00540	0.0200	*Best case*	925,000	25,000
					Maximum	2.27	8.400	*0.108*	*0.400*	2.38	8.80	2.16	7.98	0.119	0.440	2.28	8.42	*Worst case*	2,220	59.4
					Median	0.46	1.700	*0.108*	0.400	0.568	2.10	0.437	1.62	0.0284	0.105	0.465	1.72	*Median*	10,800	290.7

[a] In the absence of available data for the thyroid-to-thyroid dose equivalent from internalized radioiodine in children of I131-treated hyperthyroid patients where radiation precautions were *not* observed, the corresponding data in children of I131-treated hyperthyroid patients where radiation precautions *were* observed were used (indicated by the italicized entries).

[b] In the absence of available data for the thyroid-to-thyroid dose equivalent from internalized radioiodine in children of I131-treated thyroid cancer patients where radiation precautions were *not* observed, the corresponding data in children of I131-treated thyroid cancer patients where radiation precautions *were* observed were used (indicated by the italicized entries).

[c] NA = Not Available

[d] Data for the thyroid-to-thyroid dose equivalent from internalized radioiodine in adults / spouses of I131-treated thyroid cancer patients are available for only one subject, a subject for whom radiations precautions were observed. These data were therefore used as the median, minimum, and maximum and the minimum and maximum thyroid-to-thyroid dose equivalents values for adults / spouses of I131-treated thyroid cancer patients where radiation precautions *were* and were *not* observed, respectively (indicated by the italicized entries).