SAFE HANDLING OF BODIES CONTAINING RADIOACTIVE ISOTOPES

(A Guide for Surgeons, Pathologists, and Funeral Directors)

Handbook 65

U. S. Department of Commerce
National Bureau of Standards

U. S. Department of Commerce • Sinclair Weeks, Secretary
National Bureau of Standards • A. V. Astin, Director

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(A Guide for Surgeons, Pathologists, and Funeral Directors)

Recommendations of the
National Committee on Radiation Protection
and Measurements

National Bureau of Standards Handbook 65
Issued July 10, 1958
(Supersedes Handbook 56)

For sale by the Superintendent of Documents, Washington 25, D. C. - Price 15 cents

Preface

The present Handbook is a modified version of Handbook 56, Safe Handling of Cadavers Containing Radioactive Isotopes, published in 1953. New information and revised permissible dose levels developed since 1953 are taken into consideration. This Handbook provides pertinent information for the guidance of mortuary and medical personnel involved in the handling and autopsy of bodies containing radioactive materials. More general information on radiation protection is available in other NBS Handbooks by the National Committee on Radiation Protection and Measurements.

With the increasing use of radioactive isotopes by industry, the medical profession, and research laboratories, it is essential that certain minimal precautions be taken to protect the user and the public. The recommendations contained in this Handbook represent what is believed to be the best available opinions on the subject as of this date. As our experience with radioisotopes broadens, we will undoubtedly be able to improve and strengthen the recommendations given in this report. In the meantime, comments and suggestions will be welcomed by the committee.

The National Committee on Radiation Protection and Measurements (originally known as the Advisory Committee on X-ray and Radium Protection) was formed in 1929 upon the recommendation of the International Commission on Radiological Protection. The Committee is sponsored by the National Bureau of Standards and governed by representatives of participating organizations. Eighteen subcommittees have been established, each charged with the responsibility of preparing recommendations in its particular field. The reports of the subcommittees are approved by the main committee before publication.

The following parent organizations and individuals comprise the main committee:

American College of Radiology: R. H. Chamberlain and M. D. Schulz.
American Dental Association: R. J. Nelsen.
American Industrial Hygiene Association: E. C. Barnes and J. H. Sterner.
American Medical Association: P. C. Hodges.
American Radium Society: T. P. Eberhard and E. H. Quimby.
American Roentgen Ray Society: T. C. Evans and R. R. Newell.
Atomic Industrial Forum: W. A. McAdams.
Health Physics Society: K. Z. Morgan and J. W. Healy.
International Association of Government Labor Officials: A. C. Blackman and M. Kleinfeld.
National Bureau of Standards: L. S. Taylor, Chairman, and S. W. Raskin, Secretary.

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U. S. Public Health Service: H. L. Andrews and C. Powell.
Representatives-at-large: J. C. Bugher, G. Failla, Shields Warren, J. L. Weatherwax, and E. G. Williams.
Subcommittee Chairmen: see below.

The following are the subcommittees and their chairmen:

Subcommittee 1. Permissible Dose from External Sources.
Subcommittee 2. Permissible Internal Dose, K. Z. Morgan.
Subcommittee 3. X-rays up to Two Million Volts, T. P. Eberhard.
Subcommittee 4. Heavy Particles (Neutrons, Protons, and Heavier), H. H. Rossi.
Subcommittee 5. Electrons, Gamma Rays, and X-rays above Two Million Volts, H. W. Koch.
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Subcommittee 11. Incineration of Radioactive Waste, G. W. Morgan.
Subcommittee 12. Electron Protection, L. S. Skaggs.
Subcommittee 13. Safe Handling of Bodies Containing Radioactive Isotopes, E. H. Quimby.
Subcommittee 14. Permissible Exposure Doses Under Emergency Conditions, L. S. Taylor, Acting Chairman.
Subcommittee M-1. Standards and Measurement of Radioactivity for Radiological Use, W. B. Mann.
Subcommittee M-2. Standards and Measurement of Radiological Exposure Dose, H. O. Wyckoff.
Subcommittee M-3. Standards and Measurement of Absorbed Radiation Dose, H. O. Wyckoff.
Subcommittee M-4. Relative Biological Effectiveness, W. H. Langham.

The present Handbook was prepared by the Subcommittee on Safe Handling of Bodies Containing Radioactive Isotopes. Its membership is as follows:

Edith H. Quimby, Chairman.
S. Feitelberg.
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E. G. Maier, Consultant.

A. V. Astin, *Director.*

Contents

Safe Handling of Bodies Containing Radioactive Isotopes

(A guide for surgeons, pathologists, and funeral directors)

This is one of a series of reports prepared by the National Committee on Radiation Protection and Measurements. The present Handbook is a revision of Handbook 56, Safe Handling of Cadavers Containing Radioactive Isotopes. This revision was prepared in order to include information on additional isotopes used in therapy and encountered in the handling of bodies, and to conform with the lowered maximum permissible radiation levels recently recommended both nationally and internationally.

1. Introduction

In the present state of our knowledge, it is considered wise to avoid all unnecessary irradiation. The human race has developed in a field of natural radiation from cosmic rays and radioactive material in the earth; this may be considered normal. A much higher level of radiation exposure is known to be definitely harmful. Between these two extremes it is assumed that there is a level of exposure that can be tolerated by human beings without expectation of ill effects. When such a level is established, methods can be devised for assuring that it is not exceeded.

The International Commission on Radiological Protection, after study of the great mass of data available on radiation effects, has established permissible levels for occupational and nonoccupational exposure to radiation. The matter is discussed in detail in National Bureau of Standards Handbook 59, Permissible Dose from External Sources of Ionizing Radiation [1] [1], in a modification issued in 1957 [1a], and in internal documents of the NCRP. Because of their application to protection problems of an occasional nature, it seems desirable to repeat parts of the modified statements in the present Handbook. The pertinent material is as follows:

A. For occupational exposure.

The maximum permissible dose to the most critical organs, accumulated at any age, shall not exceed 5 rems multiplied by the number of years beyond age 18, and the dose in any 13 consecutive weeks shall not exceed 3 rems.[2] Thus the accumulated MPD=5 (N–18) rems,

[1] Figures in brackets indicate the literature references on page 19.

[2] The rem is the quantity of any ionizing radiation such that its biological effectiveness is the same as that of 1 rad of intermediate voltage X-rays. It is a unit devised to take account of the greater biological effectiveness of neutron and heavy particle irradiation. For the beta and gamma rays from radioactive isotopes, the number of rems is numerically equal to the number of rads. The rad, the presently accepted unit of absorbed dose of ionizing radiation, is 100 ergs/g. To the accuracy required for protection purposes, the biological effect of 1 rad of beta or gamma radiation is essentially the same as that of 1 roentgen.

where N is the age and greater than 18. This applies to all critical organs except the skin of the whole body, for which the values are double.

For the extremities (hands, forearms, feet, and ankles) the accumulated MPD shall not exceed 75 rems/yr and the dose in any 13 consecutive weeks shall not exceed 25 rems.

Exposure of any part of the body to X-rays resulting from ordinary medical diagnostic procedures need not be included in the radiation tolerance status of the person concerned.

B. For the whole population.

The principle of limiting nonoccupational exposure in the vicinity of radiation sources to 1/10 of the occupational exposure limits will be continued; the 1/10 factor applies to the new average yearly level of 5 rems. Averaging may be done over a period of 1 year taking advantage of workload, use factor, and occupancy factor. This is necessary because outside-controlled areas include inhabited regions where persons might be exposed throughout life. Applying the 1/10th factor to the new permissible average annual dose results in a permissible total accumulated gonad dose of 15 rems in a period of 30 years. This is higher than the average of 10 r recommended by the International Commission on Radiological Protection for the general population, which also includes medical exposure. It is, nevertheless, satisfactory because it applies to the relatively few individuals living closest to a controlled area, and the average for the whole population would be much lower. Obviously an *average* gonad dose for the whole population implies that some persons will get more and others less than the average.

In addition to the above, the following recommendation has been made for internal emitters:

In controlled areas the permissible radiation levels for internal emitters conform as far as possible to the general radiation principles outlined above. Where the critical organ is the gonad or the whole body, the maximum permissible concentrations of radionuclides in air and water will be one-third the values heretofore specified for radiation workers. Where single organs other than the gonads are regarded as the critical organ, the present maximum permissible concentrations will continue. For individuals outside of controlled areas, the maximum permissible concentrations shall be one-tenth of those of occupational exposures.

In the following discussions, the intent is to reduce the occasional exposure concerned with a radioactive body to an average weekly level. However, from the above recommendations it is evident that in the case of an emergency, or even of an important procedure which is not likely to be carried out more often than once in 3 months, there need be no hesitancy in accepting the permissible 13-week levels specified above.

If a patient comes to emergency surgery, or dies, shortly after having received a large internal therapeutic dose of a radioactive isotope, the handling of the body may pose problems of radiation exposure for the surgeon, the pathologist, or the embalmer. It is important for members of these groups to realize the existence and the magnitude of this problem and to know how to meet it. It is equally important not to exaggerate the danger and not to be unreasonably fearful when the hazard is minimal or nonexistent.[3]

2. General Considerations

At the present time, and at least for the next few years, highly radioactive bodies will be encountered rarely. In principle, such therapy is not given to moribund patients. It will be seen below that if a few days intervene between treatment and subsequent surgery or death, the radiation hazard is considerably reduced. In any hospital the number of patients receiving large internal doses of radioisotopes in any one week is small; any institution would seldom have as many as five highly radioactive patients at one time. The need for emergency surgery would not be usual, nor would the death of one of these patients. In a particular hospital, the same pathologist might perform all of the autopsies but it is unlikely that the same embalmer would prepare all the bodies for burial. It is even less likely that a surgeon will perform an appreciable number of operations on patients containing a significant quantity of radioactive material.

The problem should be approached, therefore, as one of relatively rare occurrence, not as something to be expected every week or month. Although calculations and recommendations in the present report are based on the maximum permissible doses for occupational exposure, it should be understood that doses occasionally exceeding these are not expected to be harmful.

It can readily be shown that the permissible exposure will never be reached in handling the body of an individual who has received only a tracer dose of any isotope, such as is likely to be used for diagnostic purposes. In general, high levels of radiation only occur during treatment of malignant diseases. The Advisory Committee on Isotope Distribution of the U. S. Atomic Energy Commission advises that all patients receiving large doses of radioisotopes be hospitalized

[3] There is, of course, no danger from any patient who has been treated by external irradiation with X-rays, radium, or any radioactive substance. No radiation remains in the patient after the treatment is over. It is only when actual radioactive material is present that there can be any problem.

until the isotope content is not more than 30 mc.[4] Accordingly, in cases that die outside the hospital the funeral director should not encounter bodies containing more than 30 mc of a radioactive isotope. It will be shown that if such a body is embalmed without opening, using standard aspiration and injection methods, the hazard is minimal. Furthermore, if the body is to be interred or cremated without embalming, there will be no radiation hazard from the necessary external handling. If, however, such a death comes under the jurisdiction of a Medical Examiner or a Coroner, an autopsy may be performed. The same recommendations should apply as would obtain for a patient who dies in a hospital.

If a patient containing this material dies in the hospital, it is highly probable that an autopsy will be performed. During this procedure the radiation hazard may be significant. However, in such a case, the examination will be carried out in an institution equipped for treatment with large doses of the isotope in question. There will be available an official radiation protection officer (as required by the Isotopes Extension of the Division of Civilian Application of the Atomic Energy Commission) who carries the responsibility for radiological safety throughout his institution; his advice and cooperation are to be counted upon. *If a body contains appreciably more than 5 mc of any radioactive isotope, an autopsy should be done only with the advice of this protection officer.*

A body containing less than 30 mc may be released directly to the funeral director for embalming without the advice of a safety officer.

If emergency surgery is to be performed on a patient who has recently received a therapeutic dose of radioactive material, the risk will depend largely on the relative locations of the isotope and the operative site. An appendectomy done on a patient with a large amount of radioactive iodine in the thyroid gland would present no problem, whereas special precautions would be required if the abdominal cavity were to contain radioactive material.

The identification of a particular patient as radioactive is the responsibility of the doctor in charge of the case. While the patient is in the hospital, a distinctive label should be attached to his chart stating the amount and kind of isotope administered and the time of its administration. Such a label may also be attached to the patient's bed unless this is psychologically undesirable. Many hospitals have such a system already in operation for radium; it can be easily

[4] The millicurie (mc) is that amount of radioactive material in which 37 million atoms disintegrate each second. Therapeutic doses of isotopes are generally in millicurie amounts, tracer doses in microcuries (μc). 1 μc=0.001 mc.

TABLE 1.[a] *Probable radioactive content of body at various times after various doses*

A guide for consideration before autopsy or surgery. For values *below* heavy lines no precautions are necessary except wearing surgical rubber gloves. For values *above* lines, consultation with radiation protection officer is indicated.

Millicuries administered	Days elapsed since administration—										
	1	2	3	4	6	8	10	15	20	25	30
Au^{198} or Y^{90}	Millicuries of isotope remaining in injected cavity or injected tissues, assuming no physiological elimination.										
150	115	90	69	52	32	20	12	3			
125	96	75	58	44	27	16	10	3			
100	77	60	46	35	21	13	8	2			
75	58	45	35	26	16	10	6	2			
50	38	30	23	18	11	7	4	1			
40	31	24	18	14	9	5	3	1			
30	23	18	14	10	6	4	2	1			
20	16	12	9	7	5	3	2	1			
I^{131}	Millicuries of isotope remaining in functioning thyroid tissue or metastases following administration for thyroid ablation or cancer treatment. Assumed 50% uptake and 6-day effective half life. (These doses are maximal; usually residuals will be smaller.)										
200	89	78	71	63	50	40	32	18	10	6	3
150	67	58	53	47	38	30	24	14	8	5	3
125	56	49	44	39	31	25	20	11	6	3	2
100	45	39	36	32	25	20	16	9	5	3	2
80	36	31	28	25	20	16	13	7	4	2	1
60	27	23	21	19	15	12	10	5	3	2	1
50	22	20	18	16	13	10	8	4	2	1	
40	18	16	14	13	10	8	6	3	2		
30	13	12	11	9	8	6	5	3	2		
20	9	8	7	6	5	4	3	2	1		
10	5	4	4	3	3	2	2	1	1		
P^{32}	Millicuries of isotope remaining in injected cavity or injected tissues, assuming no physiological elimination.										
30	29	27	26	25	22	20	18	15	11	10	7
25	24	23	22	21	19	17	15	12	9	8	6
20	19	18	17	16	15	14	12	10	8	7	5
16	15	15	14	13	12	11	10	8	6	5	4
12	11	11	10	10	9	8	7	6	5	4	3
10	10	9	9	8	7	7	6	5	4	3	2
8	8	7	7	7	6	5	5	4	3	3	2
6	6	5	5	5	4	4	4	3	2	2	1
4	4	4	3	3	3	3	2	2	2	1	1

[a] Duplicate copies of the tables are included in the back of this Handbook and may be removed for posting.

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extended to isotopes. The label may be removed when the radioactivity is below 5 mc.

If such a patient dies in the hospital, the doctor who pronounces him dead should attach blank copies of the radioactivity form (see appendix 1, page 19) to the death certificate, to the autopsy permission slip, and to the patient's chart. These forms should be filled in before the body is taken to the hospital morgue. The physician in charge of the case should also be notified at once, in order that he may consult with the radiation protection officer, if he considers it advisable.

Meantime, if the body is taken to the autopsy room, the statement of dose and date of its administration on the radioactivity label enables the pathologist, by reference to table 1 or its equivalent, to decide whether he can commence his examination without waiting for the protection officer. The alternative to the use of such a table is to summon the protection officer for any death occurring within 2 weeks following the administration of a therapeutic dose of a radioactive isotope.

If a radioactive patient requires an emergency operation, the attending physician or the resident should inform the surgeon of the date of isotope therapy, the amount of radioactive material administered, and its location. If the isotope is concentrated in a region which will not be opened by the surgeon, the operation may be carried out forthwith. If as much as 100 mc of radioactive iodine has been administered less than 24 hr previously, there may still be an appreciable amount of the isotope generally distributed throughout the body fluids, and every effort should be made to delay surgery at least until the 24-hr period has elapsed. If the cavity to be opened contains appreciably more than 5 mc of an isotope, as ascertained from the patient's history and table 1, the same precautions should be observed as for autopsy.

3. Analysis of Extreme Cases

Precautions to be taken depend on the nature and quantity of the isotope present, and on whether it is a question of simple embalming for burial or cremation, or whether autopsy or surgery is to be performed. It will be shown below that, in general, no appreciable hazard exists unless the body is to be opened. The surgeon or the pathologist may then have to work in the contaminated cavity, so that his hands may receive considerable radiation. Furthermore, if the cavity is widely opened, his face may be also exposed. The length of time which should be allowed for carrying out

procedures depends on the radiation dose rate. A method of dosage calculation which may be applied to any isotope is outlined in appendix 2. Results of such calculations, for specific problems, are discussed below.

3.1. Preparation for Burial or Cremation without Autopsy

Consider first the cases in which no autopsy is to be performed, and the body need not be opened. Embalming will be by the injection method, and the likelihood of contamination is small. Nevertheless, even in these cases, rubber gloves should be worn by all who are involved in the procedures, in order to avoid the possibility of contamination by radioactive fluids from the body.

a. Radioactive Gold, Au^{198}, in Body Cavity

A few hours after a patient has received 150 mc of Au^{198} in the abdominal cavity,[5] an ionization-chamber type survey meter placed close to the overlying surface shows a dose rate of about 1.5 r/hr; the rate is very much less at the shoulders and extremities. At 50 cm from the abdomen, which is the distance of much of the body of the operator, the observed rate is approximately one-tenth that found at the close position. The distribution of activity does not change appreciably with time, but its intensity decreases by about 25 percent in every 24 hr, because of radioactive decay.

If the embalming procedure can be carried out in 2 hr, without opening the body, anyone standing very close to it for the entire time would receive only a small fraction of the permissible dose. It may be noted that a man standing close to the abdominal region of the body would receive a dose to his gonads somewhat higher than the average to his entire person; under the extreme conditions here discussed the absorbed dose rate might be as much as 0.3 rads/hr at the start of the procedure. However, before much time had elapsed the ascitic fluid would have been removed (see below) and the dose rates close to the body correspondingly lowered.[6] Thus it appears that under average condi-

[5] This is the largest dose likely to be administered. Intracavitary gold is also employed in treatment of pleural effusion due to cancer, but the dose is not as large as this.

[6] The suggestion is sometimes made that a fluoroscopic lead-rubber apron would give considerable protection during these procedures. Actually the gamma rays are much more penetrating than the diagnostic X-rays for which the aprons were designed. The standard apron would reduce the gamma-ray dose rate by only about 10 percent and hence would serve no useful purpose.

tions, several bodies could be embalmed each week without exceeding the permissible exposure.

If ascitic or pleural fluid is to be removed in the embalming process, it must be noted that this may contain a significant fraction of the radioactive material. Unless other instructions are given by the radiation protection officer, fluid should be removed from the body by means of a trocar and tubing, into a closed system, with suction if necessary. The trocar should be fixed to the body in such a manner that it is not necessary for anyone to hold the trocar or the tube while the fluid is being withdrawn. At the completion of the drainage, the fluid can be disposed of directly into the sewer, followed by a large volume of water. If an aliquot of the fluid is to be saved for any purpose the sample should be taken by means of a remote control pipette or other device, and placed in such a shielded container as may be recommended by the protection officer. There will be no appreciable activity in the blood or urine, and these may be disposed of without special precautions.

b. Any Isotope in Body Cavity; No Autopsy

Any beta-ray emitter deposited in a body cavity will deliver only insignificant radiation outside the body, as long as the cavity is not opened. With a practical dose of any gamma-ray emitter, the radiation from the unopened body will not greatly exceed that from gold-198. When colloidal preparations of any isotope are injected into body cavities, a considerable part of the active material flocculates out and settles on the serous surfaces. However, some may remain in the fluid. The same precautions for its removal should be followed as those outlined in the preceding paragraph.

c. Radioactive I ne, I^{131}, Orally or Intravenously

The dose of I^{131} administered in the treatment of thyroid cancer rarely exceeds 100 mc. Within an hour after a patient has received this dose, measurements with an ionization-chamber type of survey meter indicate a surface dose rate over the abdomen of the order of 0.3 r/hr. The isotope is circulating freely throughout the body, and no part will be more active than the abdomen; but shoulders and legs will be more active than in the case of the body with the same amount of radioactive gold. Again at a distance of 50 cm the exposure is reduced to about one-tenth of that close to

the surface. With these cases, accordingly, there is no risk from the unopened body.

During the first 24 hr after administration of I^{131}, the blood and urine may contain a good deal of radioactivity. These fluids should accordingly be removed into closed systems, (as recommended for the ascitic fluid in the preceding section) and later flushed directly into the sewer, followed by an adequate volume of water [2].

A day after administration, the general distribution of radiation is greatly reduced, both by urinary excretion of a large part of the isotope, and by concentration of the remaining part in functioning thyroid tissue. At this time only radiation from these regions of iodine storage need be considered. If as much as 50 mc is concentrated in a thyroid gland or metastasis (which is more than the amount usually to be expected even with very large initial doses), the dose rate directly over this site may be as much as 25 r/hr; at 10 cm this would be reduced to about 1 r/hr, and at 50 cm to 0.04 r/hr. Thus with an average distance of the order of 50 cm from most parts of the body of the embalmer, there would be no radiation hazard from general handling of the body. Any region of high activity should be marked by the protection officer, so that it can be avoided. The embalmer may, however, spend 20 to 30 min working on the face. If the average distance from the gland to the fingers is about 10 cm (about 4 in.), this would mean that the fingers might receive 500 millirads. This is only one-third of the average weekly dose for hands (1.5 rads).

d. Any Isotope Injected Interstitially or in "Seeds"; No Autopsy

Various colloidal isotope preparations may be injected interstitially into tumors. Radon seeds, radioactive gold wires, yttrium pellets, and other preparations may be implanted in limited regions. If the isotope emits only beta rays, it is unlikely that there will be any appreciable external irradiation. If it is a gamma emitter, the region can be identified and avoided, as discussed above for local I^{131} deposits.

From the above sections, it is evident that a body containing as large an amount of any isotope as is currently administered presents no radiation hazard if the body is embalmed by injection procedures alone and fluids handled as indicated. In other words, the permissible dose to the entire person of the embalmer would not be exceeded under conditions likely to be encountered when the body is not opened, even if several such cases were handled every week.

3.2. Body to be Opened for Surgery or Autopsy

As long as the body remains unopened, the radiation received by anyone near it is due almost entirely to gamma rays, and the dose rate remains low. Information concerning radiation to the whole body and to the gonads, presented in the previous section, also applies here. The change in emphasis when autopsy or an operation is to be performed is due to the exposure of the hands and face to relatively intense beta radiation. When the organs and serous surfaces are exposed, the beta radiation previously absorbed by the superficial tissues can reach the pathologist or the surgeon as he dissects out the organs. This radiation will not penetrate more than a few millimeters into the body; it may constitute a hazard for the skin and the eyes. It is readily absorbed by material interposed between its source and the operator.

Even rubber gloves are useful in this regard. Double thicknesses of surgical gloves reduce the beta radiation from I^{131} or Au^{198} to about one-third, and double thicknesses of heavy rubber autopsy gloves reduce it to about one-sixth of the unshielded value. Rubber gloves would not be as effective against the more penetrating rays of P^{32} or Y^{90}, but would still be worthwhile. The gamma rays are not absorbed appreciably by rubber gloves.

In the following sections, suggestions are given for avoiding undesirable exposure to radiation during autopsy or surgery. In addition, the usual precautions for preventing the spread of infectious material should aid in keeping the radioactive material localized. However, the usual techniques for carrying out surgery or autopsy may have to be considerably modified, due to the additional hazard of the radiation. The general principle is to remove the main source of radiation hazard as early as possible, without causing general contamination. If this cannot be done, regions of high activity should be avoided or shielded.

If a cavity contains a large amount of radioactive material, it may be advisable to cover all except the immediate working area with a plastic shield about 4-mm thick. It is especially important that such a shield be interposed between the eyes and the working area, or that goggles or glasses should be worn, to prevent an accidental splash into the eye. Motorcycle or similar goggles are satisfactory.

An analysis of autopsy or surgical procedures on very radioactive patients will indicate particular details. Because it is not possible to have prior accurate information regarding dose rate levels within the body, in every hospital where there is a possibility of the need for special procedures, the radiation protection officer should be responsible for the safety of operators during the entire procedure. For autopsy, if the body is assumed to contain 5 mc or more of radioactive isotope, it should not be opened until the protection officer or his deputy is present. The protection officer should evaluate the radiation hazard and suggest suitable procedures. (Data in tables 1, 2, and 3, pages 5 and 14, will be helpful.) If the radiation level is very high, the use of a team to alternate during the autopsy may be desirable.

It should be pointed out that any delay that can be interposed between death and autopsy reduces the radiation levels by the natural decay of the radioactive material. In the case of P^{32} or I^{131} the daily decrease is small, but for Y^{90} and Au^{198} it is considerable.

If a surgical procedure is truly an emergency, little or no delay is possible. Moreover at night or over a weekend the radiation protection officer may not be immediately available. However, he usually has a deputy (possibly a resident in radiology) who should be helpful. If there is reason to believe that the radiation dose will be high, some arrangement should be made whereby members of the surgical team share the part of the operation involving the greatest exposure.

a. Radioactive Gold, Au^{198}, in Abdominal or Chest Cavity

(1) *Autopsy.* If a patient comes to autopsy after having received a dose of Au^{198} into a body cavity, probably a considerable amount will have deposited on the serous surfaces, the remainder being in the cavity fluid. As much as possible of this fluid should be removed before the body is opened. This is best done by means of a suction apparatus; the material is collected in the jar or trap, and can either be saved or washed down the drain in accordance with the instructions of the radiation protection officer. When the cavity is opened, the remaining fluid should be soaked up in sponges held in long forceps. These can be deposited in a waste container for the attention of the protection officer. It will then be unlikely that dangerous contamination of the exterior of the body, or of those handling it, will occur.

The remaining radioactive material is widely distributed over the surfaces of the cavity and of the organs within it. It is difficult to make any estimate of radiation rates. Even assuming uniform distribution over all serous surfaces, the folds and convolutions of these surfaces distort the picture.

As had been stated, an approximate method of evaluating dose rates is outlined in appendix 2. On this basis, for 100 mc of Au^{198} residual in the cavity, the beta-ray dose rate to the bare hands at any point inside would be about 60 r/hr, and the gamma about 4 r/hr. Double heavy autopsy gloves (100 mg/cm^2) would reduce the beta dose rate to about 10 r/hr, so that the total dose rate would be about 14 r/hr. The average weekly dose to the hands being 1.5 rads, the heavily gloved hands could work in this cavity 6 min and remain within the limits of the permissible dose. If the procedure is considered to be one that will seldom occur, the exposure could be as large as 25 rems provided the 13-consecutive-week exposure is not exceeded. For smaller quantities of Au^{198}, permissible exposure times are proportionately longer.

The use of heavy gloves may reduce digital sensitivity and dexterity; thus the removal of organs may take longer than with surgical gloves alone, and manipulation depending on delicate sense of touch may not be possible. If the hands are in the cavity not more than 10 min, double surgical gloves may be sufficient. The use of bare hands should never be tolerated because of contamination of skin and nails and difficulty of complete removal of such contamination. When a staff of well-trained pathologists is available, it may be preferable to set up a team to work in relays on such a procedure as the one just outlined. If each of three men could work for 10 min, obviously a more careful job could be done than if only one man could work for this period. In any case, autopsies on radioactive bodies should be performed by a senior pathologist or one having experience with isotopes.

Monitoring the body after removal of the viscera may indicate a radiation level low enough so that subsequent procedures can be carried out safely. Regions of high activity, if present, can be indicated and avoided or approached with precautions.

If the removed organs are to be dissected immediately, each one should be monitored and treated in accordance with the findings. It will be expected that everything in the abdominal cavity will be radioactive (since the Au^{198} was put into this cavity). Other tissues should not be active, unless they have become contaminated during the procedure. Dissection of active material should be carried out with long forceps (8 in.) and with long-handled scissors. Rubber gloves should always be worn. When possible, separate organs should be promptly removed from the main mass,

and detailed dissection carried out a few feet away. After desired small samples have been taken, the active tissues that are to be retained should be immediately placed in heavy crocks or glass jars for storage or for disposal according to procedures approved by the radiation protection officer.

In the modern hospital where adequate cold storage facilities are available, organs may be stored for several days without gross pathologic alternations, or the viscera may be fixed. Thus, to take advantage of radioactive decay, the usual order of the autopsy may be altered, permitting finer dissections after a period of such cold storage or fixation. Blocks of tissue for microscopic work may be taken immediately for prompt fixation, with handling precautions as noted in the following sections.

(2) *Emergency Surgery.* If surgery must be carried out within a highly radioactive cavity, speed is essential. Accordingly an experienced surgeon should perform the operation. Since such an occurrence will be very rare, and is unavoidable, the surgeon's exposure may be set at the 13-week permissible dose for long-time occupational exposure. With 100 mc of Au^{198} residual in the abdominal cavity of the patient, the surgeon's gloved hands, while within this cavity, would be exposed to a dose rate of the order of about 40 r/hr. Thus, in about one-half hour, the hands would receive the 13-week permissible dose. It has been noted that this is acceptable for an exposure which will occur only very seldom. It is unlikely that the surgeon's hands will be actually within the active cavity for this length of time during emergency surgery. The time the hands are outside the cavity is much less important. Glasses or goggles should be worn by the surgeon and his assistants for the protection of the eyes.

b. Any Radioactive Isotope in a Body Cavity

The procedures outlined above for radioactive gold apply to any radioactive colloidal preparation in a body cavity. The isotopes currently used (1958) in this manner are Y^{90}, Au^{198}, and P^{32} (as $CrP^{32}O_4$). The first two have much shorter half-lives than P^{32}, about 2.7 days as compared to 14.3 days. Thus, there may be hazard for 1 or 2 weeks for the first two, while for phosphorus the hazard may persist for a month or more. However, the doses of phosphorus usually employed are much less than those for the shorter-lived isotopes, so that the quantity of isotope present will usually be less.

The dose rates to the hands in the cavity per hour per millicurie given in table 2 are computed according to the method given in the appendix for the beta-ray dose rates, with additional consideration of the gamma radiation for gold.

Using the data of table 2 it is possible to calculate the time during which the hands in the peritoneal cavity would receive the average weekly dose. This information is given in table 3.

TABLE 2. *Radiation dose in rads per millicurie per hour to hands in peritoneal cavity*

Isotope	No gloves	Single surgical gloves	Double autopsy gloves
	Rads/mc/hr	*Rads/mc/hr*	*Rads/mc/hr*
[a] Au^{198}	0.7	0.4	0.1
[b] P^{32} or Y^{90}	.8	.5	.3

[a] The Au^{198} values include a factor for the gamma rays.
[b] The same values are given for P^{32} and for Y^{90}. These values would also be good for any other beta-ray emitter whose radiation energies were 1.5 Mev or greater. For beta radiation of less energy, doses will be markedly less, especially when gloves are used.

TABLE 3. *Approximate time* [a] *for hands in peritoneal cavity to receive 1.5 rads* [b]

Total activity on surface	Au^{198}		P^{32} or Y^{90}	
	Single surgical gloves	Double autopsy gloves	Single surgical gloves	Double autopsy gloves
mc	*min*	*min*	*min*	*min*
10	21	64	17	32
20	11	32	8	17
30	7	21	6	11
40	5	16	4	8
50	4	13	3	6
60	4	11	3	5
70	3	9	2	5
80	3	8	2	4
90	2	7	2	4
100	2	6	2	3

[a] Times in this table are given to the nearest minute.
[b] Twenty-five rems is permissible if the procedure is not expected to occur oftener than once in any 13 consecutive weeks, and no other exposure is to be received in this period.

c. Radioactive Iodine, I^{131}, Orally or Intravenously

During the first day after administration of I^{131}, radioactivity is distributed unevenly throughout the body. If a large dose has been given, autopsy procedure should be on a basis of step-by-step monitoring, as in the case of Au^{198} just discussed. Urine should be drained away, and blood disposed of, if possible, in the same manner as if no autopsy were to be performed (see section 3.1). Surgery should be postponed for a day if possible.

After the first day, excretion has greatly decreased the total activity and any regions of high activity can be identified and either avoided or removed with suitable precautions. Adequate precautions include shielding the specimen with a towel or gauze, and using forceps for handling.

After these very active tissues have been removed from the body, their further dissection for study should be carried out rapidly, with the same precautions as described in the case of Au^{198} above, or else this procedure should be postponed to allow for radioactive decay. The residue should be deposited in heavy jars or crocks for storage (see below).

d. Interstitial Implants and Colloidal Interstitial Infiltration

As stated in section 2, radioactive colloids are injected interstitially into localized malignant growths, and radioactive seeds, wires, and pellets are also implanted and left permanently in place. At autopsy or surgery these regions can readily be identified and either avoided or removed. If the entire block of tissue containing the radioisotope can readily be removed, this should be done first. The rest of the autopsy can then proceed as usual. If only a sample of the treated region is to be taken, this part of the body should be avoided until the rest of the autopsy has been carried out. Once the radioactive region is entered, monitoring precautions should be used thereafter, to control both exposure and contamination.

When small specimens have been taken from the removed portions and put into bottles, they can probably be handled without special precautions. However, actual contact with even the small specimens should be avoided if the concentration of the isotope is estimated to be more than 100 $\mu c/g$ of the tissue. Wearing gloves and using forceps and knives that keep the fingers 5 cm or more from the tissue should give adequate protection. If the monitor shows less than 20 mr/hr in close proximity to the specimen, its radioactivity may be ignored during further work with it. The rest of the tissue to be retained should be put in containers, covered with preservative, and stored until radioactive decay permits safe handling. Each jar should carry a label giving the following information:

Date.
Name and hospital number of patient.
Isotope and radiation level at stated date.
Date when radiation level will be below permissible level for disposal, or handling without precautions.[7]

After 3 weeks, the residue from any Au^{198} or Y^{90} patient can be considered inactive (8 half-lives; reduction to less than 0.4 percent). For I^{131} the corresponding period is 2 months, and for P^{32}, 4 months.

Following removal of active foci, the general body level of radiation should be very low. When this level has been reduced below 20 mr/hr, no extra precautions are necessary except the wearing of rubber gloves.

When the body is released to the funeral director, it should be accompanied by a radioactivity form stating the activity level and pointing out any necessary precautions. An acceptable form is given in appendix 1. A copy of this form should also be attached to the deceased patient's chart.

It is recommended that, if the radioactivity is above the level of 30 mc, the funeral director embalm the body in the hospital morgue, with the advice of the hospital radiation protection officer.

4. Accident or Injury During Surgery or Autopsy

In case of an injury occurring during surgery or autopsy, where the rubber gloves are cut or torn and radioactive material may be introduced into the wound, the gloves should be removed, and the wound washed with large quantities of running water, the edges being spread to facilitate flushing action [3]. The radiation protection officer should be notified at once, and should check for residual contamination sufficient to warrant special decontamination measures.

[7] Disposal of such material will be by incineration. A handbook on such disposal is in preparation [4]. In the interim, it is considered safe to incinerate a specimen containing 100 μc of any isotope under consideration here.

5. Contaminated Clothing or Instruments

Clothing and instruments that become contaminated during surgery or autopsy require special handling. If practicable, they should be turned over directly to the radiation protection officer, to be returned after decontamination. However, low-level contamination can be removed by personnel themselves, following the instructions in the pertinent sections of National Bureau of Standards Handbook 48 [3].[8] The instruments can usually be brought to a safe level by soaking them with soap or a detergent, rinsing them well in running water, and repeating these steps if necessary. Gloves should be thoroughly washed before being removed from the hands. If contamination persists, the gloves may be soaked and rinsed again, and if necessary, they may be stored when dry in a location approved by the radiation protection officer, until the radioactivity has decayed to a safe level.

Gowns, towels, etc., should be monitored, and if activity is above the permissible levels cited in the NBS Handbook 48 [3], they should be stored for suitable decay before being sent to the laundry. With these articles, as with gloves, soaking with soap or detergent will frequently bring the activity to a low level. In this procedure, of course, the hands should not be used either to agitate the articles or to wring them out. A simple hand wringer will be serviceable if such a procedure is decided upon. Disposable waste (rags, wipes, etc.) should be collected in approved garbage bags and disposed of in accordance with instructions of the radiation protection officer.

Special care should be taken to prevent the floor of the operating room or autopsy room from being contaminated. Such contamination is inevitably transferred to the shoes, and thereby spread all over the institution. In addition, the floors of autopsy rooms are often of rough concrete or other material that is difficult to decontaminate, and flushing or scrubbing them with water may only spread the contamination. Therefore, great care should be taken that all body fluids are properly discharged down the drain. In case of accidental overflow, the fluid should immediately be taken up as completely as possible with dry disposable waste, held in tongs or forceps, and put promptly into a suitable receptacle.

[8] This Handbook should be in the hands of every isotope user. It is not necessary to quote large sections of it here.

6. Cremation

If the body is to be cremated without autopsy or embalming, there will be no preliminary preparation, and no handling precautions are necessary before the body is brought to the crematorium. If previous embalming is to be carried out, or if autopsy is to be performed, the procedures are the same as those discussed earlier.

In modern crematories, by a combination of high temperature and forced draft, all soft parts of the body are completely disposed of as smoke or very finely divided ash; at the end of the process only the bone ash remains on the tray. Therefore two types of hazards need to be considered: (1) that to the general population in the vicinity of a crematorium, from radioactivity emitted with the stack gases, and (2) that to crematorium employees from inhalation of dust while handling radioactive ashes.

It is possible to calculate the amount of radioactive materials in bodies cremated during 1 yr, which would keep the radiation exposure to the general population and to crematorium workers within the limits considered permissible for outside-controlled areas. Such calculations are based on a variety of factors, some of which are volatility of various isotopes, dilution by combustion gases, dilution of these gases in the atmosphere, proximity of dwellings to the stack top, average wind velocity in the country over a year, concentration of ash in air during ash handling, and time required to collect the ashes. These factors are considered in detail and relevant calculations carried out in a forthcoming Handbook [4] dealing with the incineration of radioactive materials.

On a basis of these calculations it is found that no radiation hazard would exist if each crematorium were to handle in a year a number of bodies containing an over-all total of not more than 200 mc of I^{131}, and 2,000 mc of all other isotopes discussed in this Handbook. It is recommended that each crematorium keep records of the type and amount of radioactivity in all bodies received containing such material. If there is any possibility that a crematorium might exceed the specified annual isotope load, a radiation protection expert should be consulted.

At the present or any contemplated rate of utilization of radioisotopes for therapeutic purposes, it is unlikely that any crematorium would exceed this annual cremation rate for these materials; there is, therefore, no need to establish additional general regulations for the cremation of bodies at the present time.

7. References

[1] National Bureau of Standards Handbook 59, Permissible dose from external sources of ionizing radiation. Recommendation of NCRP (1954).

[1a] Maximum permissible radiation exposures to man, A preliminary report of the National Committee on Radiation Protection and Measurements, Radiology **68**, 260, (1957); Am. J. Roentgenol., Radium Therapy and Nuclear Med. **77**, 910 (1957).

[2] National Bureau of Standards Handbook 49, Recommendations for waste disposal of phosphorus-32 and iodine-131 for medical users. Recommendation of NCRP (1951).

[3] National Bureau of Standards Handbook 48, Control and removal of radioactive contamination in laboratories. Recommendation of NCRP (1951).

[4] National Bureau of Standards Handbook; Incineration of radioactive wastes, Recommendation of NCRP (in preparation).

[5] R. J. Walton, and W. K. Sinclair, Intracavitary irradiation with radioactive colloidal gold in the palliative treatment of malignant pleural and peritoneal effusions, Brit. Med. Bull. **8**, 165 (1952).

[6] R. Loevinger, E. M. Japha, and G. L. Brownell, Discrete radioisotope sources, Ch. 16, Radiation Dosimetry (Brownell and Hine, Academic Press, Inc., New York, 1956).

Appendix 1. An Acceptable Form for Radioactivity Report Accompanying Body

[NAME OF HOSPITAL]

REPORT ON RADIOACTIVITY TO FUNERAL DIRECTOR FROM RADIATION PROTECTION OFFICER OR DELEGATE

☐ This body contains less than 30 mc of radioactive material. No special precautions are required if only standard embalming procedures are employed.

☐ This body contains more than 30 mc of radioactive material. The following precautions are recommended:

____

____

____

Signed ________________

Date ________________

Appendix 2. Method of Dosage Calculation

The calculation of dose from beta particles is complicated by their low penetration and the consequent necessity for accurate geometrical description. In cases considered in this Handbook, gamma radiation in amounts requiring protection precautions is emitted only by radioactive gold and radioactive iodine and for dosage considerations a correction factor can be employed. Accordingly it is recognized that dose rates presented in table 2 and repeated here are only approximate. They are, however, adequate for the problems considered.

After withdrawal of fluid, a distribution of an isotope on the surfaces of a body cavity and its viscera is assumed to be uniform. The dose received by the hands is computed from formulas relating a dose at any depth in tissue to the surface density of radioactivity. If the cavity is fully opened, the dose to the face of the operator is nearly the same as that to the hands, because the distance from the face to the cavity is comparable to the dimensions of the opened cavity.

The surface area of the peritoneal cavity has been taken to be 10,000 cm^2 [5]. Thus if 1 mc remains in this cavity after the removal of the fluid, the total surface density of radioactivity is 0.1 $\mu c/cm^2$. For the pleural cavity, where the surface area is only one-third as great, the same residual radioactivity would give a surface density of 0.3 $\mu c/cm^2$.

When the surface density of radioactivity and the beta spectrum of the isotope are known, the calculation of the dose at any depth below a plane surface can be accomplished by using an equation derived by Loevinger [6]. For the unprotected hands, the dose rates given in the text and tables are computed at a point 0.1 mm (10 mg/cm^2) below the surface of the skin. The depth is taken as 30 mg/cm^2 for one thickness of surgical gloves, and 100 mg/cm^2 for two thicknesses of autopsy gloves.

Submitted for the National Committee on Radiation Protection and Measurements.

LAURISTON S. TAYLOR, *Chairman.*

WASHINGTON, November 15, 1957.

U. S. GOVERNMENT PRINTING OFFICE: 1958

TABLE 1.[a] *Probable radioactive content of body at various times after various doses*

A guide for consideration before autopsy or surgery. For values *below* heavy lines no precautions are necessary except wearing surgical rubber gloves. For values *above* lines, consultation with radiation protection officer is indicated.

Millicuries administered	Days elapsed since administration—										
	1	2	3	4	6	8	10	15	20	25	30
Au^{198} or Y^{90}	Millicuries of isotope remaining in injected cavity or injected tissues, assuming no physiological elimination.										
150	115	90	69	52	32	20	12	3			
125	96	75	58	44	27	16	10	3			
100	77	60	46	35	21	13	8	2			
75	58	45	35	26	16	10	6	2			
50	38	30	23	18	11	7	4	1			
40	31	24	18	14	9	5	3	1			
30	23	18	14	10	6	4	2	1			
20	16	12	9	7	5	3	2	1			
I^{131}	Millicuries of isotope remaining in functioning thyroid tissue or metastases following administration for thyroid ablation or cancer treatment. Assumed 50% uptake and 6-day effective half life. (These doses are maximal; usually residuals will be smaller.)										
200	89	78	71	63	50	40	32	18	10	6	3
150	67	58	53	47	38	30	24	14	8	5	3
125	56	49	44	39	31	25	20	11	6	3	2
100	45	39	36	32	25	20	16	9	5	3	2
80	36	31	28	25	20	16	13	7	4	2	1
60	27	23	21	19	15	12	10	5	3	2	1
50	22	20	18	16	13	10	8	4	2	1	
40	18	16	14	13	10	8	6	3	2		
30	13	12	11	9	8	6	5	3	2		
20	9	8	7	6	5	4	3	2	1		
10	5	4	4	3	3	2	2	1	1		
P^{32}	Millicuries of isotope remaining in injected cavity or injected tissues, assuming no physiological elimination.										
30	29	27	26	25	22	20	18	15	11	10	7
25	24	23	22	21	19	17	15	12	9	8	6
20	19	18	17	16	15	14	12	10	8	7	5
16	15	15	14	13	12	11	10	8	6	5	4
12	11	11	10	10	9	8	7	6	5	4	3
10	10	9	9	8	7	7	6	5	4	3	2
8	8	7	7	7	6	5	5	4	3	3	2
6	6	5	5	5	4	4	4	3	2	2	1
4	4	4	3	3	3	3	2	2	2	1	1

[a] Reprinted from NBS Handbook 65, Safe Handling of Bodies Containing Radioactive Isotopes (A Guide for Surgeons, Pathologists, and Funeral Directors), dated May 1958.

TABLE 2.[c] *Radiation dose in rads per millicurie per hour to hands in peritoneal cavity*

Isotope	No gloves	Single surgical gloves	Double autopsy gloves
	Rads/mc/hr	*Rads/mc/hr*	*Rads/mc/hr*
[a] Au^{198}	0.7	0.4	0.1
[b] P^{32} or Y^{90}	.8	.5	.3

[a] The Au^{198} values include a factor for the gamma rays.
[b] The same values are given for P^{32} and for Y^{90}. These values would also be good for any other beta-ray emitter whose radiation energies were 1.5 Mev or greater. For beta radiation of less energy, doses will be markedly less, especially when gloves are used.
[c] Reprinted from NBS Handbook 65, Safe Handling of Bodies Containing Radioactive Isotopes (A Guide for Surgeons, Pathologists, and Funeral Directors), dated May 1958.

TABLE 3.[c] *Approximate time*[a] *for hands in peritoneal cavity to receive 1.5 rads*[b]

Total activity on surface	Au^{198}		P^{32} or Y^{90}	
	Single surgical gloves	Double autopsy gloves	Single surgical gloves	Double autopsy gloves
mc	*min*	*min*	*min*	*min*
10	21	64	17	32
20	11	32	8	17
30	7	21	6	11
40	5	16	4	8
50	4	13	3	6
60	4	11	3	5
70	3	9	2	5
80	3	8	2	4
90	2	7	2	4
100	2	6	2	3

[a] Times in this table are given to the nearest minute.
[b] Twenty-five rems is permissible if the procedure is not expected to occur oftener than once in any 13 consecutive weeks, and no other exposure is to be received in this period.
[c] Reprinted from NBS Handbook 65, Safe Handling of Bodies Containing Radioactive Isotopes (A Guide for Surgeons, Pathologists, and Funeral Directors), dated May 1958.