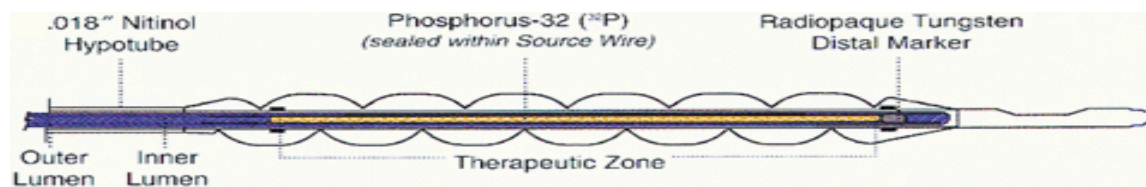


Radiation Safety of Brachytherapy and Unsealed Source Therapies



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Brachytherapy

Brachytherapy literally means “short” therapy, as treatments are delivered over an abbreviated time span compared to other types of radiation therapy.

There are two types: Low Dose Rate (L.D.R.) and High Dose Rate (H.D.R.)

There are two modes: Temporary and Permanent

There are intracavitary insertions, interstitial, endobronchial, and endovascular applications

Brachytherapy deals with the treatment of malignant and benign conditions with small sealed sources of radioactive material

Permanent Implant Examples

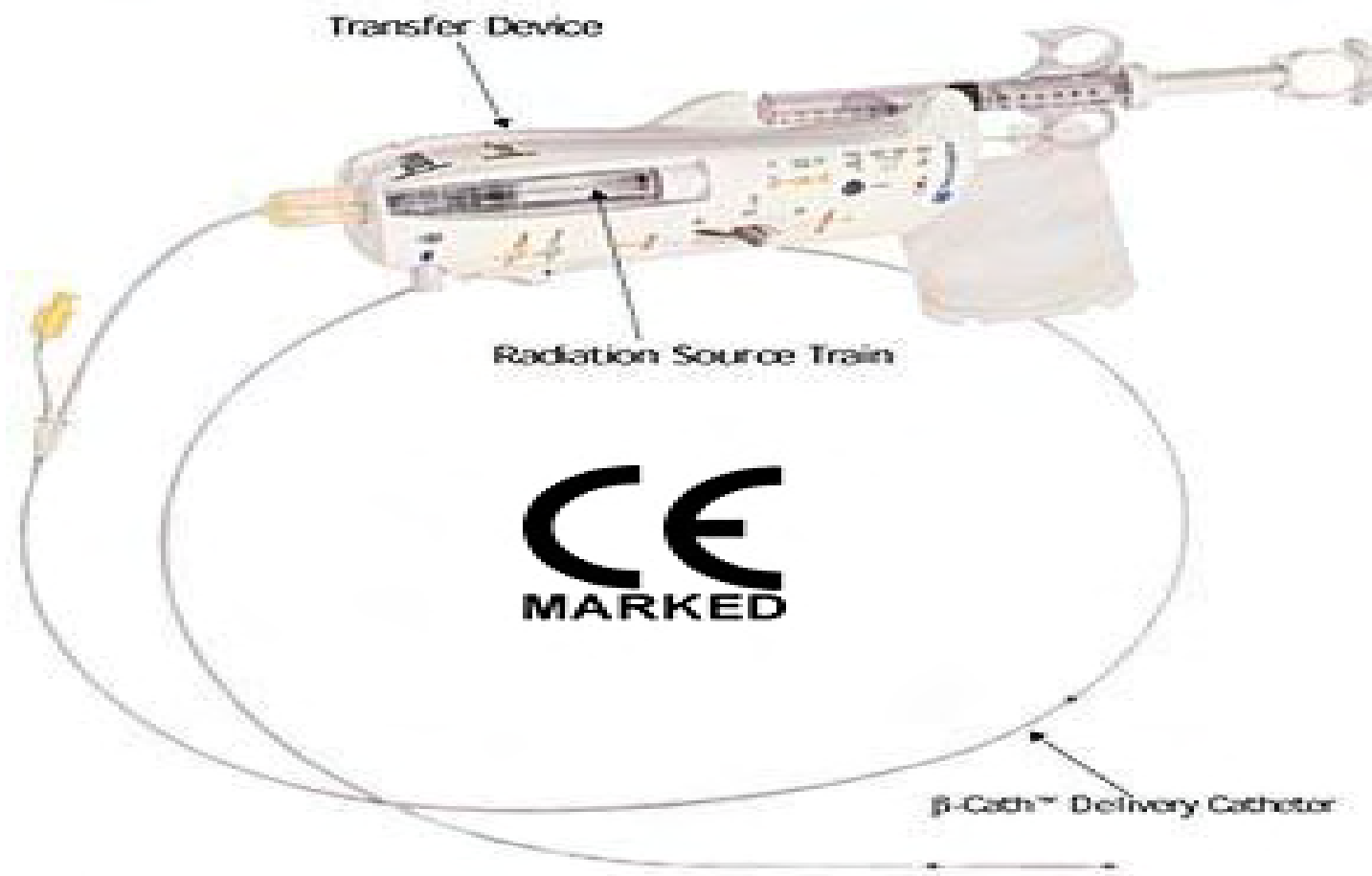
Historically, Radon Rn-222 and Gold Au-198 seeds were used

Pd-103 or I-125 seeds about (5 mm x 1 mm) are now placed in a patient to treat prostate cancer

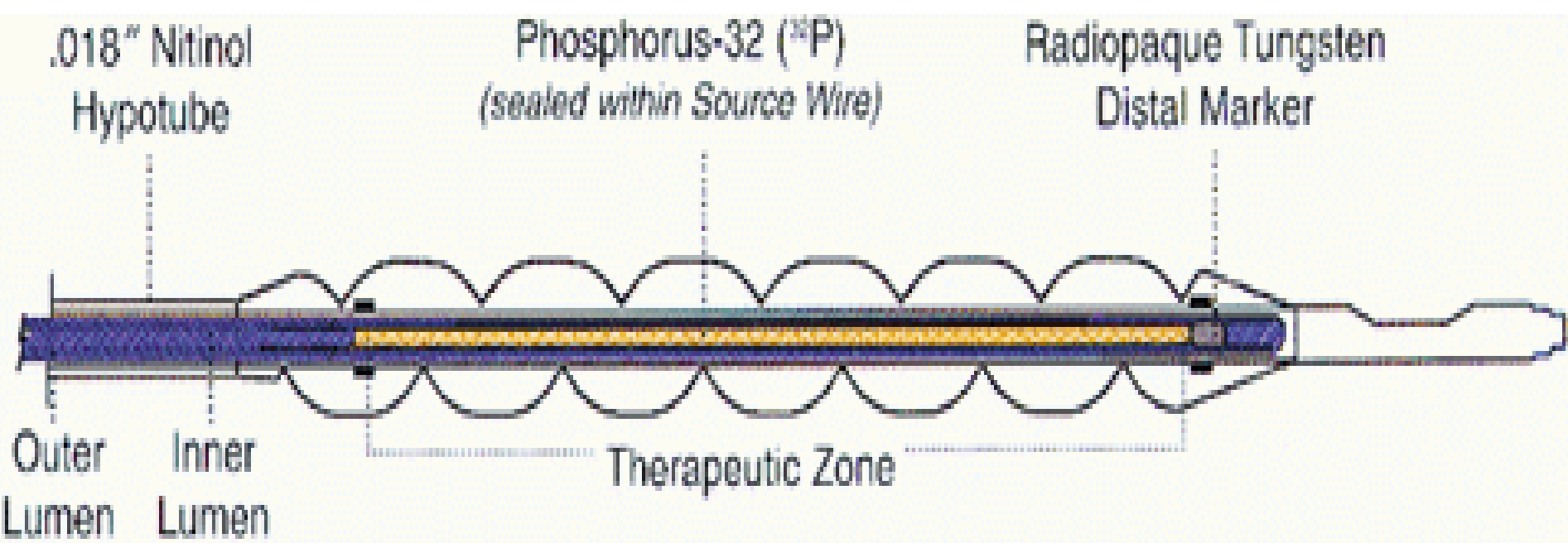
Temporary Implant Examples

- **Historically, Radium 226 sources were used, but today Cs-137 sources are used to treat cervical and intrauterine cancer in a LDR method**
- **Ir-192 is used to open bronchial pathways and occasionally it is used to treat superficial lesions**
- **P-32 and Sr-90 (pure beta-emitters) are used for the endovascular treatment of in-stent restenosis**

Example of an Endovascular Brachytherapy Dose Delivery Device



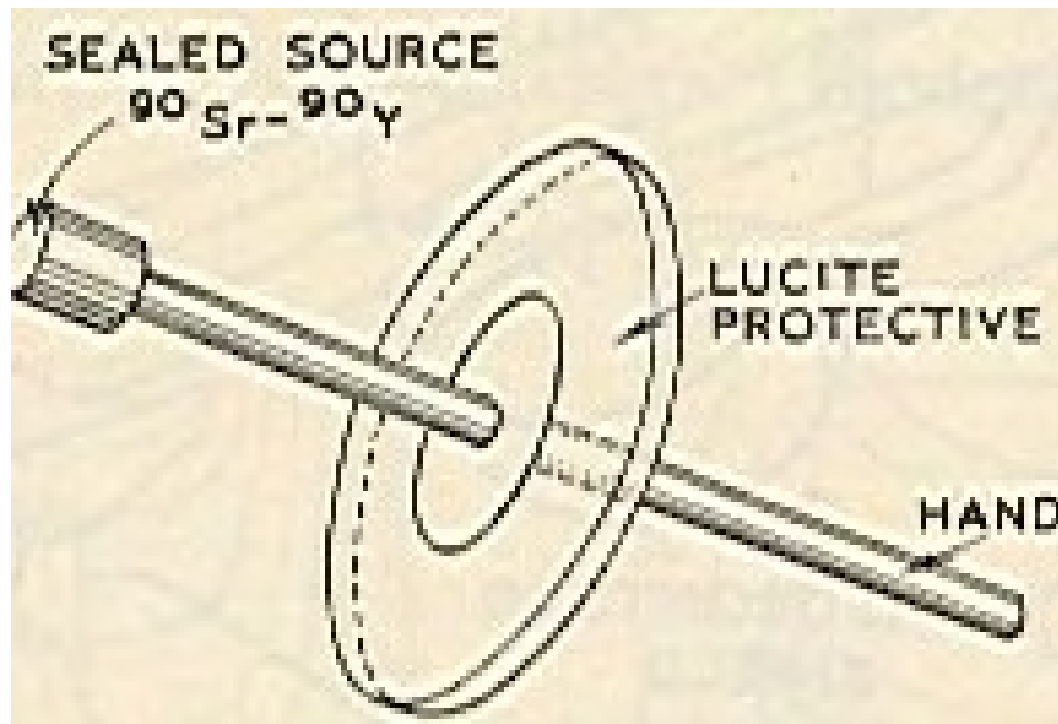
Example of Endovascular Brachytherapy Treatment Catheter



Sr-90 Pterygium Eye Applicator

- **A Sr-90 source is used to treat pterygium of the eyes**
- **The source is in a hand-held applicator that is held temporarily at a close proximity to the eye to be treated**

Sr-90 Pterygium
Eye Applicator →

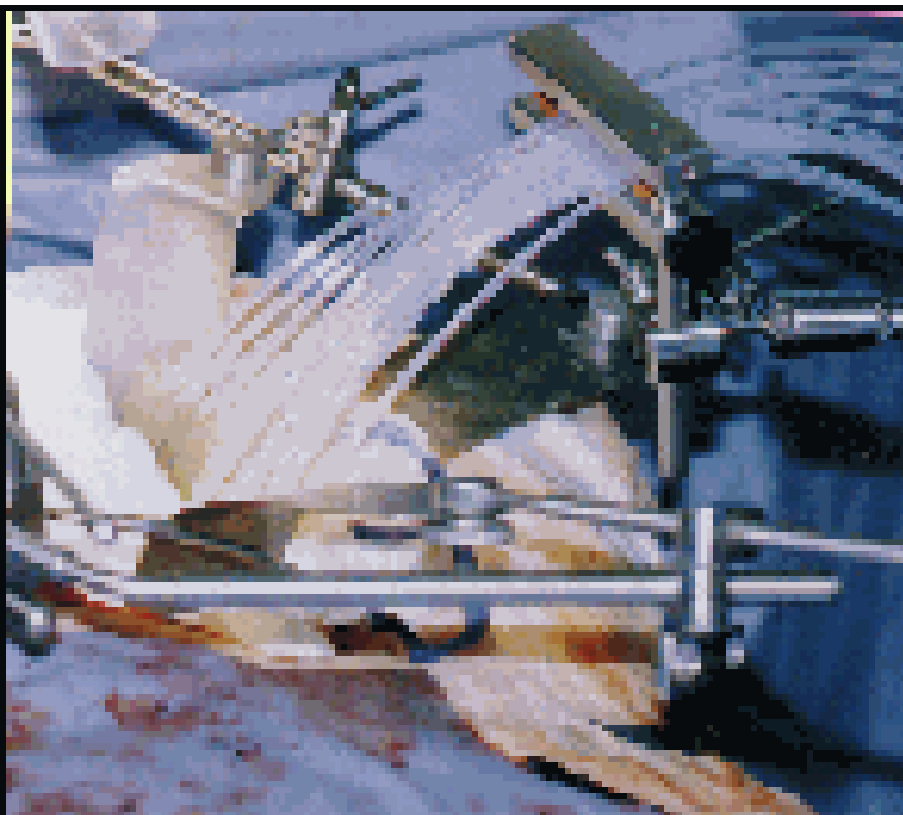


← Triangular Pterygium in Eye

High Dose Rate (HDR) Brachytherapy

- **Ir-192 is transported pneumatically from a lead-shielded device in a concrete-shielded room through tubing into a patient that is treated for a course of daily therapies for a variety of malignant conditions.**

HDR Treatment Unit →



HDR Source Tubing Entering

← Patient

Comparison of Brachytherapy Sources

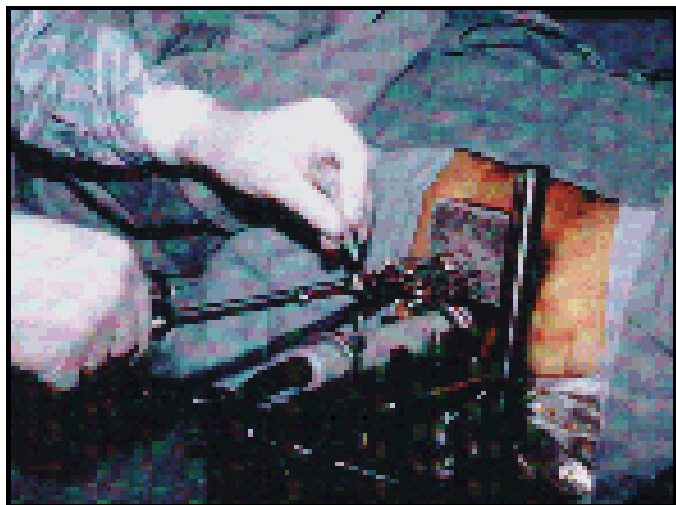
Radionuclide	Half-Life	Emissions
Ra-226	1700 yrs.	0.18-3.0 MeV gamma
Cs-137	30 yrs.	0.662 MeV gamma
Ir-192	74 days	0.316 MeV gamma
Pd-103	17 days	0.02-0.023 MeV gamma
I-125	60 days	0.025-0.035 MeV gamma
Sr-90	12 yrs.	0.5-0.7 MeV max. beta
P-32	14 days	1.7-1.9 MeV max. beta

Temporary Brachytherapy Pitfalls

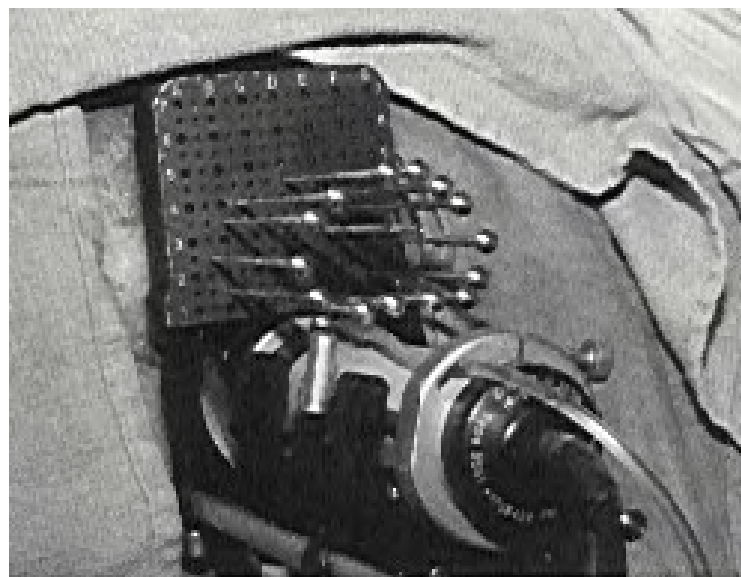
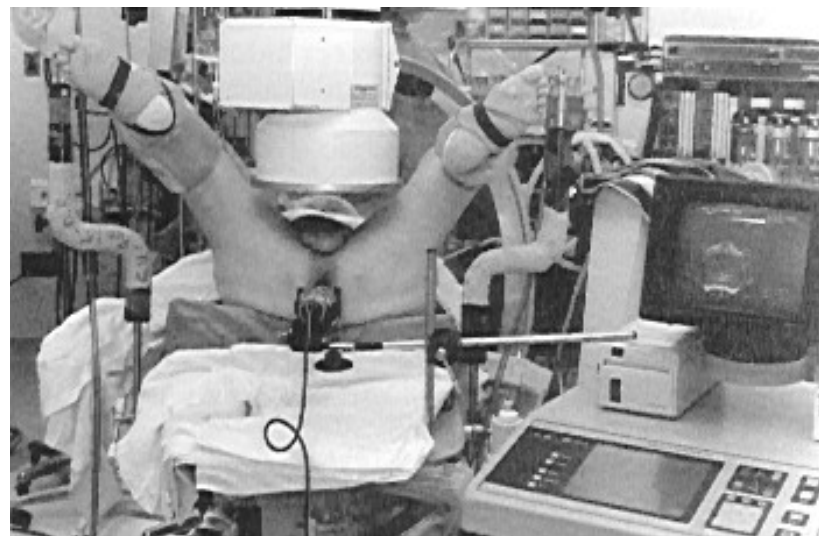
- **HDR procedures must have exposure times and source locations controlled very closely and require a medical physicist and radiation oncologist's presence**
- **LDR treatments require nursing staff involvement with the potential for patient removal of source applicators**

Permanent Brachytherapy Pitfalls

- Clinical seed distribution/placement makes prescribed treatment dose confirmation difficult
- Seeds are small and potentially misplaced
- Each patient's required number of seeds varies, so seeds left from previous therapies must be wasted or inventoried and logged for future usage



Prostate seed insertion procedures



Actual size of prostate seeds

Unsealed Source Therapies

Historically, colloids of Au-198 and chromic phosphate (P-32) were used by infusion to treat pleural effusions and ascites. Soluble sodium phosphate (P-32) was also used to treat leukemia and polycythemia vera.

I-131 is used to treat hyperthyroidism and to ablate residual thyroid tissue and to treat thyroid cancer metastases

Sr-89 and Sm-153 is used occasionally for the palliation of bone pain

Required Health Physics Duties For a Brachytherapy Program

- **Inventory control of radioactive sealed sources. (Quarterly with survey, and In and Out Log)**
- **Semiannual leak testing of all sealed sources in possession**
- **Distribution and collection of personnel monitors, any required mobile lead shields, nursing instructions, etc.**
- **A Quality Management Program (Q.M.P.) to catch misadministrations, recordable events, and unintended deviations from protocol must be in place and filed with the applicable regulatory agency.**

Wipe-Testing Brachytherapy Sources

Individual sources do not have to be wipe-tested if they are part of a whole package. For instance, I-125 seeds in a vial or jar do not have to be individually wipe-tested, because to do so would cause more detriment to personal safety than the projected elimination of future hazard. Other examples are Ir-192 sources in a sterile unused package in a lead tube. Individual Cs-137 sources should be wipe-tested individually since they are reused frequently; they therefore, are subjected to additional potential damage.

Assay of Brachytherapy Sources

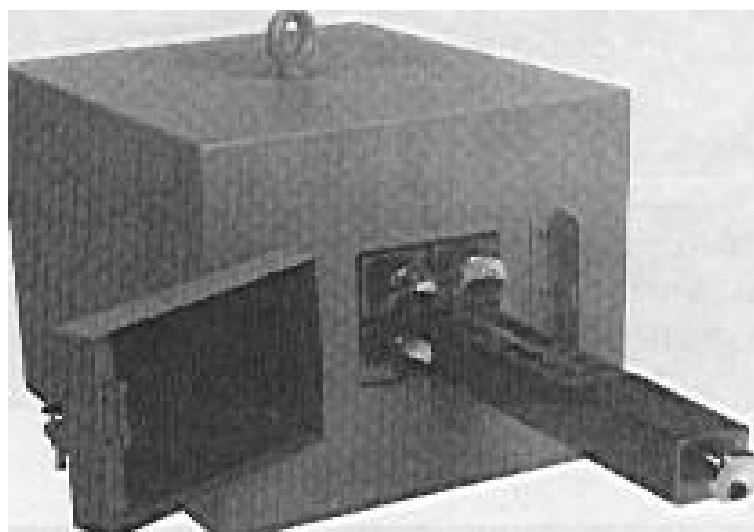
Most brachytherapy sources are not individually assayed (Ir-192 in a sterile sealed ribbon), but others are, like new HDR Ir-192 and Sr-90/Y-90 (endovascular) sources. Cs-137 sources are usually assayed once, and decayed thereafter. Some physicists calibrate or assay them on a regular 5 yr. interval. For sources requiring individual assay, a re-entrant well ionization chamber is used, with assay in microCoulombs.

Radiation Safety Equipment Required For a Brachytherapy Program

- **1. 2” thick lead safe for Cs-137 temporary sources**
- **2. Storage closet for safe, etc., with proper signs**
- **3. 1-2” thick “L”-block shield**
- **4. Remote handling tongs**
- **5. Radiation Survey Meters –(1) measurement type and (1) detection type (beta sensitive if Sr-90, P-32, Pd-103, or I-125 is used)**
- **6. 1-2” thick mobile lead barrier shields for patient rooms**
- **7. Assay device, preferably a re-entrant well ionization chamber designed to assay beta and gamma brachytherapy sealed sources in their usual configurations**
- **8. T.L.D. ring badges for all who handle the sources and pocket dosimeters or Luxel/Film badges for nursing staff**



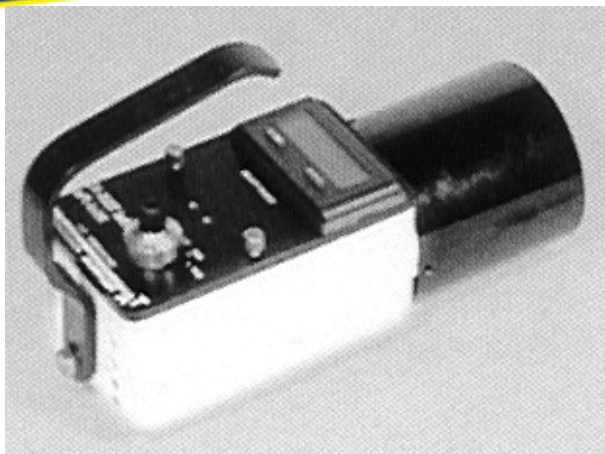
Mobile Lead Barrier Shield



← Lead “L”-Block



← Lead Cs-137 Source “Safe”



← Digital “Cutie Pie” measurement-type radiation survey meter

Re-entrant Well Chamber →



← “Beta-sensitive” GM detection-type radiation survey meter with pancake GM probe



Radiation Safety Equipment Required For a Unsealed Source Therapy Program

- **1. Standard Nuclear Medicine Hot Lab Equipment**
- **2. Lab Hood, with absolute filter, only if liquid I-131 will be possessed**
- **3. Radiation Survey Meters –(1) measurement type and (1) detection type (beta sensitive if Sr-89, Sm-153, or P-32 will be used)**
- **4. 1-2” thick mobile lead barrier shields for patient rooms**
- **5. Assay device, usually a conventional dose calibrator (calibration factors for beta-emitters may have to be empirically determined)**
- **6. T.L.D. ring badges for all who handle the sources**
- **7. Disposable trays, food containers, gloves, Chux pads, bed pads, and plastic bags**
- **8. Pocket dosimeters or Luxel/Film badges for nursing staff**

Comparison of Unsealed Therapy Sources

Radionuclide	Half-Life	Emissions
Au-198	2.7 days	0.414 MeV gamma
I-131	8 days	0.364 MeV gamma
Sm-153	2 days	0.8 MeV max. beta
Sr-89	50 days	1.5 MeV max. beta
P-32	14 days	1.7-1.9 MeV max. beta

Unsealed Source Therapy Pitfalls

- **I-131 capsules must be assured to have been swallowed**
- **I-131 liquid requires a lab hood, staff bioassays, and a patient administration contamination risk**
- **P-32 requires the correct pharmaceutical form for the proper application**
- **Sr-89 & Sm-153 are beta emitters requiring an empirical dose calibrator factor**
- **Inpatient room room radioactive decontamination**

I-131 Inpatient Therapy Room Preparation

The sink, toilet bowl, and toilet seat are covered with Saran Wrap for easy decontamination. *Obviously, you do not stretch the Saran Wrap across the toilet seat opening.*

The bathroom floor is lined with Chux pads or absorbent paper. The bedroom floor is not required to be covered, but a room without carpet is desired.

A large plastic bag is taped to the bedroom wall to collect the disposable food tray, plates, cups, food, and disposable gloves.

An absorbent paper is inserted under the sheets above the mattress cover.

The patient is encouraged to use disposable gloves when touching the phone, light switches, etc. The patient is encouraged to use disposable toothbrush, comb, etc.

Caution Radiation and Caution Radioactive Material signs are placed on the entry door. Pocket dosimeters are placed on a table outside the room (if safe). Documentation is left with nurses.

Capsules or Liquid NaI-131

Capsules are recommended even though slightly more expensive. For doses greater than 30 mCi of I-131, all staff handling capsules or liquid NaI-131 must have a bioassay performed within 24-48 hrs. Capsular use precludes the necessity for a hot lab ventilation hood. Capsules drastically reduce the risk of procedural contamination. To prevent multiple capsule doses, order early and be specific to request a single capsule only-especially if patient has real or perceived dysphagia.

P-32 Pitfalls

Colloidal Chromic Phosphate is a light blue radiopharmaceutical administered by infusion for treatment of pleural effusions and ascites. Dosage: 10-15 mCi infused

Soluble Sodium Phosphate is a yellow radiopharmaceutical administered for the treatment of leukemia, polycythemia vera, and bone metastases. Dosage: 1-5 mCi I.V.

P-32 is now available for insertion in the Guidant HDR device used as endovascular treatment of in-stent restenosis

Assay of Radioactive Material

Unsealed source therapy doses are assayed in the same ion chamber dose calibrator that diagnostic doses are assayed in (in units of mCi or MBq). This detector is suitable for syringes and vials.

Intense brachytherapy sources are assayed in an ion chamber called a “re-entrant well”. This detector is designed to handle the higher intensity sources, and the small point-source-like sized sources. Special plastic insert jigs are used to position the sources on the central axis.

Special dose calibrators are now available as dedicated beta assay detection devices. Some of these use plastic scintillators as detectors.

Hazards of Gamma vs. Beta

Gamma rays are more penetrating than beta particles. Therefore, lead is used to protect oneself from gamma-emitters. Beta-emitters can be effectively shielded by glass or plexiglas (plastic). Intense (> mCi) sources of beta-emitters can emit bremsstrahlung X-rays that can be shielded with lead (ironically, shielding the beta-emitter with thin lead only produces bremsstrahlung). The conversion of beta intensity to X-ray intensity is proportional, but not equal. Standing 1 meter from most beta sources, reduces the exposure to zero-due to the charged particle's stopping power in air. Gamma source exposure follows the inverse square law (doubling the distance reduces the exposure to one quarter). The amount of lead that reduces gamma rays intensity by one half is called the "half value layer".

Regulatory Agencies

- **Non-agreement states regulate only Pd-103, as it is produced in a cyclotron**
- **The N.R.C. or Agreement States regulate all other brachytherapy sources and unsealed source therapies**
- **NRC regulations are covered in 10 CFR 19, 20, 35, 70, 71. License conditions are traceable to commitments to follow the model procedures Regulatory Guide 10.8 Appendices P. & Q. NUREG 1556 Vol. 9 and NUREG 1492 are more recent and helpful**

Outpatients or Inpatients: which really has the lowest overhead?

- **Who will assess the suitable patient candidacy, calculate the patient specific data, and provide the radioactive material safety precaution literature to the outpatient?**
- **Is a room chosen with proper shielding for inpatient treatments?**
- **Has the nursing staff been trained to handle inpatient radioactive material therapies?**
- **What personnel monitors will be used for nurses who care for for inpatients?**
- **Is there a mechanism to control possible outpatient incontinence or improper contamination disposal?**

The Decision: In, Out, or Both?

Only following a frank discussion of the answers to the preceding 5 questions, can a sound management decision be made.

Also, a decision of whether to test all child-bearing aged women for pregnancy before any radioactive material therapy must be made. It is recommended to do so.

Breastfeeding women must completely cease breastfeeding following I-131 in the NaI form for treatment or diagnostic doses.

Who will calculate and provide patient safety literature?

Usually, the authorized licensed physician discusses the safety precautions with the potential outpatient. If he/she ascertains that the patient has a suitable lifestyle for “the outpatient release program”, then the patient must confirm by signature that they got the written precautions and will abide by them.

The calculations can be performed by the authorized user, the nuclear medicine technologist or the medical radiation health physicist

Which is the Proper Room For a Radioactive Therapy Patient?

A private room is chosen that usually has two outside walls, a corridor wall, and a wall adjacent to another patient. If the exposure in the adjacent patient's room is above 2 mR/hr at 1 foot, then either a lead barrier must be interposed, or the radioactive patient must be moved further from the adjacent wall. For I-131 thyroid ablation and cancer metastases treatments, the internal bathroom must be prepared to facilitate rapid clean-up, and minimize *radioactivity contamination* of toilet, sink, and floor. The patient receives restrictions and sleep room precautions, disposable gloves, plastic disposable waste bag, etc. Contamination is not an issue with brachytherapy.

Nursing Staff Radiation Safety Training

Annually, the brachytherapy and I-131 unsealed source therapy patient-handling nurses must have radiation safety training. Basic protocols are reviewed for new staff, and past problem solutions are discussed. If no problems occurred, then the discussion centers on the potential problems, decontamination of unsealed source spills, personnel monitor use, radiation exposures in perspective, radiation exposure during pregnancy policy, and recognition of sealed sources for brachytherapy. This training can be “live” or in recorded format, but attendees must be documented in writing.

What Personnel Monitors Should Be Used?

Anyone handling brachytherapy or unsealed sources must, by license condition, wear whole body *and* T.L.D. ring badges.

Nurses are usually provided with pocket dosimeters since treatments are infrequent and the badges provide instant feedback of the dose accumulated. Some busy hospitals subscribe to film badges for these nurses. In either case, the nurses must be taught how to use them and their respective shortcomings. Nurses are not provided with ring badges.

There are digital “alarming” type personnel monitors that are more costly, and therefore, are seldom available.

Endovascular Brachytherapy Special Considerations with Personnel Monitoring

The vast majority of staff radiation exposure from endovascular brachytherapy exposure comes from the scattered X-rays from the associated fluoroscopy. The N.R.C. requires personnel performing these procedures to be badged. They will review the staff personnel monitoring records at inspections. The exposure, recorded in mREM, will be a combination of X-ray exposure and beta exposure. The beta exposure is controlled by the N.R.C. The X-ray exposure is controlled by the State (in non-agreement states). In agreement states, the state controls all, and the problem is modified, but not rectified.

Endovascular Brachytherapy Special Considerations with Personnel Monitoring Cont'd

There is no way to separate the badge's accumulated exposure into a beta portion and an X-ray portion. Cardiovascular staff get very large exposures, and states allow the Effective Dose Equivalent (EDE) formula to be applied: i.e. 6000 mREM/yr. (from a badge worn outside a lead apron) $\times 0.3 = 1800$ mREM/r. (EDE), which becomes the number for regulatory action. The N.R.C. does not recognize the EDE formula's application; therefore, will declare the 6000 mREM/yr. to be in violation. However, that state would consider the data of regulatory concern to be the 1800/yr., which is under 5000/yr., and therefore, within regulatory limits, and not in violation.

A Solution?



The solution is not easy when two regulators are in conflict. In agreement states, a simple memorandum of understanding directed to inspectors may be the solution. For the NRC vs. the states, the only outside solution may be to wear two badges outside the lead apron. One only worn for beta procedures. The other worn for all procedures, with the apparent difference the beta component. The only problem with this is that of human nature and geometry. If the wearer forgets to wear one or the other badge the data calculation is ruined. If the wearer places the two badges in two different locations, it will produce two different readings without any beta exposure. Who calculates and records the differences, the R.S.O.? The person who handles the beta sources and the “applicator gun” should wear a ring T.L.D. badge. But the same regulatory duality problems exist.

Patient Responsibilities

Temporary Brachytherapy inpatients must be informed not to leave the room, and not to remove the source applicator.

I-131 unsealed source therapy patients must be informed not to leave the room, and how to prevent radioactivity contamination of their personal effects, as well as the patient's suite.

Both must be told that guests will be limited by age, pregnancy status, and length of stay. They will be limited to visit from a prescribed safe distance, usually for a prescribed safe time. In some instances, the visitor will be issued a pocket dosimeter, but this is rare.

Additional Patient Responsibilities

I-131 unsealed source therapy patients released to return to their homes must receive specific written precautions. One precaution is for the patient not to dispose of I-131 contaminated waste in the regular trash disposal stream for three months. The patient must realize that they will be held personally responsible for the error or omission allowing improper waste disposal. Only with proper recognition of this fact in writing, can the licensee divert liability of regulatory investigations due to the tripping of alarms in waste disposal facilities.

Patient Responsibilities For Permanent Implant Brachytherapy

Prostate seed implant protocols have improved drastically to be able to provide more focused treatment to actual carcinogenic tissues; however, unknown to the installer of the seeds, an occasional seed will penetrate the bladder wall, or in some way become dislodged (migrate). This migration does change the original dose accuracy slightly. This migration may result in the discharge of a prostate seed in a patient's toilet following urination. If this occurs, the patient should be instructed to try to safely salvage the seed, and call the radiation oncology department of the hospital where he got the seeds implanted.