Safety Reports Series
No. 63

Release of Patients After Radionuclide Therapy

With contributions from the

ICRP

IAEA
International Atomic Energy Agency

IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards.

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety. The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

Information on the IAEA's safety standards programme is available at the IAEA Internet site

http://www-ns.iaea.org/standards/

The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at P.O. Box 100, 1400 Vienna, Austria.

All users of IAEA safety standards are invited to inform the IAEA of experience in their use (e.g. as a basis for national regulations, for safety reviews and for training courses) for the purpose of ensuring that they continue to meet users' needs. Information may be provided via the IAEA Internet site or by post, as above, or by email to Official.Mail@iaea.org.

OTHER SAFETY RELATED PUBLICATIONS

The IAEA provides for the application of the standards and, under the terms of Articles III and VIII.C of its Statute, makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

Reports on safety and protection in nuclear activities are issued as **Safety Reports**, which provide practical examples and detailed methods that can be used in support of the safety standards.

Other safety related IAEA publications are issued as **Radiological Assessment Reports**, the International Nuclear Safety Group's **INSAG Reports**, **Technical Reports** and **TECDOCs**. The IAEA also issues reports on radiological accidents, training manuals and practical manuals, and other special safety related publications. Security related publications are issued in the **IAEA Nuclear Security Series**.

RELEASE OF PATIENTS AFTER RADIONUCLIDE THERAPY

SAFETY REPORTS SERIES No. 63

RELEASE OF PATIENTS AFTER RADIONUCLIDE THERAPY

WITH CONTRIBUTIONS FROM
THE INTERNATIONAL COMMISSION
ON RADIOLOGICAL PROTECTION

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2009

COPYRIGHT NOTICE

Sales and Promotion, Publishing Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
fax: +43 1 2600 29302
tel.: +43 1 2600 22417
email: sales.publications@iaea.org
http://www.iaea.org/books

Printed by the IAEA in Austria
October 2009
STI/PUB/1417

IAEA Library Cataloguing in Publication Data

Release of patients after radionuclide therapy / with contributions from the International Commission on Radiological Protection. — Vienna : International Atomic Energy Agency, 2009.
p. ; 24 cm. — (Safety reports series, ISSN 1020–6450 ; no. 63)
STI/PUB/1417
ISBN 978–92–0–108909–0
Includes bibliographical references.

1. Radiotherapy — Safety measures. 2. Radiation — Dosage. 3. Patient discharge instructions. I. International Atomic Energy Agency. II. Series.

IAEAL 09–00601

FOREWORD

The use of unsealed radiopharmaceuticals for treatment of disease is common practice worldwide. This approach was widely employed some years ago and, following a decline, there has recently been a resurgence of interest in it. The combination of newly accessible radionuclides, improved labelling technology and developments in biotechnology has resulted in more enthusiasm and a wider range of applications for this form of therapy.

Radionuclide treatments are performed with either the patient admitted to hospital or as an outpatient only. The criteria to determine which approach is best vary considerably, and are not always closely linked with the well established standards of radiation protection practice. Safety issues for the patient, their family, associated carers, staff and the general public arise with either approach. The potential risks are from both external irradiation and contamination. The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) specify the dose constraints and limits for all of these groups, and their more general provisions with respect to the as low as reasonably achievable principle and justification also apply.

One way of managing exposures of the various groups is to control when patients are released from hospital. While they are in hospital, it is relatively easy to control exposure. Once they have returned to their family in the community, they must be advised on how to restrict the exposure of those people that they will come into contact with. Until recently, the International Commission on Radiological Protection (ICRP) did not provide specific advice in this area, and relied on the application of dose limits and constraints. However, regulators in some countries took a prescriptive approach, often using estimates of retained activity as a release criterion. These only loosely relate to dose limits. This publication attempts to bring newly available advice from the ICRP to bear on providing a more consistent approach in this area.

The approach to this issue is developed within the IAEA's framework of statutory responsibility to establish standards for the protection of people against exposure to ionizing radiation and to provide for worldwide application of these standards. The Fundamental Safety Principles and the BSS, issued by the IAEA and co-sponsored by the Food and Agriculture Organization of the United Nations, the International Labour Office, the OECD Nuclear Energy Agency, the World Health Organization and the Pan American Health Organization, require the radiological protection of patients undergoing medical exposures through justification of the procedures involved and through optimization. This challenge is taken up here by expanding on an area dealt with relatively briefly in the recent IAEA publication, Applying

Radiation Safety Standards in Nuclear Medicine (Safety Reports Series No. 40), and other initiatives in the areas of nuclear medicine and radiotherapy, to provide additional useful advice for Member States, particularly for practitioners of radionuclide therapy. This is timely given the wide divergences in practice throughout the world and the advice newly available from the ICRP. It endorses the ICRP's view that infants and young children, as well as casual visitors, be limited to the public dose limit, and that patients should be released on the basis of an individual assessment of their specific family, medical and social circumstances while conforming to the dose limits and constraints.

The IAEA is grateful to L. Collins (Australia) for his role in compiling the initial text and to J. Malone (Ireland) for bringing the final draft to fruition. The IAEA officer responsible for this publication was M.M. Rehani of the Division of Radiation, Transport and Waste Safety.

EDITORIAL NOTE

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

During the last century, the use of unsealed radionuclide therapy to treat a variety of diseases has become common throughout the world. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimates that almost 400 000 treatments were undertaken worldwide annually between 1991 and 1996, and that the numbers involved doubled over a decade [1, 2]. This form of therapy includes treatment of both cancer and some non-malignant conditions. Among the latter, the most common is treatment of hyperthyroidism with radioactive iodine. This has been an enduring success, persisting through times when other radionuclide therapies have appeared to be in decline. At present, newer treatments, particularly those for pain palliation and synovectomy, are becoming more popular.

The range and scope of radionuclide therapies have recently undergone further expansion with the advent of, and/or improvements to, for example, targeted radiolabelled compounds, monoclonal antibodies, new radionuclides, radiolabelling techniques, and finally approaches to both localization and applications such as pain palliation [3–6]. Many of the initiatives involved are tentative and still at the research level. However, at least a dozen applications have reached a level of maturity that allows them to be classified as established applications. This publication deals with the latter group only.

The pattern of practice around the world with regard to the release of patients from hospital after therapies with unsealed radionuclides is quite varied and has not been subject to harmonization. Specifically, there is no agreement on whether it is necessary to hospitalize patients undergoing therapy, and, if so, when and under what conditions they can be released. There are significant radiation protection problems relating to management of patients. This publication is focused on the decision to release a patient and its consequences. In this area, the approaches necessary for protection of members of the family, carers and the general public require further guidance. This guidance is based on the approach of the IAEA Safety Fundamentals, the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), and Safety Reports Series No. 40, and draws heavily throughout on the new advice issued by the International Commission on Radiological Protection (ICRP) [2, 7–9] and on a number of regional and national approaches [10–13]. Furthermore, the BSS are undergoing revision, and the part pertaining to release of patients (para. II.28)

shall undergo change in line with the contents of this report. Accordingly, this publication shall form the basis for an update to the existing Safety Guide [14].

A Safety Report such as this can help to resolve the diversity of international practice in this area, particularly if it is traceable to technical or measurement problems. In such circumstances, it has been possible to simplify or clarify matters. This, for example, is the case with issues arising from the well established connection between the patient's body burden of radionuclide and the dose rate at a particular distance from it. The new approaches of the ICRP, the National Council on Radiation Protection and Measurements (NCRP) and the European Union (EU), for example, provide some useful clarification of what is appropriate in this regard. On the other hand, some of the diversity arises from the different approaches being adopted to dose limits and dose constraints by governments around the world. This reflects the variations in legal systems and underlying social attitudes to risk in general and to radiation risks in particular in different countries. This cannot be ignored and inevitably is the responsibility of society at large rather than the community of nuclear medicine radiation protection specialists. However, it is valuable to be clear on the sources of diversity and on whether they arise from technical issues or choices made by governments on behalf of society. Finally, there are contributions to diversity from increased awareness of societal costs, patient and family social issues, and considerations related to the environmental pathways of radionuclides released after therapy.

1.2. OBJECTIVES AND SCOPE

The purpose of this publication is to provide some practical guidance to Member States and the medical professionals involved in release of patients after therapy with unsealed radionuclides. This is timely following recent publication of new advice in this area [2, 11, 13]. This report presents the background to this advice with a view to helping in harmonizing the diverse regulatory and practice frameworks that exist. It also provides an essential element of any release programme, i.e. information that must be made available to the patient, their carers and family to allow release to be achieved without undue anxiety or misplaced concern. Particular attention is paid to the most frequent questions from the patients about radionuclide therapy, including those related to potential future pregnancy and the best approach to reintegration into normal life at home and at work.

Discussions of the physics of ionizing radiation, dosimetry, associated risks/biological effects, inpatient treatment regimes and general problems of waste disposal to the environment are not included. In addition, a discussion of treatment with implanted sealed sources, seeds, etc., is also excluded.

1.3. FORMAT AND STRUCTURE

The format of this publication is as follows: general background information on radionuclide therapy, including an overview of the radiation safety problems involved, is provided in Section 2. On the basis of this, the criteria for release or hospitalization commonly employed are reviewed in Section 3. Some special issues, such as pregnancy during or after therapy, breast-feeding by the treated patient, emergency readmission or possible death of the patient, are considered in Section 4. Section 5 is devoted to examples of the type of information and the instructions that must be given clearly and concisely to the patient. Section 6 provides a summary of the recommendations. Ancillary technical details and advice are available in annexes, including additional information/advice related to some specific radionuclide therapies, which is provided in Annex V.

2. RADIATION SAFETY CONSIDERATIONS

2.1. UNSEALED RADIONUCLIDE THERAPIES

Radionuclide therapies with unsealed sources rely on achieving a selective high concentration of nuclide in the target tissue, compared with that prevailing in the surrounding tissues. It is invariably administered in hospital. With short range particle emitters the dose to the target will be high compared with that to non-target tissues. Administration is normally by the oral route, intravenous injection (systemic) or instillation of colloidal suspensions into closed body cavities (intracavitary). Examples of therapy include ^{131}I sodium iodide for hyperthyroidism or thyroid cancer and ^{89}Sr for bone metastases. An example of intracavitary therapy is ^{32}P chromic phosphate for treatment of malignancies of the pleural and peritoneal cavities and intra-articular administration for synovectomy [2, 3, 13].

Radionuclide therapy is well established in the treatment of thyroid disease and is becoming increasingly important because of the number of palliative and curative treatment options it now offers for a range of other malignant and non-malignant diseases. Most of the radionuclides used in therapy emit beta particles, which have low tissue penetration. They also emit Auger electrons, gamma rays and/or characteristic X rays.

Pure beta particle emitters, with their lower tissue penetration, deposit all their energy locally within the patient. From a radiation safety perspective, the problem is contained because, while a considerable amount of radiation is involved, it is confined to the patient, their excreta and body fluids. There is no exposure of the public or others through external irradiation. Concern for the radiation safety of staff, the public and others is therefore primarily related to the patient, and handling excreta and body fluids. Examples of beta emitters include ^{89}Sr or ^{188}Rh. However, with radionuclides that emit gamma rays, such as ^{131}I or bremsstrahlung X rays, exposure of the public to external photon emissions must be considered. The more commonly used radionuclides, and their main emissions, are listed in Table 1 [2, 3, 13].

TABLE 1. RADIONUCLIDES COMMONLY USED FOR THERAPY AND THEIR MAIN EMISSIONS
(adapted from Ref. [2] and extended)

Radionuclide	Main emissions (keV)		Half-life (d)
	Beta max.	Gamma	
P-32	1710		14.3
Sr-89	1492		50.5
Y-90	2284		2.67
I-131	606	364	8.04
Sm-153	881	103	1.93
Ho-166	1850	81	1.13
Er-169	340		9.3
Lu-177	500	113, 208	6.7
Re-186	1070	137	3.8
Re-188	2120	155	0.7
Au-198	1372	411	2.696

The diminishing role of ^{32}P and the involvement of new radionuclides in the palliation of bone metastases illustrate the pattern of change and development now prevalent in radionuclide therapies. Phosphorus-32 had proved a good therapeutic agent in myeloproliferative diseases. However, the induction rate of secondary leukaemia was far from negligible. Thus, this therapy has been largely replaced by chemotherapy that has fewer untoward effects. Conversely, palliative therapy of painful bone metastases was tentatively approached for some time using ^{89}Sr, but is now becoming popular and also employs several new nuclides, including the more recently introduced ^{188}Rh [15], ^{186}Rh [16] and ^{153}Sm [17].

2.2. RADIATION PROTECTION FOLLOWING RELEASE OF PATIENTS: DOSE LIMITS, DOSE CONSTRAINTS AND PERSONS AT RISK

When the patient is kept in hospital following radionuclide therapy, the people at risk of exposure include hospital staff who may or may not be radiation workers or carers. This is a significant problem. However, it is generally felt that it can be effectively managed with well trained staff and appropriate facilities. On the other hand, once the patient has been released, the groups at risk include members of the patient's family, including children, and carers; they may also include neighbours, visitors to the household, co-workers, those encountered in public places, on public transport or at public events such as entertainments, and finally the general public.

The current system of radiation protection that is internationally accepted (ICRP and IAEA) provides no dose limits for patients. However, dose limits are prescribed for staff and members of the public. Furthermore, there are dose constraints for carers, and some countries also provide dose constraints for staff [8, 17–19]. The relevant parts of this system are treated in this section, and further details of its application to radionuclide therapy are given in Sections 3.1 and 3.2.

The dose limits recommended by the ICRP and the IAEA for members of the general public, patients and carers are set out in Table 2. The dose limit for members of the public is regulated by law in most countries, and the ICRP value of 1 mSv/a is frequently the statutory limit. This may, in special circumstances, be subject to averaging over a five year period, and weighting for the age of the exposed persons. The dose to pregnant women is further limited on the basis that the foetus is generally regarded as a member of the public and thus also has an independent limit of 1 mSv/a.

TABLE 2. ICRP 1990, 2007 AND IAEA RECOMMENDED ANNUAL DOSE LIMITS

Application	Public dose limit	Patient, comforter and carer dose limit
Effective dose	1 mSv/a*	No dose limit
Annual equivalent dose in:		
Lens of the eye	15 mSv	No dose limit
Skin	50 mSv	No dose limit

* In special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over five years does not exceed 1 mSv/a. From Refs [8, 17, 18].

In some countries, additional dose constraints, as low as one third of the dose limit, are applied to individual planned activities involving members of the public. It should be emphasized that, as viewed by the ICRP, constraints provide an advisory system to assist in control of exposure. In addition, where the constraints are met, it is expected that optimization will also be performed. There is a variation in practice from country to country with regard to the approach taken by regulatory authorities. In some countries, the constraints are interpreted and used more strictly [2, 13, 20].

Individuals who knowingly and voluntarily accept exposure while helping others undergoing medical diagnosis or treatment (other than in their occupation) are referred to as comforters and/or carers. The ICRP addressed the issue of such voluntary exposures in medicine in Ref. [21] as follows:

> "Friends and relations helping in the support and comfort of patients are also volunteers, but there is a direct benefit both to the patients and to those who care for them. Their exposures are defined as medical exposure but dose constraints should be established for use in defining the protection policy both for visitors to patients and for families at home when nuclear medicine patients are discharged from the hospital. Such groups may include children. The Commission has not recommended values for such constraints but a value in the region of a few mSv per episode is likely to be reasonable. This constraint is not to be used rigidly. For example, higher doses may well be appropriate for the parents of very sick children" (see Ref. [21]).

This advice has been endorsed by the IAEA in the BSS and by the EU in their Medical Exposures Directive, where exposures of comforters and carers are classified as medical and hence are not subject to dose limits [2, 8, 10, 13, 20, 22].

Comforters and carers include, for example, members of the patient's family, or visitors to the patient. The BSS state that the dose to a "comforter or visitor of patients shall be constrained so that it is unlikely that his or her dose will exceed 5 mSv during the period of a patient's … treatment." A more detailed and differentiated set of dose constraints recommended by the EU is presented in Table 5 (Section 3.2.1). However, the issue of the consent of comforters and carers has not yet been comprehensively treated in the radiation protection literature and needs to be addressed locally, depending on the prevailing practice and medico-legal concerns in this area [23, 24].

The dose to children visiting patients who have ingested radioactive materials should be similarly constrained to be less than 1 mSv [8, 14]. The situation concerning dose constraints for young and very young children is complicated by the fact that they may not be able to give informed consent to be involved.

2.3. RADIATION PROTECTION AFTER RELEASE OF PATIENTS: GENERAL CONSIDERATIONS

The exposure of other persons by patients who have received radionuclide therapy can occur in the following ways:

(a) External irradiation of persons close to the patient;
(b) Internal contamination of persons as a result of excreted or exhaled radionuclides.

In addition to both of the above, exposure of those immediately involved with the patient and the general population can occur through environmental pathways including sewerage, discharges to water, incinerated sludge or cremation of bodies. From the point of view of the individual doses involved, this is of relatively minor significance and will not be treated further here. It is, however, dealt with briefly in Annex IV and ICRP reviews of the relevant available information [2].

External irradiation of the persons close to the patient is related to the radionuclide used, its emissions, half-life and biokinetics, which can be important with some radionuclides. Excretion results in the possibility of contamination of the patient's environment and of inadvertent ingestion by other persons. Both are briefly introduced here and further considered separately in Annex V for each of the more frequently used forms of therapy.

Radioiodine is the most widely studied radionuclide. Others commonly used give doses to the public and carers that are thought to be orders of

magnitude less [2]. As a result, the dominant focus here will be on radioiodine, although other radionuclides are addressed from time to time where data are available.

2.3.1. External irradiation of other persons

Good estimates of the external dose and dose rate from patients to whom radioiodine has been administered are available and have recently been summarized by the ICRP [2, 13, 25–33]. These papers reinforce the conclusion that doses to other persons from treated patients are predominantly the result of external exposures. Without precautions, it is possible to envisage doses up to a number of orders of magnitude higher than the dose limits or dose constraints [2], see also Sections 3.1 and 3.2. Thus, the photon dose can give rise to a breach of statutory limits in the case of the general public, or dose constraints in the case of carers and comforters. However, this can be controlled and minimized so that dose limits and constraints are not generally breached in practice. A key element in achieving this is the information and instruction provided for the patient and their family.

In reaching these conclusions, the ICRP and others are careful to draw attention to the many methodological issues that can compromise external dose calculations including, for example:

(a) The assumption that the activity in patients behaves as an unattenuated point source;
(b) The use of the inverse square law at short distances;
(c) Issues connected with the uptake and pharmokinetics of radioiodine;
(d) Issues connected with the disease status of the patient and their stage of treatment;
(e) A tendency to use conservative assumptions.

All of these can greatly influence the estimate of dose to those in the vicinity of the patient, and it is important to give them due weight in practice. Notwithstanding these difficulties, relatively simple external dose rate measurements are often made to guide actions and to facilitate estimation of residual activity. To minimize geometrical effects, these are generally made 2–3 m from the patient, but are still subject to error (Annex II).

In making practical arrangements, it is important to note that the external dose rate per unit administered activity will be less from cancer patients after the first day or two. In these patients, the thyroid has normally been removed and/or ablated and is not acting as a source retaining radioiodine. As a result,

the vast majority of administered radioiodine is eliminated in the urine in the first two days.

2.3.2. Contamination of other persons

The main data available in respect of contamination are for radioiodine, which is generally administered orally as ^{131}I sodium iodide, in liquid or capsule form [2, 13, 20, 34]. It is rapidly absorbed from the gastrointestinal tract, into the bloodstream, and trapped and organified by functional thyroid tissue. Radioiodine labelled thyroid hormones circulate on plasma binding proteins which are metabolized by the liver and muscles. Radioactive iodine is finally excreted, primarily in the urine, with smaller amounts in saliva, sweat and faeces, and a small amount is exhaled. The risk of contamination of other persons arises from these.

The available excretory pathways for radionuclides administered in therapy include urine, faeces, saliva, sweat, lachrymal fluid and breast milk. Each pathway has different safety issues, and all can lead to contamination. The clearance rate(s) from the patient's body can vary greatly for different pathways. In addition, they vary within any one pathway, not only between radiopharmaceuticals but also for the same radiopharmaceutical in different patients.

A common rule of thumb is to assume that no more than one millionth of the activity being handled will become an intake to an individual working with the material. This is employed when examining cases of worker intakes during normal workplace operations, accidental exposures and public intake from accidental airborne releases from a facility. At least two studies have shown that the rule is valid, within an order of magnitude, in cases of intakes of individuals exposed to patients [35, 36]. With the exception of contact with a patient's urine, a number of studies have shown that the risk of contamination with radioiodine is generally low but not negligible. Usually, for adult relatives, the internal dose due to contamination is less than 10% of the external dose. In addition, in a study where skin and thyroid doses were measured, external exposures exceeded the internal thyroid dose equivalent by a factor of over 100 [36].

Measurement of activity in body parts/fluids and in the environment of patients treated with radioiodine has been undertaken by several authors [30, 37–41] and was recently reviewed by the ICRP [2]. The materials examined include the thyroid, blood, saliva, salivary glands, sweat, skin, exhaled breath, room air, breast milk, room surfaces and urine.

Contamination from thyroid cancer patients is highest at about 24 hours after radioiodine administration and is higher than that from hyperthyroid patients. Patients who washed frequently had significantly lower amounts of removable contamination. Removable contamination on surfaces that the

patients touched was very variable. Removable activity from toilet rims during the first 48 hours post-treatment was much greater for men than for women. Salivary activity was proportional to administered activity and highest 24 hours post-therapy. Some authors recommend that there be no mouth to mouth contact between the patient and family during the first 48 hours.

Wellner et al. [40] calculated that the effective dose, from air contamination, for relatives of cancer patients treated on an ambulatory basis could be up to 6.5 mSv and could, thus, exceed the 1 mSv public dose limit. However, this limit does not apply to comforters and carers. Furthermore, after three days of hospitalization, the risk of exceeding the dose limit in this way at home is eliminated. In addition, it is useful to take into account the fact that the effective dose from air contamination is reduced in well ventilated rooms.

From the above, the ICRP concludes that, in general, contamination of adults is less important than external exposure. Notwithstanding this, it is very important to avoid contamination (particularly from saliva) of pregnant women, infants and young children, owing to the sensitivity of foetal and paediatric thyroids to cancer induction.

3. THE DECISION TO RELEASE THE PATIENT

3.1. INTRODUCTION

Current recommendations regarding release of patients after therapy with unsealed radionuclides vary widely around the world. Hospitalization or release has been based on one or more of the following reasons, some of which overlap. However, each has been advanced, as a consideration in its own right, in reaching a decision:

(a) A requirement for regulatory compliance, based on:
  (i) Dose limits or constraints from the ICRP, international or national bodies;
  (ii) The residual activity in the patient;
  (iii) The dose rate at a specified distance from the patient.
(b) Isolation of the patient to reduce dose to the public and family;
(c) Issues associated with the patient:
  (i) A medical condition that requires hospitalization;
  (ii) A mental condition that might reduce compliance;
  (iii) Their home circumstances.

(d) Collection of urine and storage to reduce radioactive discharges into sewers and/or the impact of incontinence.

Release or hospitalization for one or more of these reasons is sometimes applied to all patients in an institution or country. On the other hand, the ICRP [2, 13] recommends that the decision to release a patient from hospital should be determined on an individual basis. The factors to be taken into account include the following issues related to patients:

— Their medical needs;
— Their wishes;
— Their pattern of contact with other people;
— Their age;
— Their family/home environment;
— Occupational and public exposures;
— Cost and environmental factors;
— The local social and infrastructural arrangements.

In addition, the regulatory framework must be taken into account. All of these, and further, issues are compared for hospital and home environments in Table 3. Each of these may be compelling in its own right. The ICRP also draws attention to the inevitable psychological burden and psychosocial cost for the patient and their family (especially young children) consequent on hospitalization, particularly if this involves isolation. However, it also appears that there may be unanticipated family and societal costs arising from early release that will have to be considered [42]. Due account must be taken of these, as well as the factors normally considered in the optimization process.

The BSS and many national authorities have suggested applying limits to the retained activity level at which a patient may be released. These limits are reviewed in Section 3.2. They are, in theory, based on ensuring that compliance with the dose limits and constraints for both the public and the comforters/carers are met and are based on standard anthropomorphic data. The underlying calculations, while based on well established dosimetric methods, do not generally employ standardized or harmonized assumptions. In addition, the assumptions used often err on the safe side; it is sometimes felt that they significantly overestimate the potential doses to carers and the public. Finally, while there is a legal basis for dose limits, this does not always apply to the derived values, which may thus be accorded a status that they do not have.

TABLE 3. ISSUES TO BE CONSIDERED IN PATIENT RELEASE
(adapted from ICRP [2])

Issue	Hospitalization	Released
Control of patient environment	High	Less
Occupational dose potential	Present	Minimal
Family dose potential	Minimal	Present
Public exposure potential	Minimal	Present
Method of disposal of waste	Sewage or storage	Sewage
Public exposure from waste	Present unless stored	Present unless stored
Monetary cost	Potentially high	Minimal
Psychological	Significant due to isolation	Minimal
Unanticipated behaviours	Controlled	Possible

3.2. GUIDANCE BASED ON DOSE LIMITS AND CONSTRAINTS

3.2.1. Application of general guidance to radionuclide therapy

The ICRP recommendations do not explicitly require that patients be hospitalized for radionuclide therapy. On the other hand, guidance from the IAEA in 1992 indicated that in radioiodine therapy of cancer: "it is not recommended to let the patient return home immediately. Instead, he or she should be kept at the hospital for a period of between some hours and several days" [43]. The BSS reinforce this where they state: "… a patient shall not be discharged from hospital before the activity of radioactive substances in the body falls below the level specified …". The EU states that, as a general rule, treatment of thyroid cancer using radioactive iodine should only be performed on inpatients and, for example, in Germany, essentially all patients who receive radioiodine therapy must be hospitalized for at least 48 hours. In this, some European practice differs from that required by the ICRP and that frequently described in the United States of America (USA). In this report, the more recent ICRP advice is being followed and the cornerstone of its position on patient release is dose limits for the public and dose constraints for the family and carers, as described above. The ICRP further recommends that this should be accompanied by optimization. The logic of the EU system is also similarly based, although it may have some additional requirements [2, 8, 10, 13].

TABLE 4. DESCRIPTION OF THE GROUPS INVOLVED

Group	Description
Workers	Those professionally involved, including radiation workers and others
Comforters and carers	Those who knowingly and willingly help (other than as part of their occupation) with the care and support of the patient
General public	Family, other than comforters and carers Friends and acquaintances Visitors, casual visitors and colleagues at work Those encountered socially or while travelling
Special consideration groups	Pregnant women and young children

The ICRP, IAEA and EU propose dose constraints rather than dose limits be applied to comforters and carers. The issue of consent of comforters and carers gains prominence, arising from the fact that the legal definition of comforters and carers, where it has been enacted, requires that they act knowingly and willingly (other than as part of their occupation) [10, 23, 24]. This has led to the situation where comforters and carers are clearly distinguished from visitors and other members of the patient's family, who are normally grouped with the general public. Table 4 provides a summary that may be helpful in differentiating the characteristics of the various groups involved with respect to their risk profile. A rationale and values for dose constraints for these groups was agreed by the EU [10]. These were further refined by the ICRP as detailed in Table 5 [2, 8, 10, 13, 20, 22, 44].

In Table 5, the low constraint applied to pregnant women and young children is related to the susceptibility of the thyroid in the foetus and small children to radiation induced thyroid cancer or thyroid ablation and its consequences. Thus, it is now felt that they should, in practice, be treated as members of the public. In addition, those visitors who are not essential to patient care or comforting should be treated as members of the public. The approach in many countries, including Australia, Japan, the Russian Federation, Sweden and the United Kingdom (UK), is broadly in line with the 0.32–1.0 mSv range for the dose constraint advocated, although there are differences in detail and in application [2, 45, 46].

TABLE 5. DOSE CONSTRAINTS PER EPISODE FOR DIFFERENT CATEGORIES
(adapted from ICRP 94 [2] and based on a rationale developed in the EU [10])

Type of person/caregiver	Reason for dose constraint (e.g. risks or habits)	Dose constraint (mSv)
Third person (not carer)	A fraction of the dose limit for the public	0.3/episode
Family and close friends:		
Pregnant women	Protection of the unborn child	1/a
Children up to two years old	Close physical contact with parents	1/a
Children between three and ten years old	Same risk as that for unborn child	1/episode
Children older than ten and adults up to 60 years old (average population)	Two to three times lower risk than that for younger children. Certain recommendations for partners not to be applied when comforting very ill hospitalized patients	3/episode
Adults older than 60 years	Three to ten times lower risk than that for the average population	15/episode

In 1997, the United States Nuclear Regulatory Commission (NRC) amended its regulations for the release of patients receiving treatment with radioactive materials from an activity based limit to a dose based limit [13, 47, 48]. The new regulation was based on the effective dose equivalent to a maximally exposed individual not being likely to exceed 5 mSv. Compliance with the dose limit is demonstrated by using a default table for activity or dose rate or by performing a dose calculation specific to the patient (Annex II). This approach allows patients with considerably higher levels of activity to be released [49].

3.2.2. Dose based guidance in specific circumstances

3.2.2.1. Occupational doses to hospital staff

Hospitalization of patients for several days reduces public and family exposures but increases occupational exposure of hospital staff. Data recently reviewed by the ICRP establish that the major source of occupational exposure is external radiation [2, 32, 50–52]. Experience shows that in well designed facilities with good practice, the occupational exposure of staff is generally low or negligible [53]. However, in poorly designed facilities with inexperienced staff or bad practice, it can be significant. The major advantage of retaining a patient in hospital is that, with good practice, the environment and the associated risks are controlled. The decision to release a patient is based on the assumption that the risk can be controlled when the patient returns to their home. This is generally achieved by combining an appropriate release criterion with well tailored instructions and information for the patient that will allow them to deal effectively with the potential risk.

A patient is sometimes released from hospital to another environment, such as a nursing home. In such a case, care must be taken that, in addition to practical measures and advice to ensure safety of nursing home staff, any legal requirements relevant to the second institution are also complied with [11, 33].

3.2.2.2. Exposure to persons in the home environment

In the past 15 years, a number of studies of domestic activities have become available for treated hyperthyroid patients, and have recently been critically reviewed [2, 54–57]. These include calculations and measurements of doses to relatives, household members, children and sleeping partners of patients. Calculated doses tended to be higher than those measured, partly because of conservative calculation models. This suggests that it might be possible to consider an easing of some of the contact restrictions widely in use at present. In general, the doses received by those in relatively close proximity to the patient were of the order of 1 mSv or less.

Barrington et al. have also published estimates of doses that might be received by co-workers and the families of thyroid cancer patients [32, 33, 58]. The suggested guidelines and restrictions that might be applied in the cases of both hyperthyroid and thyroid carcinoma patients arising from these studies are presented in Table 6, which summarizes the ICRP data in the area. More recent recommendations from the British Institute of Radiology, for hyperthyroid patients only, indicate a somewhat shorter period of restriction and are shown in Table 12 (in Section 3.2.3) [59].

TABLE 6. SUGGESTED GUIDELINES FOR RADIOIODINE PATIENTS TO RESTRICT DOSE TO 1 mSv IN CO-WORKERS AND FAMILY
(adapted from ICRP 1994 [2], O'Doherty et al. [30] and Barrington et al. [32, 33])

Activity (MBq)	Patient type	Time off work (d)	Time to sleep apart and restrict contact with partner (d)[a]	Time to restrict contact with child <2 years of age (d)	Time to restrict contact with child 2–5 years of age (d)	Time to restrict contact with child 5–11 years of age (d)
200	Hyperthyroid	0	15	15	11	5
400	Hyperthyroid	3	20	21	16	11
600	Hyperthyroid	6	24	24	20	14
800	Hyperthyroid	8	26	27	22	16
1850	Cancer	1, 3[b]	3, 16[b]	4, 16[b]	3, 13[b]	2, 10[b]
3700	Cancer	2, 7	4, 20	4, 20	4, 17	3, 13
5550	Cancer	2, 10	4, 22	5, 22	4, 19	3, 16
7400	Cancer	2, 12	5, 23	5, 24	4, 21	4, 17

[a] Assumes sleeping 1.0 m apart for eight hours.
[b] The first value is for cancer follow-up patients; the second is for ablation patients.

A UK study of measured doses from released hyperthyroid patients indicated that 89% of children received less than 1 mSv. However, 35% of children of age three years or younger received more than 1 mSv, indicating the need for special precautions for younger children [56]. Data from a Belgian study showed that, when children stayed away from home for the first eight days following therapy, the median doses they received over the following two weeks were 0.08 and 0.13 mSv from thyroid and hyperthyroid cancer patients, respectively [60]. Some authors have recommended that, in families with children, a short stay in hospital may be preferable [61]. This would avoid inadvertent, but difficult to exclude, contact with small children in the home.

Thus, actual measurements made of families or carers who follow radiation protection advice show that doses rarely approach or exceed a few millisieverts per episode, which is less than the ICRP recommended dose constraint for most of the groups identified in Table 5. Restrictions, once families and carers have been well instructed (Sections 5 and Annex V), should thus focus on the special consideration groups (i.e. pregnant women, infants and children).

3.2.2.3. Doses to others during patient travel

Patients travelling after radioiodine therapy rarely present a hazard to other passengers if travel times are limited to a few hours. Several studies based on calculations and measurements have been reviewed and allow this conclusion to be reached confidently [2, 30, 32, 33, 62]. Their findings are usefully illustrated in Tables 7 and 8. In these tables, 'private travel' involves contact at 1.0 m with a person other than a partner and public travel assumes contact at 0.1 m with a person. Note that in the case of thyroid cancer, the calculations are presented for private transport only.

TABLE 7. COMPARISON OF SUGGESTED RESTRICTIONS ON TRAVEL FROM DIFFERENT MODELS (TO LIMIT DOSES TO ^{131}I PATIENT CONTACTS TO 1 mSv)
(adapted from O'Doherty et al. [30] and Leslie et al. [62] (in parentheses))

Activity (MBq)	Private travel per day (h)	Public travel per day (h)
200	24 (24)*	8.0 (3.5)
400	24 (24)	4.0 (1.5)
600	24 (24)	2.5 (1.0)
800	24 (24)	2.0 (0.5)

* Values in parentheses ensure that the dose is kept below 1 mSv.

TABLE 8. TRAVEL TIME FOR THYROID CANCER PATIENTS TO RESTRICT PUBLIC DOSE TO 1 mSv
(adapted from Barrington et al. [32, 33])

Activity (MBq)	Private travel up to 24 h post-dose (h)	Private travel 24 h post-dose (h)	Private travel 48 h post-dose (h)
1850	8	20.5	24
3700	4	10	18.5, 24*
5550	2.5	6.5	12.5, 17*
7400	2	5	9, 13*

* The first value is for ablation patients and the second for follow-up patients.

3.2.2.4. Terrorism/transboundary radiation detectors

When releasing patients after therapy with radionuclides that have measurable gamma emissions, it is possible that they will trigger/activate radiation detection systems at places of employment, borders and airports where such systems are employed, for example, for security purposes. Environmental or other radiation detection devices are sensitive enough that they will usually detect patients who have received radioiodine treatment for weeks after administration. This should be noted concisely, clearly and accessibly in documentation provided to the patient, and they should be advised to take this with them when travelling. Personnel operating security detectors should be trained to identify and deal with nuclear medicine patients. However, this may not be recognized by or acceptable to poorly trained security personnel. It may be best to suggest that patients do not undertake much travelling in major public areas, unless they are willing to accept some inconvenience. If such advice is provided, it should also be made clear to the patient that the instruments currently used are extremely sensitive and will detect radiation at levels well below those that are of concern for health [2, 10, 63].

3.2.2.5. Cost–benefit analysis of hospitalization

Cost should be considered in terms of both justification and optimization of any radiation practice. Few studies have attempted to determine the costs associated with the various methodologies related to release of patients after therapy with unsealed radionuclides. To be realistic, 'costs' should include both the immediate monetary considerations and the consequences in terms of psychological impact and health outcome. A US study is available, but, while of general interest, its applicability in many countries is limited [47, 48]. This matter requires further, more detailed, work in a representative range of countries.

Finally, from the work of the various authors reported, it is clear that planned patient restrictions can in practice be highly individual, depending on their disease and its stage, the radioactivity administered, the profile of social and domestic activity they wish to engage in, their home circumstances and a number of other factors touched on above. It is also clear that within this approach based on dose limits and constraints, much flexibility is possible and much can be accomplished to accommodate the wishes of patients. Many countries use this approach, sometimes on its own, or sometimes in parallel with the approach based on retained activity described in the next section.

3.3. GUIDANCE BASED ON RETAINED ACTIVITY

Many countries and regulatory authorities use an approach to patient release after radionuclide therapy based on the activity retained in the patient. This can be in addition to the dose limit/constraint approach described in Section 3.1 or, in some cases, is used as an alternative to it. The retained activity limits employed can be inconsistent; as already noted, they are sometimes based on unduly conservative or worst case calculation models. They are generally derived from an estimate of a consequent dose or dose rate to carers, family members, members of the public, or combinations of all three. A simple protocol for retained activity estimation for photon emitting radionuclides is outlined in Annex II. Alternative approaches to calculating retained activity based on physical half-life and biokinetics are required for radionuclides that do not emit photons. Annex II also provides a listing of the retained activities corresponding to effective doses of 1 and 5 mSv to other persons, which is useful for estimation of public and family exposures.

The BSS include a maximum retained activity for discharge of radioiodine therapy patients from a hospital. They state that "… a patient shall not be discharged from hospital before the activity of radioactive substances in the body falls below the level specified …". The specified level refers to ^{131}I only and is 1100 MBq, with an additional point in a footnote indicating that in some countries 400 MBq is used as a measure of good practice (Table 10) [2, 8]. The IAEA reiterated this in 2002, but some emphasis was placed on taking account of local conditions and the potential exposures of other members of the households of patients.

The countries in the EU work within a general framework similar to that of the BSS. However, EU guidelines in this area can be quite demanding; for example, a dose of 400 MBq can lead to restrictions of two to three weeks for those with young families. Member States of the EU apply a derived residual activity constraint ranging from about 100 to 800 MBq but, as indicated in Tables 9 and 10, in most it is set between 400 and 600 MBq. Other national bodies and professional associations have also issued recommendations based on retained activity. For example, the European Thyroid Association favours treatment with ^{131}I on an outpatient basis for patients receiving up to 800 MBq, provided they adhere to certain restrictions. From these, a selection is given in Tables 9 and 10 [10, 13, 45, 47, 48, 64–67].

Some of the above countries also restrict dose or dose rate. When there is a conflict between the dose and the retained activity approaches, the ICRP takes the view that the dose approach, based as it is on dose limits, is closer to its primary recommendations and hence more fundamental. However, care must be taken with how this is applied in practice, in each country, as the

status of the different national regulations involved may not mirror this priority.

Where exposure of young children is possible, Mathieu et al. [60] have indicated that close contact with the patient should not occur until their thyroid activity has fallen below 100 and 50 MBq for contact with infants and pregnant women, respectively.

In Tables 9 and 10, it is important to note that the IAEA and US values substantially exceed all of the others. The latter is, in effect, a historical value, as the US NRC has amended its regulations from an activity based limit to a dose based limit referenced to the maximally exposed individual other than the patient [13, 47, 48, 68]. This has resulted in many individuals who would previously have had to be treated as inpatients being able to return home without hospitalization and in practice, in the USA, competent and cooperative patients are now routinely discharged with activities of up to 8 or 9 GBq of ^{131}I [69]. This has resulted in some previously unreported practices among patients which need to be kept under review. Annex II provides some information on the US approach [2, 68, 70].

TABLE 9. SOME NATIONAL MAXIMUM ACTIVITIES FOR PATIENT RELEASE

Radionuclide	Retained activity (MBq)					
	USA	Germany [64]	Sweden [65]	Finland [71]	Japan [67]	Australia [45]
	NRC [47], NUREG-1556 [68]					
Phosphorus-32	[a]		1200			1200
Strontium-89	[a]				200	300
Yttrium-90	[a]		1200		1200	4000
Iodine-131	1200[b]	75	600	800	500	600
Samarium-153	26 000					4000

[a] Value not given because of minimal exposure of the public.
[b] Historic value prior to change in approach to that based on 5 mSv. See Annex II.

TABLE 10. EXAMPLES OF OTHER IODINE-131 RELEASE CRITERIA

Country or organization	Release limit for I-131 (MBq)
BSS*	1100 (guidance level)
European Thyroid Association	800
Japan	500 or <30 μSv/h at 1 m
Germany	250 (based on 3.5 μSv/h at 1 m)
Other EU Member States	95–800, mostly 400–600

* The revised BSS are not expected to contain numerical values.

The release criteria in individual countries are sometimes accompanied by detailed instructions to the patient and their family, as well as consideration of the patient's circumstances. Tables 11 and 12 illustrate how this can be applied with respect to the duration for which patients must follow the special instructions they are given in the EU [20] and in the UK [11, 59]. In addition, thyroid cancer treatments are normally associated with a period of hospitalization in the EU [2, 20]. This approach is at least partly consistent with that recommended by the ICRP [2] when it states that:

> "a single model for release criteria would not be appropriate optimization. It is recommended that release of patients should be based on an individual basis (rather than retained activity and the worst-case scenario). It is also recommended that where there are many contiguous countries, a uniform or similar approach to releasing patients should be developed."

The regulatory authorities in different countries may decide dose limits for staff, members of the public, dose constraints for family members, comforters and/or carers, and the maximum activity in sewage, in addition to national infrastructure and licensing and inspections of facilities. The day-to-day management of hospitalization and release of patients should be the responsibility of the licensee.

TABLE 11. RESIDUAL ACTIVITIES, DOSE RATES AND TIME PERIODS FOR WHICH INSTRUCTIONS MUST BE FOLLOWED ACCORDING TO EU RADIOIODINE RECOMMENDATIONS
(adapted from Ref. [10])

Effective dose rate at 1 m from patient (μSv/h)	Corresponding residual activity (MBq)	Period for which instructions must be followed
<40	<800	3 weeks
<20	<400	2 weeks
<10	<200	1 week
<5	<100	4 d
<3	<60	24 h after administration

TABLE 12. PERIODS FOR RESTRICTIONS AFTER ADMINISTRATION OF IODINE-131
(adapted from the British Institute of Radiology [59] and ICRP 94 [2]. The doses are those associated with treatment of hyperthyroidism.)

Activity (MBq)	All close contact, children or pregnant women (d)	Extended contact, children or pregnant women (d)	Do not share bed (d)	Avoid prolonged close contact with others (d)
600–800	14	27	8	1
400–600	12	25	4	—
30–400	9	21	—	—

4. SPECIAL SITUATIONS

4.1. INTRODUCTION

A number of situations requiring special consideration arise when patients are released from hospital and return home after radionuclide therapy, and include issues with respect to pregnancy, future pregnancies,

breast-feeding, hospital readmission or the death of a patient. Matters relating to the information requirements for the patient and their carers are critical to the functioning of a release programme and are dealt with comprehensively in Section 5 and Annex V. The other issues are dealt with here.

4.2. PREGNANCY AND RADIONUCLIDE THERAPY

4.2.1. Pregnant or potentially pregnant women and therapy

Pregnancy is a strong contraindication to unsealed radionuclide therapy, unless the therapy is life saving. This advice is all the more valid for radioiodine therapy and for other radionuclides with the potential to impart radiation doses to the foetus in the range of a few millisieverts. Therefore, where treatment is likely or anticipated, the patient should be advised to take appropriate contraceptive measures in the time prior to therapy.

As already discussed, the ICRP takes the view that "dose limits for the foetus are broadly comparable with those for the general public". This provides an important part of the context for dealing with pregnancy of patients during or following radionuclide therapy. Thus, once pregnancy has been declared, the dose to the embryo/foetus should not exceed about 1 mGy during the remainder of pregnancy. This is largely a matter of protecting the maternal organs, particularly the bladder, from external radiation. Later, once organ development commences, the foetal thyroid is also at risk of ablation during radioiodine therapy.

Some radiopharmaceuticals, including ^{131}I as iodide and ^{32}P as phosphate, rapidly cross the placenta, so that the possibility of pregnancy should be carefully excluded before administration. In practice, in women, thyroid cancers are relatively non-aggressive, and as a result both surgical and radioiodine treatment can often be delayed until after pregnancy [2, 11, 45, 72]. Thus, as a rule, a pregnant woman should not be treated with radionuclides like iodine unless the situation is serious, as, for example, would be the case if the therapy is required to save her life. If such an event arises, the potential absorbed dose and risk to the foetus should be estimated and conveyed to the patient and the referring physician, to determine the best course of action in the circumstances [2, 11, 73].

When a patient, who is not thought to be pregnant, is treated and is subsequently found to be pregnant, the situation requires careful attention. Most commonly, the pregnancy is in its early stages, and the major problem is embryonic or foetal whole body dose due to gamma emissions from radioiodine in the maternal bladder. During pregnancy, the whole body dose to

the embryo/foetus is in the range of 50–100 μGy/MBq of administered activity. Further information on foetal doses is available [2, 73, 74]. The dose can be reduced by orally hydrating the patient and by encouraging frequent voiding. This is a common recommendation for all patients whether pregnant or not.

When the foetus is more than eight weeks post-conception, the thyroid may accumulate iodine, and is at risk later of both cancer induction and ablation. If pregnancy is discovered within twelve hours of iodine administration, giving the mother 60–130 mg of stable potassium iodide (KI) will partially block the foetal thyroid and reduce dose. From twelve hours after administration of radioiodine, this intervention is not very effective.

4.2.2. Pregnancy subsequent to radionuclide therapy

On returning home, patients may be anxious about resuming sexual activity and/or becoming pregnant. Thus, the question arises about the advisability of becoming pregnant after radionuclide treatment [2, 11]. While sexual activity may be resumed on the basis indicated in Section 6, the ICRP recommends that female patients be advised to avoid pregnancy for the time periods indicated in Table 13. This is partly to ensure that the dose to an embryo or foetus will not exceed the limit of 1 mGy. However, the interval is also important in ensuring that the disease (e.g. the hyperthyroidism or cancer) is controlled and thus that another treatment will not be needed during a new pregnancy [2, 11, 46, 72]. Some practitioners use a 6–12 month gap [71], with a view to providing further confidence in this regard. It is also widely recommended in practice, on the basis of prudence, that male patients take steps to avoid fathering children during the months immediately following therapy [11]. However, there is no strong evidence base to support this view [46].

4.3. BREAST-FEEDING

Many radiopharmaceuticals can appear in breast milk and thereby give rise to a potential hazard to breast-fed infants [75]. Thus, therapeutic radiopharmaceuticals, regardless of the route of administration, are potentially hazardous, and therefore breast-feeding must be discontinued indefinitely [2, 8, 11, 13, 20]. The principal risk to the infant is cancer induction, although with ^{131}I the infant may develop permanent hypothyroidism or be at high risk of subsequent thyroid cancer. Hence, it is important not to administer therapy to a breast-feeding mother until such time as she is both willing and able to ensure compliance with the requirement that it be discontinued [11].

TABLE 13. PERIOD DURING WHICH PREGNANCY SHOULD BE AVOIDED FOLLOWING RADIONUCLIDE THERAPY[a]

Radionuclide and form	Disease treated	Activity upper limit (MBq)	Pregnancy avoidance period (months)
I-131 iodide	Hyperthyroidism	800	4 (ICRP) [2] 6 (ARSAC[b]) [46]
I-131 iodide	Thyroid cancer	6000	4 (ICRP) [2] 6 (ARSAC)
I-131 MIBG[c]	Neuroendocrine tumours	7500	3
P-32 phosphate	Myeloproliferative disease	200	3
Sr-89 chloride	Bone metastases	150	24
Y-90 colloid	Synovectomy	400	0
Y-90 colloid	Malignancies	4000	1
Au colloid	Malignancies	10 000	2
Er-169	Synovectomy	400	0

[a] Based on ICRP recommendations [2].
[b] ARSAC: Administration of Radioactive Substances Advisory Committee.
[c] MIBG: meta-iodobenzylguanidine.

In theory, intracavitary administrations of suspended particles such as yttrium (^{90}Y) silicate should represent little hazard. However, in practice, inadvertent leakage may occur, and cessation of breast-feeding is generally advised even for this form of therapy [2]. In addition to the ingestion hazard to the infant, the necessary proximity of the child to the mother may also represent an external hazard. Finally, cessation of breast-feeding prior to radionuclide therapy is also advised with a view to inactivating breast tissue, and thereby reducing breast dose [67]. In this regard, some physicians find it helpful to have women cease breast-feeding two to three weeks before receiving radioiodine therapy. This has the additional advantages that there is no danger of non-compliance and that contaminated brassieres and breast binders will not have to be dealt with.

4.4. DEATH OF THE PATIENT FOLLOWING RELEASE

Should the patient die in the period immediately following therapy, special consideration may need to be given to the treatment of the corpse. To facilitate this, the patient should be given a small card with details of their treatment and contact details for a radiation protection specialist/medical physicist associated with the department responsible for the therapy (Section 5, and Annexes IV and V). Such cases will increasingly arise as the use of radionuclides in palliative treatments increases. In cases where the death occurs in a hospital, access to the room occupied by the deceased should be controlled until the room has been decontaminated and surveyed. Radioactive bodies should be identified as potential hazards by a specified form of identifier. A body bag may need to be used to contain leakage of radioactive substances. To minimize external radiation risk, the corpse may need to be retained in a clearly delineated radiation controlled area. Controls may also be needed at subsequent stages of disposal, including transfer from the mortuary to the crematorium, cemetery or chapel of rest/church. This will be dependent on the maximum time that funeral directors and their staff can spend in close proximity to the corpse and on the ability to control access.

Funeral directors will need to be advised of any necessary precautions, and notification of the relevant national competent authorities may be required. It is essential that funeral directors and ministers of religion do not overreact to the risks associated with the radioactive corpse. Careful communication is needed to ensure that adequate controls are implemented without compromising dignity. Situations where the wishes of next of kin have to be significantly disrupted should be rare.

Areas of concern arise with respect to embalming, burial or cremation of the corpse and the conduct of autopsy examinations. National regulations, some quite dated, are available for some or all of these in many countries, but there is a lack of international recommendations. Practice tends to be guided by an untidy mixture of custom, professional guidance and national regulation [76].

Recent reports have emphasized the need to be sensitive to the wishes of the deceased and their family when decisions about the disposal of the corpse are being made. This may be particularly important if the possibility of retaining some organs for radiation protection reasons is being considered [77]. Furthermore, a proportion of the activity retained will appear in cremated remains and may be sufficient, particularly in the case of long lived radionuclides such as ^{89}Sr, to require controls to be specified. The main concern is in respect to the scattering of ashes, although contact dose rates with the container may have to be considered if cremation takes place shortly after administration [78].

The authorities in many countries now place limits on the radioactivity that may be present in the corpse before autopsy, embalming, burial or cremation. No special precautions are required for direct burial or cremation, without embalming, provided the activity involved is not in excess of national limits. No special precautions are required for embalming if activities do not exceed the levels mentioned in Table 14 for autopsy. If the activities are greater, then a corpse should not normally be embalmed, but if embalming is required a radiation safety officer should be consulted. Table 14 provides examples of such levels. However, as can be seen, there are significant variations between countries and it is advisable to establish an approach consistent with local requirements. In addition, it may be necessary to take account of developments in regulatory practice, particularly vis-à-vis dose limits and dose constraints that have been introduced after some of these limits were established.

TABLE 14. SUGGESTED CORPSE ACTIVITY LIMITS
(adapted from information reviewed in ICRP 94 [2] from Australia [79], Sweden [65], the UK [76–78, 80, 81] and the USA [82])

	Activity limit (MBq)		
Radionuclide	Autopsy/embalming	Burial	Cremation
Phosphorus-32	100 (IPEM)[a] 300 (Aus)[b] 400 (S)[c]	2000 (IPEM)	30 (IPEM) 400 (Aus) 400 (S)
Strontium-89	50 (IPEM)	2000 (IPEM)	20 (IPEM)
Yttrium-90	200 (IPEM) 150 (colloidal, Aus) 450 (sealed, Aus) 200 (S)	2000 (IPEM)	70 (IPEM) 1000 (Aus) 1200 (S)
Iodine-131	10 (IPEM) 450 (Aus) 600 (S)	400 (IPEM) 400 (UK)	400 (IPEM) 1000 (Aus) 1200 (S)
Gold-198	150 (Aus) colloidal 450 (Aus) sealed		1000 (Aus)
All			74 (US)

[a] IPEM: The Institute of Physics and Engineering in Medicine.
[b] Aus: Australia.
[c] S: Sweden.

Some available reports and measurements have been summarized by Refs [2, 51, 65, 76, 79–82]. Additional well considered and valuable advice on autopsy is available in a recent UK publication and is summarized in Annex IV [82]. Measurements made during autopsy are reassuring, but depending on the retained activity, guidance may be needed. The staff dose may be reduced by deferring the autopsy where necessary and practical. Finally, Singleton et al. [77] conclude that "provided that appropriate precautions are implemented, determined through consultation with a qualified expert in radiation protection and by completion of risk assessment, the radioactive autopsy can be undertaken safely and in compliance with relevant legislative requirements."

5. SPECIAL INFORMATION AND DOCUMENTATION FOR PATIENTS

5.1. INTRODUCTION

Much anxiety can surround any aspect of treatment of the diseases mentioned above. When the treatment involves radioactivity, the anxiety may be amplified. It can be further increased by concerns about the patient's release from hospital, their return home and possible further readmission later. Well written, clearly expressed, reliable and unambiguous information will help reduce this anxiety and contribute to effective and humane management of a delicate situation.

Patients should be given information about their own safety and that of others before their treatment is started. This information should be provided by a person the patient will not have difficulty understanding or believing. This information must include enough details on the period following discharge to facilitate making appropriate plans. In addition, at discharge, the patient should be provided with a small card with the details of their therapy on it and the contact details of the department responsible. Examples of two pretreatment sheets and such a card are provided below. Some departments may wish to phrase presentation of this information differently. Both examples will need to be adapted for other nuclides and for the varying cultural and regulatory environments that prevail in different parts of the world (Annex V). For completeness, some of the additional more frequently asked questions (FAQs) and answers on broader topics, such as environmental issues, are included in Annex III. Radioiodine is chosen to illustrate what is desirable, as more

information is available on this than on any of the other nuclides used. Much of the material included here is also available on the web at: http://rpop.iaea.org

5.2. PRETREATMENT INFORMATION LEAFLET/CARD

This example of a pretreatment information leaflet is for radioiodine treatment for hyperthyroidism, where the dose given is below that which will trigger any statutory patient release criteria applied locally. Obviously, different leaflets are needed for different therapy regimes, particularly radioiodine cancer therapy. However, the essential features to be captured are well illustrated here. This version of the leaflet draws on that proposed by the ICRP [2]. The framework provided here for radioiodine may be used as a starting point for information sheets for other nuclides and therapies.

5.2.1. Pretreatment leaflet for radioiodine treatment for hyperthyroidism

5.2.1.1. Why do I need treatment?

You have a condition called hyperthyroidism. This means that your thyroid gland is overactive. If it is not properly treated, your health may be affected in the future.

5.2.1.2. Is any preparation required?

Some blood tests, scans, X rays and adjustments to your medications may be necessary. These will be discussed with you by your hospital doctor. It is important to advise them of any medications, vitamins or supplements that you are taking, or other scans or X rays that you may recently have had, as these may influence your therapy.

You should not be pregnant at the time of treatment; so, if necessary, effective steps to avoid becoming pregnant should be taken. Should you become pregnant, it will normally be necessary to postpone your treatment.

5.2.1.3. What is radioiodine treatment?

Radioiodine treatment uses a form of iodine that is radioactive. Iodine is selectively taken up by the thyroid gland. Your doctor considers that this is the best form of treatment for you.

5.2.1.4. Will I need to stay in hospital?

No, this is not usually necessary for your treatment. Radioiodine is used for other treatments including cancer, and in that case it is usually necessary to stay in hospital for a few days.

5.2.1.5. Where does the radioactivity go?

Most of the iodine is taken up by the thyroid. The rest mainly passes out of your body in urine and, to a lesser extent, in saliva, sweat and breast milk if you are breast-feeding.

5.2.1.6. How is the iodine given?

Radioiodine is colourless and tasteless. You will be asked to swallow a liquid or a capsule containing the radioiodine.

5.2.1.7. Will I have any side effects?

Minor side effects (such as a sore throat) may be associated with treatment.

5.2.1.8. Is radioiodine treatment safe?

Radioiodine has been used for over 40 years to treat hyperthyroidism. Patients treated this way have been studied carefully. This form of treatment is considered to be safe and effective.

5.2.1.9. Are there any extra risks in having children afterwards?

There has been no effect on the health of the children of patients who have received radioiodine treatment. However, we do ask you to avoid pregnancy and breast-feeding children for several months after radioiodine treatment. See your instructions leaflet for more detailed information.

5.2.1.10. Is there a risk to others?

No, provided you follow the simple instructions given to you on how to behave when you leave the hospital. Following these instructions will ensure that there is no unnecessary risk to others. However, they may need to be made aware of the situation and be advised of the instructions you have been given.

5.2.1.11. Will I need to see a doctor after the radioiodine treatment?

You should be seen by your doctor after the treatment and have blood tests taken. These are to check how your gland has responded. It takes between two and three months for radioiodine to have its effect.

5.2.1.12. How many radioiodine treatments will I need?

Occasionally, a second, or even a third, treatment is necessary. The blood tests after your first treatment will show whether further treatment is needed.

5.2.1.13. Are there any long term effects?

Radioiodine is a very safe treatment. However, your thyroid gland will probably eventually become underactive after your treatment. This could happen within a few months or after many years. That is why blood tests to check the function of your thyroid are important and should be performed from time to time, as advised by your doctor, for the rest of your life. If your thyroid becomes underactive you will be started on thyroxine treatment. This has no side effects, and need be taken only once a day.

5.3. PATIENT INSTRUCTIONS LEAFLET/CARD

The following is an example of a set of instructions to be presented to the patient or their legal guardian. For convenience, they are presented in the format of FAQs and have been adapted from Ref. [10]. Obviously, different leaflets are needed for different therapy regimes, particularly radioiodine cancer therapy.

5.3.1. Instructions on behaviour after release from hospital following radioiodine therapy for a hyperactive thyroid

You have been treated with radioactive iodine to cure a thyroid problem. Most of the iodine will leave your body through the urine. When you are released from hospital, the dose remaining in your body or experienced by others in your vicinity is below any statutory limits applicable in this area. For several weeks, however, some of the iodine remains in your body, which means that you in turn can irradiate other people who are physically close to you. It is your responsibility to protect relatives, friends, colleagues and others. The following questions and answers are designed to provide you with instructions

that are adequate to meet the circumstances of daily life. If questions over and above these arise, you should raise them with your doctor or the department in which your therapy was administered. You have already been informed about how long you should follow these instructions for, given your personal, home and family circumstances.

5.3.1.1. What is the most important precaution?

Do not sit or stay close to any person either at home or at work. Try to maintain a distance of at least one metre. For long periods (more than one hour), stay two metres away.

5.3.1.2. What about contact with pregnant women?

Contact with pregnant women should be minimized. Try to stay at least two metres away from a pregnant woman.

5.3.1.3. Is it safe to become pregnant or to father children?

You should not become pregnant or father children for four months after your therapy.

5.3.1.4. Can I still see my children and care for them?

If your children are under ten years old, please avoid close contact with them, such as hugging or holding, whenever possible. The risk is higher for young children than for adults; therefore, it is advisable to avoid unnecessary contact for an additional week in addition to the recommended period.

5.3.1.5. What about infants?

Children under two years old should be looked after by someone else. If possible, arrange for them to stay with relatives or friends. If you have a baby, it is best to have someone else care for them. If this is not possible, you can probably care for the baby but ask for additional advice from your doctor and do not allow the baby to be too close to you (e.g. while sleeping or sitting on your lap, other than for very short periods of time).

5.3.1.6. Can I continue with breast-feeding?

Radioactive iodine is passed on in breast milk for quite a long time. Therefore, *breast-feeding must be stopped completely!*

5.3.1.7. Can I be in close contact with my partner or other people at home?

Close contact such as hugging or sex should be limited to half an hour a day. You should sleep in a separate bed. Beds should be two metres apart, even if there is a wall separating them. This is because the walls of a house do not provide good protection against this type of radiation.

5.3.1.8. What if my partner is pregnant?

If your partner is pregnant, it is important to avoid close contact with her.

5.3.1.9. Do the precautions also apply to those over 60?

For those over 60 years, the risk is much lower than for other people. Special precautions are for that reason less important.

5.3.1.10. Can I receive visitors?

Short visits, of less than two hours, create no problem. Keep a distance of about two metres from visitors and preferably avoid close contact. You should discourage visits by young children and pregnant women.

5.3.1.11. Can I go to work?

If possible, delay returning to work until two days after administration. If this is not practical, seek the advice of your doctor, who may be able to review and adjust the situation with you. If, by the nature of your work, you are within two metres of the same individual(s) for more than two hours per day, you should seek advice from your doctor. You should also inform your manager.

5.3.1.12. What if I am a nursery school teacher or work with pregnant women?

Nursery school teachers, or others who are in close contact with young children during working hours, should stay off work. Similar considerations apply to those working with pregnant women. Your doctor will indicate the required period of time for this restriction.

5.3.1.13. What if my work involves food handling?

If you work preparing food for others, it may be necessary to postpone returning to work for several weeks. Seek advice in the department where you were treated.

5.3.1.14. Can I go to the cinema or other entertainment?

Preferably not. Avoid visiting cinemas and other social events where you are close to other people for more than one hour.

5.3.1.15. May I use public transport?

For one week, you should restrict public transport to journeys lasting no more than two hours. Longer trips should only be undertaken if unavoidable. In such a case, try to find a place where you can sit alone and be at least one metre from others. If you must sit beside someone on longer trips, move around so that you are not sitting beside the same person all the time. Ask your doctor for advice if such a trip is unavoidable.

It is advisable to defer air travel if possible, unless you are willing to encounter additional security problems at airports. The advice given about longer trips in the previous paragraph should also be followed. It is possible that for some time after therapy you may trigger sensitive radiation security alarms. Security departments are briefed on this possibility, but not all will be acutely aware of it at the time of an alarm.

5.3.1.16. What about using a taxi?

Sit in the back on the opposite side from the driver. Do not spend more than two hours with any one taxi driver.

5.3.1.17. Can I use the same bathroom/toilet as other people?

If it is practical to have sole use of a bathroom/toilet, do so. If not, it is acceptable to use the same toilet as others, but spilling of urine must be avoided. Therefore, pass urine while seated (including men). Always dry your genitals with toilet paper and flush the toilet. Obviously, special consideration will need to be given to avoiding splashing, and to cleaning after use, particularly with squat toilets. It is also important to wash your hands immediately (preferably in the toilet room), even when only urinating. Have a

shower on a daily basis if possible, especially on the first two days. Rinse the shower or bath tub well after use.

5.3.1.18. What about cutlery, crockery, bed linen, towels, etc.?

Radioactive iodine also leaves the body in the saliva and the sweat of patients. Therefore, cutlery, crockery, towels, bed linen, etc., should not be shared with others. After thorough washing, cutlery and crockery are safe. Disposable crockery is sometimes advised, but this is not necessary if the crockery is in good condition with an intact glaze. Separate towels, facecloths and toothbrush from the rest of the family should be used. Your clothing and bedclothes should be washed separately from the laundry of other family members.

5.3.1.19. What happens if I have to go into hospital?

If you have to go to hospital unexpectedly, please inform the medical staff that you have been treated with radioactive iodine recently, and show them the card with details of the therapy that you were given on release from hospital. This applies even when it is the same hospital where you were treated.

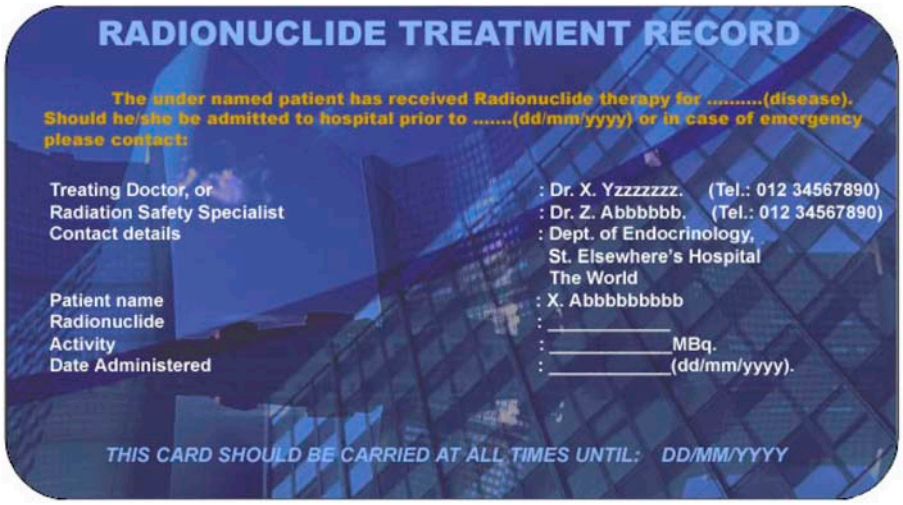
If in doubt, you should *always* seek advice from the department in which you obtained your treatment.

5.4. POST-THERAPY WALLET PATIENT CARD

The following is an example of a credit card style card that might be given to a patient at the time of discharge (Fig. 1). It carries a useful summary of the instructions issued to patients on one side (Fig. 1(b)). The more crucial information is on the other side (Fig. 1(a)), and should be given to the medical staff involved if the patient has a medical emergency or is admitted or readmitted to hospital within the time span specified on the card. It is important that the patient carry this card at all times for the required time period (which is frequently up to four weeks).

The importance of information of the above type to a successful release programme and to its successful communication and adaptation to the circumstances of the individual patient cannot be overstated.

(a)



(b)

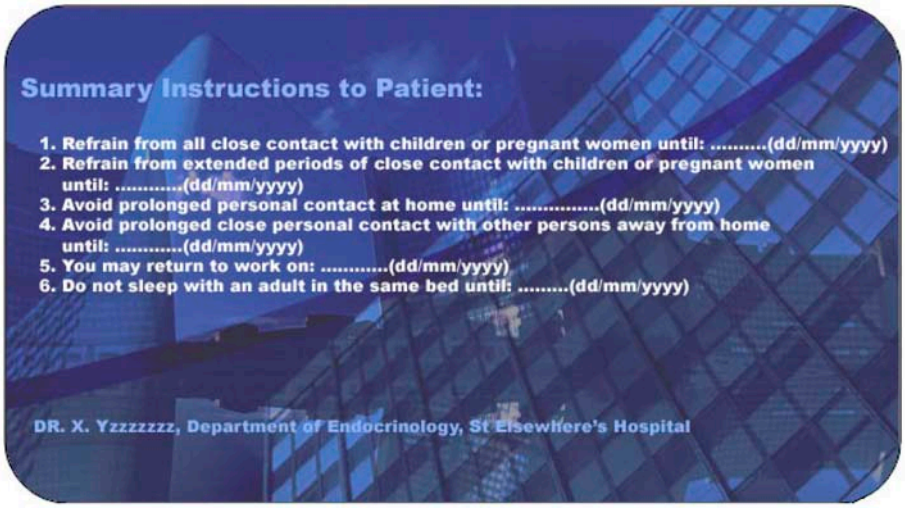


FIG. 1. An example of a credit card style card that might be given to a patient at the time of discharge: (a) front side, (b) rear side.

6. SUMMARY AND MAIN RECOMMENDATIONS

After therapeutic procedures with unsealed radionuclides, doses to comforters and carers, family members, the public, co-workers and others need to be limited or constrained in accordance with national regulations. The control arrangements should focus on the dose limits or dose constraints that are generally applied, rather than on secondary limits, such as retained activity.

Recent publications indicate that some assumptions and models used to estimate retained activity are unduly conservative, may overstate the doses to the public and carers, and in consequence lead to unnecessary hospitalization.

The approach advocated here provides a practical and humane implementable solution to the problems of patient release that is consistent with most regulatory systems. Where differences in regulatory systems exist between different countries or regions, the approach provides a basis for practical harmonization that will also be beneficial.

Patients do not need to be hospitalized automatically after all radionuclide therapies. Instead, the relevant national dose limits and dose constraints should be observed. This should be followed by optimization.

The decision to hospitalize or release a patient should be determined on an individual basis. This decision should take into account many factors, including the patient's wishes, their medical circumstances, the regulatory environment, occupational and public exposures, family considerations, cost and environmental factors.

The concept of a dose constraint of a few millisieverts per episode for carers has sometimes been inappropriately interpreted as a rigid annual dose limit. Some authorities require, for example, hospitalization of patients or storage of urine, based only on a retained activity loosely linked to the dose constraint, without appropriate optimization for the individual patient being taken into account. There is a need for, and would be some benefit from, harmonization in this area.

Internal contamination of family members is most likely in the first seven days after treatment. In most circumstances, the risks from internal contamination of others are less significant than those from external exposure. Because of its physical properties and the extent of its use, ^{131}I accounts for the majority of the dose to medical staff, the public and family members after therapeutic administration of unsealed radionuclides.

A major concern that needs to be addressed when releasing a patient with radioiodine is the external exposure of others. Once the patient has been released, the groups at risk include members of their family, including children, and carers; they may also include neighbours, visitors to the household,

co-workers, those encountered in public places, on public transport or at public events such as entertainments, and, finally, the general public.

Further points that should be noted are the following:

(a) Casual visitors to the patient at home, neighbours, co-workers, those encountered in public places, on public transport or at public events such as entertainments, and finally the general public, should also be subject to public dose limits.
(b) Thyroid cancer as a result of radiation exposure is a significant risk for unborn children, infants and younger persons. Particular care should be taken to avoid contamination of pregnant women, infants and children. The dose limit for members of the public should be applied to these groups.
(c) The exposure of close family members and others who knowingly and willingly agree to act as comforters and carers is regarded as medical exposure, and hence is not subject to dose limits.

Actual measurements of families or carers who follow radiation protection advice show that doses rarely approach or exceed a few millisieverts per episode, which is less than the dose constraint for most of the groups identified. Restrictions, once families and carers have been well instructed, should thus focus on the special consideration groups (i.e. pregnant women, infants and children).

Further points that should be noted are the following:

(a) Infants and young children may not be able to give the consent required to knowingly and willingly act as comforters and carers.
(b) The dose constraints established for comforters and carers are advisory, should be noted and where possible met.
(c) Pregnancy is contraindicated for those undergoing unsealed source therapies. Breast-feeding is also absolutely contraindicated after radioiodine therapy.
(d) Specific consideration needs to be given to the issues that arise in the event of the death of a patient. Autopsies of radioactive corpses can, with appropriate precautions, be undertaken safely and in compliance with the relevant legislative requirements. Situations where the wishes of next of kin have to be significantly disrupted with respect to disposal of the remains should be rare.

(e) The success of a patient release programme 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.
(f) There is a lack of audit data on the behaviour of patients and the consequences of early release programmes. There is some evidence of unanticipated consequences of early release programmes in the USA that requires assessment and evaluation.

There is a lack of good data on which to base patient advice for most radionuclides except radioiodine. A serious commitment is required to correct this.

REFERENCES

[1] UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION, Sources and Effects of Ionizing Radiation, UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes, United Nations, Vienna (2000).
[2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Release of Patients After Radionuclide Therapy with Unsealed Radionuclides, Publication 94, Elsevier, Oxford (2004).
[3] ELL, P.J., GAMBHIR, S.S. (Eds), Nuclear Medicine in Clinical Diagnosis and Treatment, Vol. 1, Churchill Livingstone, Edinburgh (2004).
[4] OYEN, W.J.G., et al., Targeted therapy in nuclear medicine — Current status and future prospects, review, Ann. Oncol. **18** 11 (2007) 1782–1792.
[5] SAMPSON, C.B., Textbook of Radiopharmacy, 3rd edn, Gordon and Breach, New York (1999).
[6] SAHA, G.B., Fundamentals of Nuclear Pharmacy, 5th edn, Springer-Verlag, Berlin (2004).
[7] EUROPEAN ATOMIC ENERGY COMMUNITY, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Fundamental Safety Principles, IAEA Safety Standards Series No. SF-1, IAEA, Vienna (2006).

[8] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, INTERNATIONAL ORGANIZATION FOR MEDICAL PHYSICS, PAN AMERICAN HEALTH ORGANIZATION, WORLD FEDERATION OF NUCLEAR MEDICINE AND BIOLOGY, WORLD HEALTH ORGANIZATION, Applying Radiation Safety Standards in Nuclear Medicine, Safety Reports Series No. 40, IAEA, Vienna (2005).

[10] EUROPEAN COMMISSION, Radiation Protection Following Iodine-131 Therapy (Exposures due to Out-patients or Discharged In-patients), Radiation Protection 97, European Commission, Luxembourg (1998).

[11] ROYAL COLLEGE OF PHYSICIANS, Radioiodine in the Management of Benign Thyroid Disease, Clinical Guidelines, Report of a Working Party, RCP, London (2007).

[12] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Precautions in the Management of Patients who have Received Therapeutic Amounts of Radionuclides, Rep. 37, NCRP, Bethesda, MD (1970).

[13] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Management of Radionuclide Therapy Patients, Rep. 155, NCRP, Bethesda, MD (2006).

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, Radiological Protection for Medical Exposure to Ionizing Radiation, IAEA Safety Standards Series No. RS-G-1.5, IAEA, Vienna (2002).

[15] LIEPE, K., et al., Rhenium-188-HEDP in the palliative treatment of bone metastases, Cancer Biother. Radiopharm. **15** (2000) 261–265.

[16] STRIGARI, L., et al., Radiopharmaceutical therapy of bone metastases with $^{89}SrCl_2$, ^{186}Re-HEDP and ^{153}Sm-EDTMP: Dosimetric study using Monte Carlo simulation, Eur. J. Nucl. Med. Mol. Imag. **34** (2007) 1031–1038.

[17] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Recommendations of the ICRP, Publication 60, Pergamon Press, Oxford (1991).

[18] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Recommendations of the ICRP, Publication 103, Elsevier, Oxford (2008).

[19] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Radiological Protection in Medicine, Publication 105, Elsevier, Oxford (2008).

[20] EUROPEAN UNION, COUNCIL OF THE EUROPEAN UNION, Council Directive 1997/43/Euratom on health protection of individuals against ionizing radiation in relation to medical exposure, Off. J. Eur. Commun. L. **180**, 09.07.1997 (1997) 22–27.
[21] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Radiological Protection and Safety in Medicine, Publication 73, Pergamon Press, Oxford (1996).
[22] EUROPEAN UNION, COUNCIL OF THE EUROPEAN UNION, Guideline 96/29 Euratom to determine basic directions of health protection of public and workers against ionizing radiation related dangers, Off. J. Eur. Commun. L. **159/1**, 29.06.1996 (1996).
[23] MALONE, J.F., New ethical issues for radiation protection in diagnostic radiology, Radiat. Prot. Dosim. **129** (2008) 6–12.
[24] MALONE, J.F., Radiation protection in medicine: Ethical framework revisited, Radiat. Prot. Dosim. **135** (2009) 71–78.
[25] SIEGEL, J.A., MARCUS, C.S., SPARKS, R.B., Calculating the absorbed dose from radioactive patients: The line-source versus point-source model, J. Nucl. Med. **43** (2002) 1241–1244.
[26] SIEGEL, J.A., SPARKS, R.B., Radioactivity appearing at landfills in household trash of nuclear medicine patients: Much ado about Nothing? Health Phys **82** 3 (2002) 367–372.
[27] SIEGEL, J.A., et al., A practical methodology for patient release after Tositumomab and Iodine 131 Tositumomab therapy, J. Nucl. Med. **43** 3 (2002) 354–363.
[28] LUBIN, E., Definitive improvement in the approach to the treated patient as a radioactive source, J. Nucl. Med. **43** (2002) 364–365.
[29] CULVER, C.M., DWORKIN, H.J., Radiation safety considerations for post-iodine-131 hyperthyroid therapy, J. Nucl. Med. **32** (1991) 169–173.
[30] O'DOHERTY, M.J., et al., Radiation dose rates from adult patients receiving ^{131}I therapy for hyperthyroidism, Nucl. Med. Commun. **14** (1993) 160–168.
[31] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Dose Limits for Individuals Who Receive Exposure from Radionuclide Therapy Patients, Commentary No. 11, NCRP, Bethesda, MD (1995).
[32] BARRINGTON, S.F., et al., Radiation dose rates from patients receiving iodine-131 therapy for carcinoma of the thyroid, Eur. J. Nucl. Med. **23** 2 (1996) 123–130.
[33] BARRINGTON, S.F., et al., RCP guidelines on radiation protection following radioiodine therapy for hyperthyroidism: Are they appropriate? Nucl. Med. Commun. **17** (1996) 275 (abstract).
[34] JOHNSON, T.K., LIN, E., HAUGEN, B., Contamination as a route for ^{131}I uptake in family members: Implications for public health, J. Nucl. Med. **43** Suppl. (2002) abstract.
[35] BUCHAN, R.C.T., BRINDLE, M.A., Radioiodine therapy to out-patients — The contamination hazard, Brit. J. Radiol. **43** (1970) 479–483.

[36] JACOBSON, A.P., PLATO, P.A., TOEROEK, D., Contamination of the home environment by patients treated with iodine-131: Initial results, Am. J. Public Health **68** 3 (1978) 225–230.
[37] NISHIZAWA, K., et al., Monitoring of I excretions and used materials of patients treated with ^{131}I, Health Phys. **38** (1980) 467–481.
[38] LASSMANN, M., HANSCHEID, H., SCHELPER, L.F., Measurement of incorporation in family members of patients with benign thyroid disease after radioiodine therapy, Nuklearmedizin **37** (1998) 120–123.
[39] SCHOMAECKER, K., et al., Exhalation of iodine-131 after radioiodine therapy: Time dependence and chemical form, J. Nucl. Med. **41** 5 Suppl. (2000) 251 (abstract).
[40] WELLNER, U., et al., The exposure of relatives to patients of a nuclear medicine ward after radioiodine therapy by inhalation of ^{131}I in their home, Nuklearmedizin **37** (1998) 113–119.
[41] IBIS, E., et al., Iodine-131 contamination from thyroid cancer patients, J. Nucl. Med. **33** (1992) 2110–2115.
[42] Report, USA Today (19 Nov. 2007) 1.
[43] INTERNATIONAL ATOMIC ENERGY AGENCY, Manual on Therapeutic Uses of Iodine-131, Practical Radiation Safety Manual, IAEA, Vienna (1996).
[44] BEIERWALTES, W.H., WIDMAN, J., How harmful to others are iodine-131 treated patients? J. Nucl. Med. **33** (1992) 2116–2117 (editorial).
[45] AUSTRALIAN RADIATION PROTECTION AND NUCLEAR SAFETY AGENCY, Recommendations for the Discharge of Patients Undergoing Treatment with Radioactive Substances, Radiation Protection Series No. 4, ARPANSA, Yallambie (2002).
[46] ADMINISTRATION OF RADIOACTIVE SUBSTANCES ADVISORY COMMITTEE (ARSAC), Notes for Guidance on the Clinical Administration of Radiopharmaceuticals and Use of Sealed Radioactive Sources — March 2006, *http://www.arsac.org.uk/notes_for_guidance/index.htm*
[47] NUCLEAR REGULATORY COMMISSION, Release of Patients Administered Radioactive Materials, Regulatory Guide No. 8.39, US Govt Printing Office, Washington, DC (1997).
[48] NUCLEAR REGULATORY COMMISSION, Regulatory Analysis on Criteria for the Release of Patients Administered Radioactive Material, NUREG-1492, US Govt Printing Office, Washington, DC (1997).
[49] HILDITCH, T.E., et al., Radiological protection guidance for radioactive patients — New data for therapeutic ^{131}I, Nucl. Med. Commun. **12** (1991) 485–495.
[50] CASTRONOVO, F.P., BEH, R.A., VEILLEUX, N.M., Iodine-131 therapy patients: Radiation dose to staff, Radiat. Prot. Dosim. **15** 1 (1986) 45–49.
[51] HO, S.Y., SHEARER, D.R., Radioactive contamination in hospitals from nuclear medicine patients, Health Phys. **62** 5 (1992) 462–466.
[52] DENMAN, A.R., MARTIN, S., Care of a terminally ill patient following a thyroid ablation dose of ^{131}I sodium iodide, Br. J. Radiol. **74** (2001) 1077–1078.

[53] NEW SOUTH WALES HOSPITAL AND UNIVERSITY RADIATION SAFETY OFFICERS GROUP (HURSOG), Guide to Radioiodine Therapy Facility Design, HURSOG (1997), http://www.hursog.org
[54] MATHIEU, I., CAUSSIN, J., SMEESTERS, P., WAMBERSIE, A., BECKERS, C., Doses in family members after ^{131}I treatment, Lancet **350** (1997) 1074–1075.
[55] MONSIEURS, M., et al., Real-life radiation burden to relatives of patients treated with iodine-131: A study in 8 centers in Flanders (Belgium), Eur. J. Nucl. Med. **25** 10 (1998) 1368–1376.
[56] BARRINGTON, S.F., et al., Radiation exposure of families of outpatients treated with radioactive iodine (iodine-131) for hyperthyroidism, Eur. J. Nucl. Med. **26** (1999) 686–692.
[57] GRISBY, P.W., et al., Radiation exposure from outpatient radioactive iodine (I-131) therapy for thyroid carcinoma, J. Am. Med. Assoc. **283** (2000) 2272–2274.
[58] BARRINGTON, S.F., et al., Does significant contamination occur in families of patients treated with 131-I for hyperthyroidism? Eur. J. Nucl. Med. **30** Suppl. 2 (1999) S164 (abstract 69).
[59] BRITISH INSTITUTE OF RADIOLOGY, Patients leaving hospital after administration of radioactive substances, Br. J. Radiol. **72** (1999) 121–125.
[60] MATHIEU, I., et al., Recommended restrictions after iodine-131 therapy: Measured doses in family members, Health Phys. **76** 2 (1999) 129–136.
[61] REINERS, C., LASSMANN, M., Radioiodine (^{131}I) treatment of hyperthyroidism: Radiation protection and quality assurance, Eur. J. Nucl. Med. **26** (1999) 683–685.
[62] LESLIE, W.D., HAVELOCK, J., PALSER, R., ABRAMS, D.N., Large-body radiation doses following radioiodine therapy, Nucl. Med. Commun. **23** (2002) 1091–1097.
[63] INTERNATIONAL ATOMIC ENERGY AGENCY, Detection of Radioactive Materials at Borders, IAEA-TECDOC-1312, IAEA, Vienna (2002).
[64] DE KLERK, J.M.H., I-131 therapy: Inpatient or outpatient? J. Nucl. Med. **41** 11 (2000) 1876–1878.
[65] SWEDISH RADIATION PROTECTION INSTITUTE, Regulations and General Advice on Nuclear Medicine, SSIFS 2000-3, SRPI, Stockholm (2000).
[66] EUROPEAN THYROID ASSOCIATION, I^{131} therapy for hyperthyroidism towards 2000, Eur. J. Nucl. Med. **23** 4 (1996) BP13–BP15.
[67] HOSONO, M., Kinki University School of Medicine, Japan, personal communication, 2008.
[68] NUCLEAR REGULATORY COMMISSION, Consolidated Guidance About Materials Licenses, NUREG-1556, Vol. 9, US Govt Printing Office, Washington, DC (2002).
[69] PANZEGRAU, B., GORDON, L., GOUDY, G.H., Outpatient therapeutic I-131 for thyroid cancer, J. Nucl. Med. Technol. **33** (2005) 28–30.
[70] COOVER, L.R., et al., Therapeutic ^{131}Iodine in outpatients: A simplified method of conforming to the Code of Federal Regulations, Title 10, Part 35.75, J. Nucl. Med. **41** 11 (2000) 1868–1875.

[71] FINNISH RADIATION AND NUCLEAR SAFETY AUTHORITY, Use of Radiation in Nuclear Medicine, Guide ST 6.3, STUK, Helsinki (2003).
[72] O'CONNELL, T.B., O'DOHERTY, M.J., Differentiated thyroid cancer and pregnancy, Nucl. Med. Commun. **21** (2000) 127–128 (editorial).
[73] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Pregnancy and Medical Radiation, Publication 84, Pergamon Press, Oxford (2001).
[74] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Doses to the Embryo and Foetus from Intakes of Radionuclides by the Mother, Publication 88, Pergamon Press, Oxford (2002).
[75] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Doses to Infants from Ingestion of Radionuclides in Mothers' Milk, Publication 95, Elsevier, Oxford (2004).
[76] THE INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, GODDEN, T.J., "Therapeutic uses of unsealed radionuclides", in Radiation Protection in Nuclear Medicine and Pathology (GOLDSTONE, K.E., MYERS, M.J., SIMPSON, A.E., Eds), IPEM, York (1991).
[77] SINGLETON, M., START, R.D., TINDALE, W., RICHARDSON, C., CONWAY, M., The radioactive autopsy: Safe working practices, Histopathology **51** 3 (2007) 289–304.
[78] AERTS, M.G., "Cremation of corpses containing bone-seeking radionuclides following medical treatment", paper presented at 10th Mtg of the International Society of Radiation Protection, Hiroshima, 2000.
[79] NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL, Code of Practice for the Safe Handling of Corpses Containing Radioactive Materials (1986), Australian Government Publishing Service, Canberra (1987).
[80] PARTHASARATHY, K.L., et al., Necropsy of a cadaver containing 50 mCi of sodium 131 iodide, J. Nucl. Med. **23** (1982) 777–780.
[81] JOHNSTON, A.S., et al., Autopsy experience with a radioactive cadaver, Health Phys. **37** (1979) 231–236.
[82] SILBERSTEIN, E.B., BUSCOMBE, J.R., McEWAN, A., TAYLOR, A.T., Jr., Society of Nuclear Medicine Procedure Guideline for Palliative Treatment of Painful Bone Metastases, Version 3.0, Society of Nuclear Medicine Procedures Manual (2003) pp. 147–154, http://interactive.snm.org/docs/pg_ch25_0403.pdf

Annex I

TYPE AND FREQUENCY OF RADIONUCLIDE THERAPY PROCEDURES

Radioiodine treatments for hyperthyroidism and thyroid cancer are the most important sources of public and family exposure from patients who have received unsealed radionuclides. The use of radiopharmaceutical treatments has almost doubled over the last decade. In developed countries, UNSCEAR estimated that the frequency of radiopharmaceutical treatments increased from 0.10 per 1000 population between 1985 and 1990 to 0.17 per 1000 between 1991 and 1996. UNSCEAR also estimated that worldwide there were about 210 000 radiopharmaceutical treatments between 1985 and 1990, and that from 1991 to 1996 there were 380 000. Actual frequencies of procedures have probably now greatly increased from these levels [I–1]; for example, NCRP estimate that there are 200 000 radioiodine procedures a year in the USA [I–2]. It is also the case that the actual number of procedures performed in a particular country may vary significantly from that which might be predicted from a simple scaling of global values.

The common types of therapy with unsealed radionuclides are oral or intravenous administration of liquids or capsules (systemic therapy) or instillation of colloidal suspensions into closed body cavities (intracavitary). Examples of systemic therapy include ^{131}I sodium iodide for hyperthyroidism or thyroid cancer and ^{89}Sr for treatment of bone metastases. Examples of intracavitary therapy are ^{32}P chromic phosphate for treatment of malignancies of the pleural and peritoneal cavities and intra-articular administration for synovectomy. The estimated numbers of common types of therapeutic procedures with unsealed radionuclides are given in Table I–1.

TABLE I–1. NUCLEAR MEDICINE THERAPY: ESTIMATED NUMBER OF ANNUAL PROCEDURES 1991–1996 [I–3]
(adapted from: UNSCEAR 2000 [I–3])

Disease	Radiopharmaceutical and route	Procedures/million population in developed countries	Procedures/million population worldwide
Thyroid malignancy	^{131}I sodium iodide (oral or IV[a])	35	15
Hyperthyroidism	^{131}I sodium iodide (oral or IV)	110	42
Polycythaemia vera	^{32}P phosphate (oral or IV)	3	1
Bone metastases	^{89}Sr strontium chloride (IV) ^{153}Sm ethylene diaminomethylene phosphoric acid (IV)	5	2
Synovitis	^{90}Y colloid ^{169}Er colloid (intra-articular)	7	2
Malignant disease (other than thyroid cancer and polycythaemia vera)	^{131}I m-iodo-benzylguanidine (IV) ^{90}Y colloid (intracavitary)	[b]	[b]

[a] IV: intravenous administration.
[b] Unknown.

REFERENCES TO ANNEX I

[I–1] HOEFNAGEL, C.A., et al., Radionuclide therapy practice and facilities in Europe, Eur. J. Nucl. Med. **26** (1999) 227–282.

[I–2] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Management of Radionuclide Therapy Patients, Rep. 155, NCRP, Bethesda, MD (2006).

[I–3] UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION, Sources and Effects of Ionizing Radiation, UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes, United Nations, Vienna (2000).

Annex II

DETERMINATION OF RETAINED ACTIVITY

II–1. METHOD OF ESTIMATION

Retained activity can easily be estimated for photon emitting radionuclides. A simple protocol for this, which requires only a basic radiation detector, is described here. The steps involved are:

(1) Determine a fixed distance of at least 3 m at which the dose rate from the patient may be regularly measured. A good approach is to have fixed marks for both the patient and the measurement positions on the wall or the floor of the room.

(2) As soon as possible after administration, and certainly before any excretion, measure the dose rate from the patient at this fixed distance. At any future times of interest, measure the dose rate again at this fixed distance. The retained activity may then be simply estimated as:

$$A_R = A_0 D/D_0$$

where:

A_R is the retained activity at the time of measurement;
A_0 is the administered activity;
D_0 is the dose rate immediately after administration; and
D is the dose rate at the time of measurement.

This is an estimate only, as the results may be influenced by redistribution of activity in the patient. However, the estimate is adequate for many purposes.

Should it be desirable to compensate for distance, it is important to take into account the fact that the inverse square law is not reliable at distances of

less than 3 m from the patient. Below 3 m, the relationship is sometimes approximated as:

$$D = D_1 x^{-1.5}$$

where:

D is the dose rate at point x;
x is the distance; and
D_1 is the dose rate at 1 m [II–1].

II–2. COMMENTS ON RETAINED ACTIVITY

For practical purposes, it is convenient to relate the activity remaining in the patient at the time of discharge to exposure of the public and family. Where this is done, such tables should be based on realistic models traceable to dose measurements. Tables II–1 and II–2 provide US NRC data that are of value in this regard. Authors from the Russian Federation, UK and USA have expressed the view that patients are sometimes unnecessarily hospitalized due to unnecessarily conservative assumptions [II–2—II–5]. In 1997, the US NRC amended its regulations for the release of patients receiving treatment with radioactive materials from an activity based limit to a dose based limit [II–6]. The new regulation was based on the maximally exposed individual not being likely to exceed an effective dose equivalent of 5 mSv (Table II–1). Compliance is demonstrated by using a default table for activity or dose rate, or performing a patient-specific dose assessment.

Specific instructions to the patient, their representative(s) and family are required as discussed in the main text. Coover et al. [II–7] have recently proposed a simplified method to facilitate conformance to US NRC regulations [II–7–II–9]. In practice, in the USA, competent and cooperative patients are now routinely discharged with activities as high as 8000 MBq of ^{131}I.

TABLE II–1. ACTIVITIES (MBq) FOR RELEASE OF PATIENTS DEPENDING ON THE EXTERNAL DOSES TO OTHER PEOPLE (mSv EFFECTIVE DOSE)

Radionuclide	Half-life[a]	MBq for 5 mSv	MBq for 1 mSv
Ag-111	7.45 d	19 000	3800
Au-198	65 h	3500	690
Cr-51	28 d	4800	960
Cu-64	13 h	8400	1700
Cu-67	61 h	14 000	2900
Ga-67	78 h	8700	1700
I-123	13 h	6000	1200
I-125	60 d	250	50
I-131	8 d	1200	240
In-111	67 h	2400	470
P-32	14.29 d	[b]	[b]
Re-186	90 h	28 000	5700
Re-188	17 h	29 000	5800
Sc-47	80 h	11 000	2300
Se-75	119.8 d	89	18
Sm-153	47 h	26 000	5200
Sn-117m	13.61 d	1100	210
Sr-89	50.5 d	[b]	[b]
Tc-99m	6 h	28 000	5600
Tl-201	74 h	16 000	3100
Y-90	64 h	[b]	[b]
Yb-169	32 d	370	73

[a] Half-lives from NUREG-1556 [II–10].
[b] No value given because of minimal exposures of the public. Adapted from US NRC, 1997 [II–6].

TABLE II–2. ACTIVITIES AND DOSE RATES BELOW WHICH PATIENT RELEASE IS AUTHORIZED BY THE US NRC

Radionuclide	Activity (GBq)	Dose rate at 1 m (mSv/h)
Au-198	3.5	0.21
Ga-67	8.7	0.18
I-123	6.0	0.26
I-131	1.2	0.07
In-111	2.4	0.2
P-32	*	*
Re-186	28	0.15
Re-188	29	0.20
Sm-153	5–26	0.06–0.3
Sr-89	*	
Tc-99m	28	0.58
Tl-201	16	0.19
Y-90	*	
Yb-169	0.37	0.02

* No value given because of minimal exposures of the public.

REFERENCES TO ANNEX II

[II–1] NEW SOUTH WALES HOSPITAL AND UNIVERSITY RADIATION SAFETY OFFICERS GROUP (HURSOG), Guide to Radioiodine Therapy Facility Design, HURSOG (1997), http://www.hursog.org/I131GUID.PDF

[II–2] DE KLERK, J.M.H., Iodine-131 therapy: Inpatient or outpatient? J. Nucl. Med. **41** 11 (2000) 1876–1878.

[II–3] SIEGEL, J.A., Considerations for Release of Patients Administered Radiopharmaceuticals, www.dose.info-radar.com/Technical%20Basis.doc

[II–4] BARRINGTON, S.F., et al., RCP guidelines on radiation protection following radioiodine therapy for hyperthyroidism: Are they appropriate? Nucl. Med. Commun. **17** (1996) 275 (abstract).

[II–5] SHISHKANOV, N.G., et al., Radiation protection of members of the public contacting patients after therapeutic treatment with radioiodine, Med. Radiol. Radiat. Prot. **5** (2001) 34–46 (in Russian).

[II–6] NUCLEAR REGULATORY COMMISSION, Release of Patients Administered Radioactive Materials, Regulatory Guide No. 8.39, US Govt Printing Office, Washington, DC (1997).
[II–7] COOVER, L.R., et al., Therapeutic ^{131}Iodine in outpatients: A simplified method of conforming to the Code of Federal Regulations, Title 10, Part 35.75, J. Nucl. Med. **41** 11 (2000) 1868–1875.
[II–8] LUBIN, E., Definitive improvement in the approach to the treated patient as a radioactive source, J. Nucl. Med. **43** (2002) 364–365.
[II–9] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Release of Patients After Therapy with Unsealed Radionuclides, Publication 94, Elsevier, Oxford (2004).
[II–10] NUCLEAR REGULATORY COMMISSION, Consolidated Guidance About Materials Licenses, NUREG-1556, Vol. 9, US Govt Printing Office, Washington, DC (1992).

Annex III

SOME ADDITIONAL FREQUENTLY ASKED QUESTIONS AND ENVIRONMENTAL CONSIDERATIONS

III–1. HOW IS THE RADIOACTIVE WASTE FROM THE PATIENT DISPOSED OF, AND DOES IT POSE A RISK?

The predominant issue is radioactive excreta: urine and faeces. Much of the activity initially administered is eventually discharged to sewers. Table III–1 shows the proportion that is typically discharged by this route, for some therapeutic radionuclides. Once a patient has been released from hospital, the excreted radioactivity levels are low enough to be discharged through the toilet in their home without exceeding public dose limits. The guidelines given to patients will protect their family, carers and neighbours, provided the patient follows these guidelines.

TABLE III–1. PROPORTION OF ADMINISTERED ACTIVITY DISCHARGED TO SEWERS
(adapted from Thompson et al. [III–1])

Nuclide and form	Disease or condition treated	Amount of activity discharged to sewers (%)
Au-198 colloid	Malignant disease	0
I-131	Hyperthyroidism	54
I-131	Thyroid carcinoma	84–90
I-131 MIBG*	Phaeochromocytoma	89
P-32 phosphate	Polycythaemia, etc.	42
Sr-89 chloride	Bone metastases	92
Y-90 colloid	Arthritic joints	0
Y-90 antibody	Malignancy	12
Er-169 colloid	Arthritic joints	0

* MIBG: meta-iodobenzylguanidine.

Other wastes such as dressings will usually, in due course, end up in landfill sites or incinerators. Again, the specific therapy discharge guidelines are designed so that any contamination will be at a low level. Solid wastes from a patient's stay in hospital is, in many institutions, incinerated at high temperature along with other wastes, or held until it decays to an acceptable level.

III–2. WILL THE PATIENT TRIGGER A SECURITY ALARM AT AN AIRPORT OR SIMILAR LOCATION?

Current international security measures, such as those in place at airports and border crossing points, can include extremely sensitive radiation detectors. It is quite possible that patients treated with gamma emitting radionuclides could trigger these alarms, particularly in the period immediately following discharge. Triggering of an alarm does not mean that a patient is emitting dangerous levels of radiation — the detectors are designed to detect levels of radioactivity far below those of concern to human health.

The security authorities are well aware of this possibility, and if a patient is likely to travel soon after discharge, the hospital or the patient's doctor should provide a written statement of the therapy and radionuclide used, for the patient to carry. This statement should be in language that will be clear and accessible to security staff. Some security staff will not be trained to deal with this situation, and so it may be best if patients avoid such travel unless they are willing to experience some additional inconvenience.

III–3. WILL THE RADIOACTIVITY FROM THE PATIENT HARM THE ENVIRONMENT?

The main radionuclide discharged into the environment following radionuclide therapy is radioiodine (^{131}I). Owing to its half-life of eight days, ^{131}I can be detected in the general environment after medical use. However, the degree of dilution and dispersion caused by mixing with normal waste, and the length of time required for any contamination to be returned to the ecosystem, reduces the environmental impact to a level that is below that suggested in all available guidelines.

Some countries require short term storage of hospital waste (usually urine only) containing radionuclides from hospitalized therapy patients until the activity has reached a particular level. For radionuclides used in bone pain palliation, it is suggested that where the therapy is conducted as an outpatient, the patient empty their bladder at least once before leaving the hospital.

Where the social system and infrastructure is such that there may be contamination risks from discharged patients, it may be necessary to hospitalize the patient or extend the normal hospitalization time, to avoid risk to the environment or other persons.

III–4. THE PATIENT IS UNDERGOING REGULAR HAEMODIALYSIS — IS THIS A RISK?

In such cases, no significant contamination of dialysis machines has been reported. There may be slight contamination of disposable items such as liners and waste bags, which may require storage for some time, in the case of ^{131}I. In most cases, however, no special precautions will be required and the dialysis and radiation safety staff will advise patients on how to deal with disposables.

REFERENCE TO ANNEX III

[III–1] THOMPSON, W., WILLIAMS, N.R., HARDING, L.K., A model of excreted activities of radiopharmaceuticals from patients to the drains, Eur. J. Nucl. Med. **21** (1994) 876.

Annex IV

RADIOACTIVE BODIES, AUTOPSY ADVICE

The following summary is based, with adaptations, on extracts from Ref. [IV–1].

IV–1. FOLLOWING DEATH

All unnecessary close contact with the deceased should be minimized, and impermeable gloves and an apron should be worn if contact with the corpse or body fluids is required. Control of exposure during the autopsy will be assisted if, immediately following death, the body is straightened and prepared for viewing by next of kin. Necessary restrictions on viewing times or distances from the deceased should be specified and communicated with sensitivity. Once the viewing is complete, the body can be placed in a body bag, to retain leaking body fluids, prior to transfer to the mortuary. Nursing staff should be provided with instructions informing them that the normal procedure of pressing down on the abdomen of a corpse must not be performed due to the radiation and/or contamination levels that may result. Items contaminated with body fluids should be retained in a clearly labelled leak-proof bag.

IV–2. PRECAUTIONS DURING AUTOPSY

The dose limits applying to pathology staff responsible for the conduct of autopsy examinations will be either those for the general public or those for radiation workers, depending on the training and classification of the staff concerned. However, it is almost inevitable that some members of the pathology staff will be classified as members of the public from a radiation protection point of view. These limits and the radiation safety procedures to be applied in practice should be determined in close consultation with the radiation safety officer from the department in which the therapy was administered.

Identification of the possibility that a body may contain radioactive substances relies on information provided in the patient records, the card described in Section 5 or information gleaned from relatives or others. Where the possibility that the corpse may be radioactive arises, a proposed autopsy should be suspended until the situation is clarified to the greatest extent

possible and a risk assessment has been undertaken by the radiation safety officer. This should establish the type, nature and location of the radioactive material used and when the therapy occurred. Any reporting or notifications required by law and/or good practice should also be undertaken.

Accurate and comprehensive clinical histories can be difficult to obtain prior to autopsy, particularly in relation to deaths in the community. Hospital clinical records may not be available and primary care records may be incorrect or incomplete. Despite the radiation protection requirement for patients containing radioactive material to carry an appropriate identifier, compliance can be poor once patients have left hospital.

Unsealed radioactive substances may be present in a particular body cavity or organ, or they may have concentrated after systemic administration (e.g. ^{131}I in the thyroid gland). Drainage of the cavity or excision of the organ will reduce exposure if undertaken at the start of the autopsy. Any sources or organs so removed should be securely stored or disposed of in accordance with legislative requirements and national practices with regard to human organ disposal. Where removal of the radioactive material is not practical, autopsy can be undertaken using normal standard precautions supplemented by radiation-specific protection measures under the guidance of a radiation protection expert/or medical physicist. In situations where radioactive material has been localized, the normal autopsy technique can be limited to reduce hazard through avoidance of the relevant areas. Radiation exposure can also be reduced by minimizing the length of time spent handling radioactive material and by increasing the distance between personnel and the source by use of instruments with long handles. Where unsealed sources have been administered, the risk of skin contamination and exposure of skin and hands to beta radiation can be minimized by the wearing of two pairs of surgeon's gloves, with the outer pair being renewed following work on highly radioactive areas. An intake of airborne material inadvertently released during cutting or movement of radioactive tissue or organs can be prevented by wearing eye protection and a face mask.

Prior to the autopsy, consideration must be given to the removal of contamination from reusable items and the disposal of solid and liquid radioactive waste. Polythene can be used to cover surfaces that may be contaminated, although this may not be necessary, as the likelihood of radioactivity becoming fixed to the mortuary cleanable surfaces is low. Contamination control may be assisted by conducting the autopsy with the body remaining in the bag. It may be appropriate to use disposable rather than reusable outer protective clothing.

TABLE IV–1. SUMMARY OF KEY POINTS FOR AUTOPSIES OF RADIOACTIVE BODIES
(adapted from Singleton et al. (2007) [IV–1])

Autopsy: key points with radioactive bodies
— Review and verify the clinical history
— Look for radioactive hazard identifiers
— Contact the treatment centre for specific information and advice
— In consultation with a radiation protection expert/medical physicist, complete a risk assessment for radioactivity contained in the body, samples, organs and waste
— Consider the national regulations, reporting requirements, restrictions and customs
— Consider the wishes of relatives with respect to disposal of the body
— Avoid an autopsy if possible
— Consider a limited or delayed autopsy
— Take advice from a radiation protection expert/medical physicist regarding procedures to reduce doses to mortuary staff and to control, store and dispose of radioactive material
— Ensure safe disposal of removable radioactive material
— Ensure that the mortuary is surveyed for contamination
— Identify hazards to others, on the body and within accompanying documentation
— Ensure safe disposal of the body

Where activity levels warrant it the mortuary, or a clearly identified part of it, should be designated as a temporary radiation controlled area and suitable warning notices displayed. Persons entering this area should be subject to radiation protection precautions. Standard general radiation protection procedures for limiting and monitoring contamination and its spread should be followed and will not be repeated here, although a useful summary is provided in Ref. [IV–1]. Likewise, care should be taken with the handling, storage and disposal of samples taken, as these can be more radioactive than the samples generally encountered in pathology or research laboratories.

In conclusion, the autopsy of a radioactive body can be undertaken safely and in compliance with relevant legislative requirements by the implementation of relatively simple precautions derived from an assessment of the radiation risks. The administering department and the radiation protection expert/medical physicist will be able to provide the case-specific information needed to complete the assessment. A summary of important practical points is provided in Table IV–1 above.

REFERENCE TO ANNEX IV

[IV–1] SINGLETON, M., START, R.D., TINDALE, W., RICHARDSON, C., CONWAY, M., The radioactive autopsy: Safe working practices, Histopathology **51** 3 (2007) 289–304.

Annex V

SPECIFIC THERAPIES AND RELEASE CONSIDERATIONS

This section reviews some of the available information on the more common therapies, taking each under the headings: radionuclide, form and activity; excretion; post-release issues; advice to patients and family; and, finally, emergencies. In many cases, the advice for therapies appearing later in the list repeats advice already given for radioiodine. Where this is the case, it is frequently simply cross-referenced. More information and experience are available for radioiodine than for the other nuclides used; thus it is often used to guide the advice for other nuclides. As documented experience grows, this situation should improve [V–1–V–15].

V–1. IODINE-131 USED IN BENIGN THYROID DISEASE (THYROTOXICOSIS, GRAVE'S DISEASE AND TOXIC GOITRE)

V–1.1. Radionuclide, form and activity

Iodine-131, as sodium or potassium iodide, is administered orally in the form of a liquid or gelatin capsule. The activity used is up to about 1 GBq, but is normally considerably less (185–740 MBq) [V–16].

V–1.2. Excretion

Radioiodine is excreted primarily via the kidneys, and, consequently, the patient should be encouraged to drink water freely to assist clearance. The next most significant pathway is via the salivary glands. This will manifest itself in contamination of eating and drinking utensils, as well as pillow coverings. Lesser pathways for contamination occur in sweat and faeces. Breast milk can contain significant amounts of radioiodine. It is best, if measurements cannot be made, to assume that contamination is present in all pathways.

V–1.3. Post-discharge issues

The activity administered in this form of therapy is less than the discharge limit applied in many countries, and thus it is widely practiced as an outpatient therapy. The activity used is almost always less than the relatively high discharge limit used by the IAEA and formerly used in the USA. However, it

can be closer to, or even greater than, the limit employed in many European countries. Hence, discharge policy must take account of local statutory requirements. In practice, where possible, it is common to discharge the patient immediately, after consideration of their circumstances. Following immediate discharge, excretion of unbound radioiodine will continue for some time, and hence both contamination and external radiation will give cause for concern, but can often be managed if good instructions are provided to the patient.

V–1.4. Advice to patients and families

Advice to patients and families is treated under two headings, contamination (Section V–1.4.1) and external radiation (Section V–1.4.2). A more comprehensive set of sample advice is provided in Section 5.

V–1.4.1. External radiation

Provided good contamination containment measures are taken, external irradiation is the most important safety issue. The persons at risk of external exposure include carers, members of the patient's family, members of the public and work colleagues. The following measures by the patient will provide protection for these groups:

(a) Avoid public transport if possible. If it must be used, limit journey time to less than two hours. Maximize distance from other passengers. If a distance of one metre can be achieved, this provides excellent protection (Section 3.1.2.3).
(b) Follow similar rules with respect to social events.
(c) Kissing or sexual intercourse should be avoided for at least two days in cases in which the retained activity on release is greater than 600 MBq. In cases in which the retained activity is 600 MBq or lower, sexual activity lasting less than 30 minutes a day is acceptable. In either case, use of a condom is advisable for the first week after therapy.
(d) Avoid prolonged physical contact with members of the family at home. Maintain a distance of at least an arm's length, and preferably one metre, for short periods of contact. For longer periods, maintain a distance of at least two metres.
(e) Minimize contact with children. If the patient has young children, who demand physical contact, this should be allowed for short periods (a few minutes) only. It may be advisable that the patient's children be accommodated elsewhere for a week, particularly if the accommodation arrangements at home require living in very close proximity.

(f) Avoid all contact with pregnant women.
(g) Return to work should be postponed for at least two days, possibly longer in cases in which the retained activity or dose rates are higher.

Once excretion is effectively complete, the external radiation will decline with the effective half-life, which in the case of ^{131}I is often taken as equal to or slightly less than the physical half-life in the range of six to eight days. These precautions should be followed for at least one week, i.e. approximately one half-life. When required, more nuanced advice can be inferred from Section 3.

V–1.4.2. Contamination

If a patient is discharged immediately, the following practical steps will minimize contamination. These must be followed for a time period depending on the residual activity present at release and consequent dose rates (Tables 11 and 12). In addition, these steps should be reviewed taking into consideration the social circumstances in which the patient lives, in respect of both the sanitary arrangements and of their proximity to other family members, particularly children and women who are or may be pregnant. Urinary excretion should be promoted by frequent fluid intake. Patients should be advised to flush the toilet twice after use, and males should avoid 'splashing' (sitting down to urinate is recommended). Special consideration will obviously need to be given to avoiding splashing and cleaning after use with squat toilets [V–17]. Patients should wash their hands frequently. Sharing food or eating utensils should be avoided. Regular showering will remove contaminated sweat. Clothing and bed linen should be separately laundered.

Breast-feeding must cease before therapy, and should not be resumed, as radioiodine persists for a considerable period in breast milk. Vomiting after oral administration of radioiodine (before absorption from the gut is complete) is a significant source of contamination. Where possible a patient who vomits should do so into a container or directly into a toilet or sluice, which must be flushed clean. If vomiting occurs in a public area, care must be taken to monitor and decontaminate it. Access to the area should be restricted, if necessary, until the contamination returns to a level not requiring access restriction or monitoring. The regulatory authorities should be notified as required nationally. Advice may be obtained from the department responsible for the therapy, which should also be notified as the effectiveness of the therapy will be diminished.

V–1.5. Emergencies

In the case of an illness or accident, requiring attendance of the patient at hospital or by a doctor, those involved must be notified of the therapy and the date, radionuclide and activity involved. Such information should be included in the card given to the patient on release (Section 5.3).

V–2. IODINE-131 USED IN THYROID CANCER

V–2.1. Radionuclide, form and activity

Iodine-131, as sodium or potassium iodide, is administered in the form of a liquid or a gelatin capsule. The activity used is up to about 14.8 GBq, with the ranges being 1.1–14.8 GBq (thyroid cancer) and 2.59–3.7 GBq (thyroid ablation) [V–16].

V–2.2. Excretion

Excretion is as for ^{131}I therapy of benign thyroid disease in Section V–1.2 above, with the following addition. In cancer patients from whom normal thyroid tissue has often been removed or ablated, most of the administered activity appears quickly in the urine. The fraction will largely be determined by the extent of remnant and metastatic thyroid tissue. In most cases, 50–60%, or more, of the administered activity is excreted in the first 24 hours, and around 85% over a hospital stay of three to five days. This represents a significant potential for radioactive contamination. Thus, the contamination level in urine will always be significant in cancer therapies. The proportion present in each of the other pathways varies widely.

V–2.3. Post-discharge issues

For higher cancer therapy doses, problems can arise from both external irradiation and contamination, and these need attentive management (Sections 3.1 and 3.2). However, if the patient has been hospitalized for a few days, by discharge the radiation safety problem has generally changed in emphasis, with the main focus being on external radiation. The external dose levels at this stage can still be significant given the higher retained activity/dose levels allowed in some countries. However, the problems involved can be susceptible to management at home with suitable patients. If active excretion is still taking place, contamination of household objects, other persons and the

toilet may occur, and will require attention. Once the retained activities and dose levels fall, the situation has much in common with that prevailing for release of patients after radioiodine therapy for hyperthyroidism, as discussed above in Section V–1.3. In practice, the retained activity and dose levels tend to fall more rapidly in thyroid cancer patients.

V–2.4. Advice to patients and families

Advice to patients and families is treated under two headings: contamination and external radiation. The period for which the advice should be followed will have to be determined locally after due account has been taken of the patient's circumstances and the rapidity with which the radioiodine is being cleared. The advice that follows is designed for patients who have spent a few days in hospital, and in whom the retained activity is less than about 600 MBq. For patients being released immediately after therapy, additional advice will be necessary that must be tailored to individual countries to ensure compliance with local regulations. After a few days in hospital, the retained activity will have declined considerably and probably be similar to that prevailing after therapy for hyperthyroidism. At this point, advice is as above for ^{131}I therapy of benign thyroid disease (Section V–1.4).

Once excretion is effectively complete, the external radiation will decline with the effective half-life. However, for cancer patients, the iodine may be less well bound than in other groups and the effective half-life is generally somewhat shorter.

V–2.5. Emergencies

The advice is as above for radioiodine therapy of benign thyroid disease (Section V–1.5).

V–3. IODINE-131 MIBG THERAPY

V–3.1. Radionuclide, form and activity

Iodine-131 labelled MIBG (meta-iodobenzylguanidine) is used. The activity used is in the range 1.9–11 GBq, a typical dose being 5 GBq. Administration is by slow injection over about 1 h. For children, the amount is 666 MBq/kg.

V–3.2. Excretion

Urinary excretion of radioiodine occurs in the first five days or so. Other iodine pathways may also be present. Vomiting does not pose the same hazard as arises with oral administration. Thus, while there are differences, in practice the situation is assumed to be similar to that applying to release following ^{131}I therapy for benign thyroid disease, which may be taken as a guideline.

V–3.3. Post-discharge issues

Post-discharge issues are as above for ^{131}I therapy of benign thyroid disease (Section V–1.3).

V–3.4. Advice to patients and families

Advice to patients and families is as above for ^{131}I therapy of benign thyroid disease (Section V–1.4).

V–3.5. Emergencies

Advice for emergencies is as above for ^{131}I therapy of benign thyroid disease (Section V–1.5).

V–4. ANTIBODY THERAPY

V–4.1. Radionuclide and form

Iodine-131 labelled monoclonal antibodies, the activity administered is typically 3 GBq, by intravenous injection. For treatment of lymphomas, the given activity must deliver 65–70 Gy to the tumour.

V–4.2. Excretion

Unbound or dissociated activity is predominantly excreted via urine. Approximately 7% is observed in the first week [V–8].

V–4.3. Post-discharge issues

Toilet precautions must be maintained for at least one week after administration.

V–4.4. Advice to patients and families

Advice to patients and families is as above for ^{131}I therapy of benign thyroid disease (Section V–1.4).

V–4.5. Emergencies

Advice for emergencies is as above for ^{131}I therapy of benign thyroid disease (Section V–1.5).

V–5. IODINE-131 LIPIODOL THERAPY

V–5.1. Radionuclide, form and activity

Iodine-131 labelled lipiodol (ethiodized oil), an activity of up to 2 GBq is used; a typical dose is 1 GBq, administered by selective hepatic arterial injection: standard activity is 2.22 GBq [V–11], 1.11–2.22 GBq (one fraction), 2.22–4.44 GBq (three fractions) [V–18].

V–5.2. Excretion

Unbound activity, not in liver or lungs, is predominantly excreted via urine. The percentage of activity excreted may be up to 30–50% by eight days. A small amount of faecal excretion (<3%) may occur.

V–5.3. Post-discharge issues

Urinary excretion is slower than that for ^{131}I as iodide, so toilet precautions may need to be maintained for longer after administration.

V–5.4. Advice to patients and families

V–5.4.1. External radiation

Advice to patients and families is as above for ^{131}I therapy of benign thyroid disease (Section V–1.4).

V–5.4.2. Contamination

With the exception of measures relating to sweat and saliva, the advice is as above for ^{131}I therapy of benign thyroid disease (Section V–1.4).

V–5.5. Emergencies

Advice for emergencies is as above for radioiodine therapy of benign thyroid disease (Section V–1.5).

V–6. YTTRIUM-90 MICROSPHERES FOR LIVER MALIGNANCIES

V–6.1. Radionuclide, form and activity

Yttrium-90 bound to resin or glass microspheres, variable activities of up to about 3 GBq are used, administered by selective arterial injection of 11.1–14.8 MBq/kg up to 1.19 GBq [V–16].

V–6.2. Excretion

Excretion is minimal or none.

V–6.3. Post-discharge issues

A low level of external radiation, and short half-life (2.7 days), means that post-discharge safety issues do not normally arise. The administered activity is often less than that noted for release in Table 9.

V–6.4. Advice to patients and families

No special precautions need be taken by patients and families other than for emergencies.

V–6.5. Emergencies

Advice for emergencies is as above for ^{131}I therapy of benign thyroid disease (Section V–1.5).

V–7. PHOSPHORUS-32 THERAPY FOR MYELOPROLIFERATIVE DISEASE

V–7.1. Radionuclide, form and activity

Phosphorus-32 is in the form of sodium phosphate. The activity used varies, but is frequently in the range 70–180 MBq, administered by intravenous injection: 111–185 MBq (polythaemia vera) and 370–555 MBq (malignant effusions) [V–16].

V–7.2. Excretion

Urinary excretion in the 48 hours following administration is significant.

V–7.3. Post-discharge issues

The main issue is urinary excretion, which requires care. Phosphorus-32 can migrate through the skin and is difficult to remove if contamination occurs.

V–7.4. Advice to patients and families

V–7.4.1. External radiation

No special radiation precautions are required [V–8].

V–7.4.2. Contamination

Toilet practices should follow those above for ^{131}I therapy of benign thyroid disease (Section V–1.4).

V–7.5. Emergencies

Advice for emergencies is as above for ^{131}I therapy of benign thyroid disease (Section V–1.5).

V–8. STRONTIUM-89 THERAPY FOR PALLIATION OF BONE PAIN

V–8.1. Radionuclide, form and activity

Strontium-89 is in the form of strontium chloride. The activity used is typically about 150 MBq [V–11] (148 MBq [V–16]), administered as an intravenous injection.

V–8.2. Excretion

Urinary excretion of unbound material occurs in the 48 hours following administration.

V–8.3. Post-discharge issues

The main issue is urinary excretion. When conducted on an outpatient basis, the patient should be kept in hospital until at least one or two post-administration bladder voidings occur. Special arrangements may be required for incontinent patients.

V–8.4. Advice to patients and families

V–8.4.1. External radiation

No special radiation precautions are required

V–8.4.2. Contamination

Toilet practices, as well as practices for cutlery, crockery and laundry, are as above for ^{131}I therapy of benign thyroid disease (Section V–1.4).

V–8.5. Emergencies

Advice for emergencies is as above for ^{131}I therapy of benign thyroid disease (Section V–1.5).

V–9. SAMARIUM-153 THERAPY FOR PALLIATION OF BONE PAIN

V–9.1. Radionuclide, form and activity

Samarium-153 is in the form of EDTMP (ethylene-diamine-tetra-methylene-phosphonate). The activity used is typically 1 GBq (37 MBq/kg), and is administered by intravenous injection [V–16].

V–9.2. Excretion

Urinary excretion of unbound material occurs in the 48 hours immediately following administration.

V–9.3. Post-discharge issues

The main issue is urinary excretion. When conducted on an outpatient basis, the patient should be kept in the hospital until at least one or two post-administration bladder voidings occur. Special arrangements may be required for incontinent patients. The gamma emission from ^{153}Sm is not a major concern.

V–9.4. Advice to patients and families

V–9.4.1. External radiation

Samarium-153 is a beta and gamma emitter; the gamma emission does not give rise to high dose rates. No special radiation safety precautions are required. However, on the basis of ICRP advice, some practitioners suggest that pregnant women and children should remain at arm's length for two days.

V–9.4.2. Contamination

Toilet practices, as well as practices with cutlery, crockery and laundry, are as above for ^{131}I therapy of benign thyroid disease (Section V–1.4), for the first few days.

V–9.5. Emergencies

Advice for emergencies is as above for ^{131}I therapy of benign thyroid disease (Section V–1.5).

V–10. RHENIUM-186 THERAPY FOR PALLIATION OF BONE PAIN

A general reference for this section is Ref. [V–9].

V–10.1. Radionuclide, form and activity

Rhenium-186 or ^{188}Re is in the form of HEDP (hydroxyethylidine diphosphonate). The activity used is in the range 1.2–4 GBq [V–11] for ^{188}Re and is 1.295 GBq [V–19] for ^{186}Re, with up to 15 intravenous injections.

V–10.2. Excretion

Urinary excretion of unbound material occurs in the early period following administration.

V–10.3. Post-discharge issues

The main issue is urinary excretion. When conducted on an outpatient basis, the patient should be kept in hospital until at least one or two post-administration bladder voidings occur. Special arrangements may be required for incontinent patients. The gamma emission from ^{186}Re is not a major concern, especially given the relatively short half-life.

V–10.4. Advice to patients and families

V–10.4.1. External radiation

No special precautions are required.

V–10.4.2. Contamination

Toilet practices, as well as practices with cutlery, crockery and laundry, are as above for ^{131}I therapy of benign thyroid disease (Section V–1.4) until the contamination risk is negligible.

V–10.5. Emergencies

Advice for emergencies is as above for ^{131}I therapy of benign thyroid disease (Section V–1.5).

V–11. RADIATION SYNOVECTOMY

V–11.1. Radionuclides, form and activity

Radiation synovectomy commonly employs three radionuclides: ^{90}Y-silicate/ferric hyroxide/resin colloids (activity 111–185 [V–11] for treatment of knees, typically 185 MBq), ^{186}Re-sulphur colloid (111 MBq ([V–11] for treatment of elbows) and 37–74 MBq) and ^{169}Er-citrate colloid (20–40 and 74 MBq [V–11] for treatment of fingers). This is a developing area, and other nuclides, such as ^{166}Ho-hydroxide macro-aggregates, ^{165}Dy-FHMA and ^{90}Y-FHMA, are also being explored. However, they will not be addressed in detail here. All are administered by intra-articular injection.

Also used are ^{153}Sm [V–11], ^{198}Au and ^{32}P (US Food and Drug Administration approved), with 37 MBq for large joints and 18.5 MBq for small joints.

V–11.2. Excretion

There is no excretion, although, theoretically, leakage from joints into the circulation is possible.

V–11.3. Post-discharge issues

There are, in general, no post-discharge issues.

V–11.4. Advice to patients and families

In general, no advice is required for patients and families.

V–11.5. Emergencies

Advice for emergencies is as above for ^{131}I therapy of benign thyroid disease (Section V–1.5).

V–12. RADIOPEPTIDE THERAPY WITH ^{177}Lu AND ^{90}Y

V–12.1. Radionuclide, form and activity

Lutetium-177 and ^{90}Y are the main radionuclides used for therapy. For therapy, typically around 28 GBq (range: 22.2–29.6) [V–20] spread over three

doses is used with ^{177}Lu and an activity of about 7.4 GBq/m^2 (22.2–29.6 GBq cumulative) is used for ^{90}Y (5.2 GBq/cycle [V–21]). Various pharmaceuticals are employed, mainly analogues of somatostatin.

V–12.2. Excretion

Kidney protection is required because of a high tubular reuptake after glomerular filtration that can lead to a kidney dose of about 20 Gy. Patients remain in hospital for, typically, three days [V–15].

V–12.3. Post-discharge issues

There is no consensus yet available about post-discharge issues.

V–12.4. Advice to patients and families

There is no consensus yet available about advice to patients and families.

V–12.5. Emergencies

Advice for emergencies is as above for ^{131}I therapy of benign thyroid disease (Section V–1.5).

V–13. HOLMIUM-166 DOTMP FOR BONE MARROW THERAPY ABLATION IN MULTIPLE MYELOMA

V–13.1. Radionuclide, form and activity

The half-life of ^{166}Ho is 26.8 days, and treatment is by injection.

Holmium-166 is a beta and gamma emitter, and is used in the form of DOTMP (1,4,7,10-tetra-azcyclododecane-1,4,7,10-tetra-methylene-phosphonate) and EDTMP for multiple myeloma therapy. Ho-HEEDTA (hydroxy-ethylethylene-diamine-triacetic acid) is used for bone marrow, Ho-CHICO (poly-D-glucosamine) for cancer and Ho-PLLA-MSs (poly-L-lactic acid microspheres) for hepatic tumours. The activity used is in the range 19.2–77.7 GBq [V–14].

V–13.2. Excretion

Over 75–80% of the dose is excreted via urine within 24 hours of injection [V–14].

V–13.3. Post-discharge issues

The main post-discharge issue is urinary excretion. The low energy and abundance of gamma rays are such that no special radiation precautions are required.

V–13.4. Advice to patients and families

V–13.4.1. External radiation

No special precautions are required.

V–13.4.2. Contamination

Toilet practices are as above for ^{131}I therapy of benign thyroid disease (Section V–1.4), until the contamination risk is negligible.

V–13.5. Emergencies

Advice for emergencies is as above for ^{131}I therapy of benign thyroid disease (Section V–1.5).

REFERENCES TO ANNEX V

[V–1] ELL, P.J., GAMBHIR, S.S. (Eds), Nuclear Medicine in Clinical Diagnosis and Treatment, Vol. 1, Churchill Livingstone, Edinburgh (2004).

[V–2] MONACO, F., SATTA, M.A., SHAPIRO, B., TRONCONE, L. (Eds), Thyroid Diseases: Clinical Fundamentals and Therapy, CRC Press, Boca Raton, FL (1993).

[V–3] COOPER, D.S. (Ed.), Medical Management of Thyroid Disease, Marcel Dekker, New York (2001).

[V–4] ACKERY, D.M., TRONCONE, L., Chairman's Report: The role of ^{131}I-metaiodobenzylguanidine in the treatment of malignant phaeochromocytoma, J. Nucl. Biol. Med. **34** (1991) 318–320.

[V–5] LAU, W.Y., et al., Adjuvant intra-arterial iodine-131-labelled lipiodol for resectable hepatocellular carcinoma: A prospective randomized trial, Lancet **353** (1999) 797–801.
[V–6] DANCY, J.E., et al., Treatment of non-resectable hepatocellular carcinoma with intrahepatic ^{90}yttrium microspheres, J. Nucl. Med. **41** 10 (2000) 1673–1681.
[V–7] BERK, P.D., et al., Therapeutic recommendations in polycythemia vera based on Polycythemia Vera Study Group protocols, Semin. Hematol. **23** 2 (1986) 132–143.
[V–8] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Release of Patients After Therapy with Unsealed Radionuclides, Publication 94, Elsevier, Oxford (2004).
[V–9] HAN, S.H., et al., The Placohren study: A double-blind, placebo-controlled, randomized radionuclide study with ^{186}Re-editronate in hormone-resistant prostate cancer patients with painful bone metastases, J. Nucl. Med. **43** (2002) 1150–1156.
[V–10] TURNER, J.H., CLARINGBOLD, P.G., A phase II study of treatment of painful multifocal skeletal metastases with single and repeated dose samarium-153 ethylenediaminetetramethylene phosphonate, Eur. J. Cancer **27** 9 (1991) 1084–1086.
[V–11] EUROPEAN ASSOCIATION OF NUCLEAR MEDICINE, Publications Guidelines (2002), http://www.eanm.org/scientific_info/guidelines
[V–12] WALDHERR, C., et al., Radionuclide therapy of somatostatin receptor positive tumours using [^{90}Y]-DOTA-D-Phe^{1}-Tyr^{3}-octreotide: The Basel experience, Bull. Suisse de Cancer **21** (2001) 65–68.
[V–13] KWEKKEBOOM, D.J., et al., Treatment with ^{177}Lu-DOTA-Tyr^{3}-octreotate in patients with somatostatin receptor positive tumors, J. Nucl. Med. **43** (2002) 34P.
[V–14] BAYOUTH, J.E., et al., Pharmacokinetics, dosimetry and toxicity of holmium-166-DOTMP for bone marrow ablation in multiple myeloma, J. Nucl. Med. **36** (1995) 730–737.
[V–15] FRILLING, A., et al., Treatment with (90)Y- and (177)Lu-DOTATAC in patients with metastatic neuroendocrine tumors, Surgery **140** 6 (2006) 968–976.
[V–16] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Management of Radionuclide Therapy Patients, Rep. 155, NCRP, Bethesda, MD (2006).
[V–17] WIKIPEDIA, Squat Toilet (2007), http://en.wikipedia.org/wiki/Squat_toilet
[V–18] LEUNG, W.T., et al., Selective internal radiation therapy with intra-arterial iodine-131-lipiodol in inoperable hepatocellular carcinoma, J. Nucl. Med. **35** (1994) 1313–1318.
[V–19] ZIADA, G., et al., Evaluation of efficacy and toxicity of treatment using Re-186 HEDP in metastatic bone disease, Med. Princ. Pract. **8** (1999) 196–200.
[V–20] KAMPEN, W.U., VOTH, M., PINKERT, J., KRAUSE, A., Therapeutic status of radiosynoviorthesis of the knee with yttrium [^{90}Y] colloid in rheumatoid arthritis and related indications, Rheumatology **46** (2007) 16–24.

[V–21] KWEKKEBOOM, D.J., et al., Overview of results of peptide receptor radionuclide therapy with 3 radiolabeled somatostatin analogs, J. Nucl. Med. **46** (2005) 629–665.

CONTRIBUTORS TO DRAFTING AND REVIEW

Collins, L.	Westmead Hospital, Australia
Cousins, C.	Addenbrooke's Hospital, United Kingdom
Holm, L.E.	International Commission on Radiological Protection
Krisanachinda, A.	Chulalongkorn University, Thailand
Malchair, F.	International Atomic Energy Agency
Malone, J.	St James's Hospital and Trinity College, Ireland
Rehani, M.M.	International Atomic Energy Agency

Members of Committee 3 of the ICRP

APPLYING RADIATION SAFETY STANDARDS IN NUCLEAR MEDICINE
Safety Reports Series No. 40
STI/PUB/1207 (137 pp.; 2005)
ISBN 92–0–111104–5 Price: €28.00

FUNDAMENTAL SAFETY PRINCIPLES
IAEA Safety Standards Series No. SF-1
STI/PUB/1273 (37 pp.; 2006)
ISBN 92–0–110706–4 Price: €25.00

RADIOLOGICAL PROTECTION FOR MEDICAL EXPOSURE TO IONIZING RADIATION
IAEA Safety Standards Series No. RS-G-1.5
STI/PUB/1117 (86 pp.; 2002)
ISBN 92–0–111302–1 Price: €14.50

The pattern of practice throughout the world with regard to the release of patients from hospital after therapies using unsealed radionuclides is quite varied and has not been subject to harmonization. This report is focused on the decision to release the patient and its consequences. It will provide guidelines for national authorities on which to base their regulations and guidance, and will help to resolve the diversity of international practices in this area. Particular attention is paid to the questions most frequently asked by patients.

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA
ISBN 978–92–0–108909–0
ISSN 1020–6450