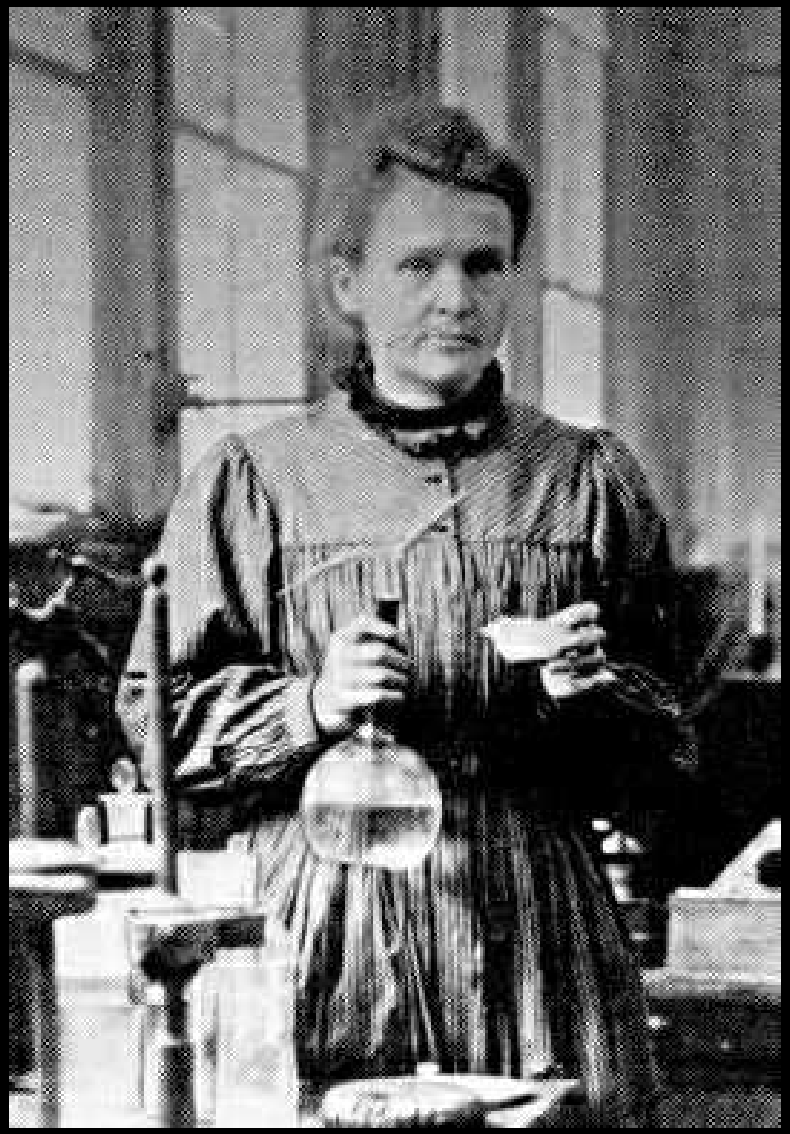
High Dose Rate Remote Afterloader Brachytherapy



Brachytherapy came into use soon after the discovery of radium by Marie Curie in 1898.

Before the 1950's, the radioactive material (mostly radium) was generally inserted directly into the tumor (called hot loading) in the operating suite.

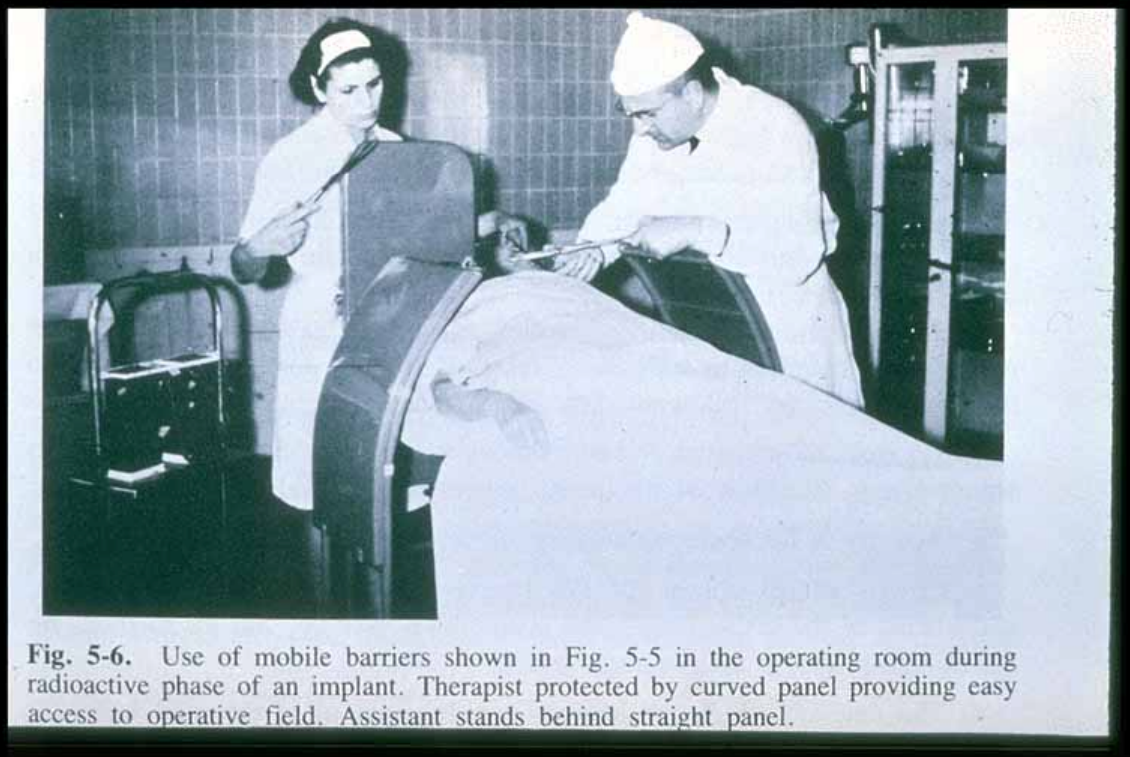


Fig. 5-6. Use of mobile barriers shown in Fig. 5-5 in the operating room during radioactive phase of an implant. Therapist protected by curved panel providing easy access to operative field. Assistant stands behind straight panel.

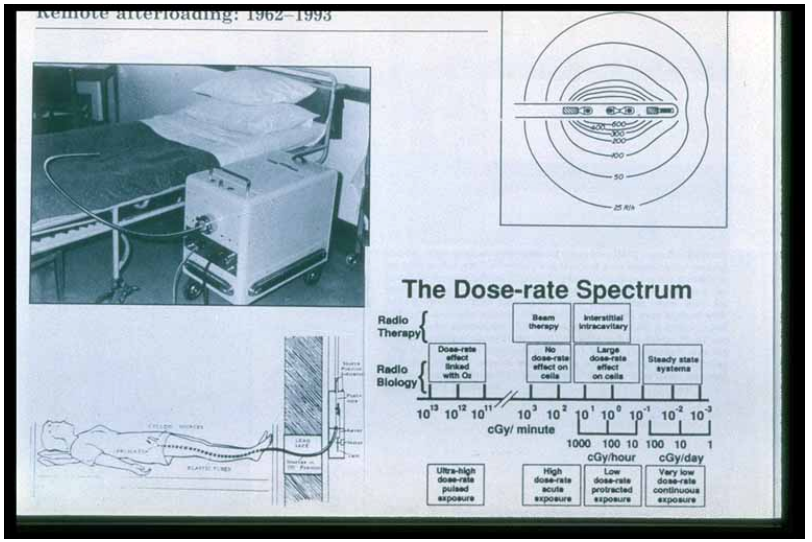
“Manual afterloading”

“Manual afterloading” was introduced to reduce the radiation exposure hazard by first inserting hollow needles or tubes into the tumor in the OR, transporting the patient to a shielded room, and then loading the radioactive material through the tubes.

Rolf Sievert first proposed the concept of "remote controlled afterloading" in 1937.

Brachytherapy treatments

- *Brachytherapy treatments using remote controlled systems began in 1964. Early systems used cobalt-60, but the first Iridium-192 machine was introduced in 1966.*



Dose Rates

Brachytherapy can be delivered at very different rates, over a wide range of treatment times varying from minutes to months. Brachytherapy dose rates have been divided into low, medium, and high by the International Commission for Radiation Units and Measurements (ICRU) and published in their report No. 38.

Low Dose Rate

- **Low Dose Rate (LDR)**: 0.4 to 2.0 Gy per hour – This is the traditional dose rate for permanent brachytherapy and manually loaded temporary brachytherapy implants. The treatment times for the manually loaded temporary implants are typically 2 to 5 days. Most of the long term clinical experience with brachytherapy is with LDR implants. The radiobiology of continuous low dose rate irradiation is well understood and documented in decades of clinical trials

Medium Dose Rate

- **Medium Dose Rate (MDR)**: 2.0 to 12.0 Gy per hour – Also called intermediate dose rate, this dose rate is rarely used in manual afterloading because of the increased exposure to radiation workers. The radiobiology is not well understood. The only current application is in Pulsed Dose Rate (PDR) Brachytherapy. PDR afterloaders expose a source for a few minutes each hour, so that the average dose rate per hour mimics LDR.

High Dose Rate

- **High Dose Rate (HDR)**: over 12.0 Gy per hour – HDR Brachytherapy is only used with remote afterloaders in well-shielded rooms. Very high activity sources are used and produce very intense radiation fields. The advantage is that a specified dose can be delivered in minutes, instead of days, and the patients are not required to remain in the hospital (as is the case with LDR). Commercially available HDR systems typically treat at a dose rate of 100 to 300 Gy per hour.

Title 10 CFR, Part 35.2 uses the same definitions but lists the ranges as:

- **Low Dose Rate**: less than or equal to 2 Gy (200 rads) per hour
- **Medium Dose Rate**: between 2 Gy (200 rads) and 12 Gy (1200 rads) per hour
- **High Dose Rate** – greater than or equal to 12 Gy (1200 rads) per hour

at the point or surface the dose is prescribed.

Dose Rate

Sometimes dose rate is specified in terms of minutes. High dose rate is greater than or equal to:

12 Gy/hr = 1200 cGy/hr = 1200 rads/hr = 20 rads/min.

Dose Rates

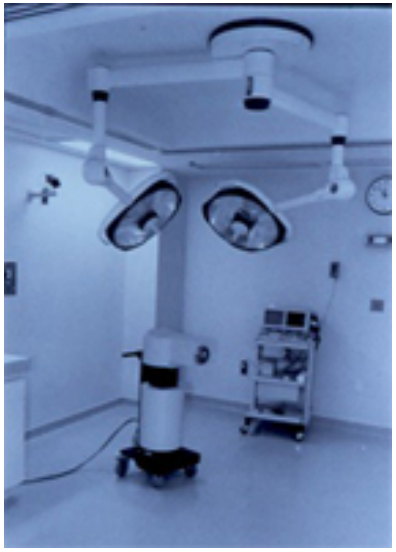
For a typical HDR remote afterloader, the dose rate can be:

300 Gy/hr = 30,000 cGy/hr = 30,000 rads/hr = 500 rads/min.

Currently, the highest dose rate reported is about 700 rads per minute at 1 cm.

Remote Afterloaders

Remote Afterloaders (also known as a source delivery units or treatment units) are only used for temporary implants in a radiation oncology department or clinic.



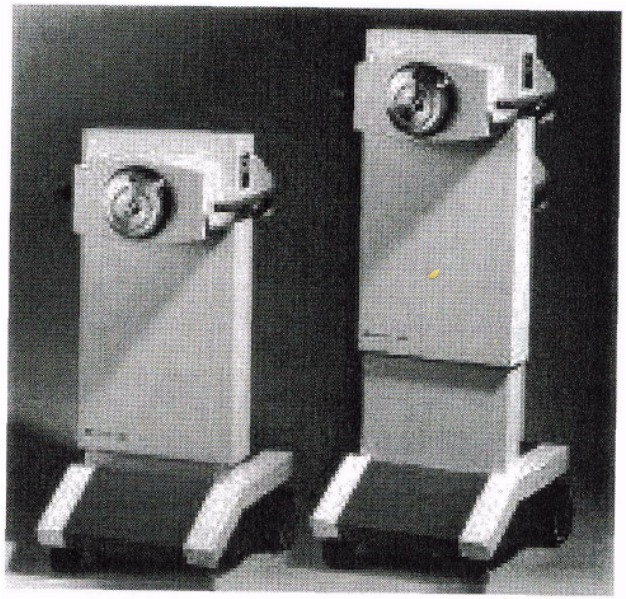
Remote Afterloaders

Currently, there are three HDR remote afterloaders available in the market:

1. The GammaMed
2. VariSource™
3. microSelectron

Remote Afterloaders

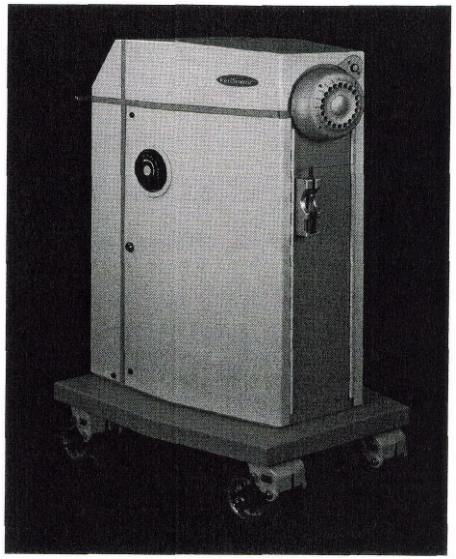
- The GammaMed marketed by Varian Associates (Palo Alto, CA)



The Varian GammaMed remote afterloader

Remote Afterloaders

- VariSource™ marketed by Varian Associates (Palo Alto, CA)



The Varian VariSource™ remote afterloader.

Remote Afterloaders

- microSelectron marketed by Nucletron (Veenendaal, The Netherlands).

The Nucletron MicroSelectron V2 high dose rate remote afterloader

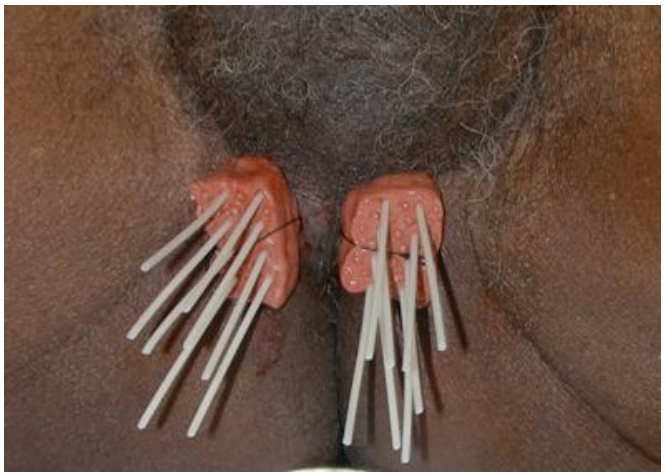
Remote Afterloaders

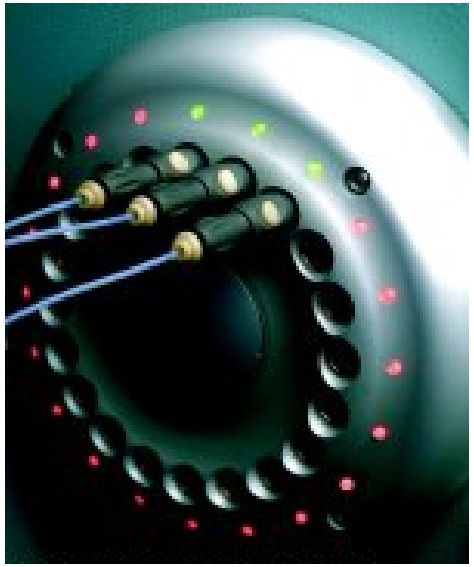
Table 1. Features of three commercially available HDR Remote Afterloader Units

	MicroSelectron V2	**GammaMed+**	**VariSource 200/200t**
Vendor	Nucletron	Varian	Varian
Sources	10 Ci of ^{192}Ir	10 Ci of ^{192}Ir	10Ciof ^{192}Ir
Source Dimension	3.5 mm L, 1.1 mm OD	4.52 mm L, 0.9 mm OD	5 mm L, 0.59 mm OD
Source Cycle	25,000 transfers	5000 transfers	5000 transfers
Channels	18	2, 3, or 24	20
Source Extension	1500 mm	1300 mm	1500mm
Channel Length	Variable	Fixed	Variable
Source Movement	Stepping forward	Stepping backward	Stepping backward
Step sizes	2.5, 5, or 10 mm	1-10 mm, 1 mm steps	2-99 mm, 1 mm steps
Dwells steps per channel	48	60	20

Remote Afterloaders

Treatment units today can move the source through hollow applicators, which usually consist of needles or catheters





Remote Afterloaders

All available HDR remote afterloaders consist of the same general components even though they differ in their technological specifications

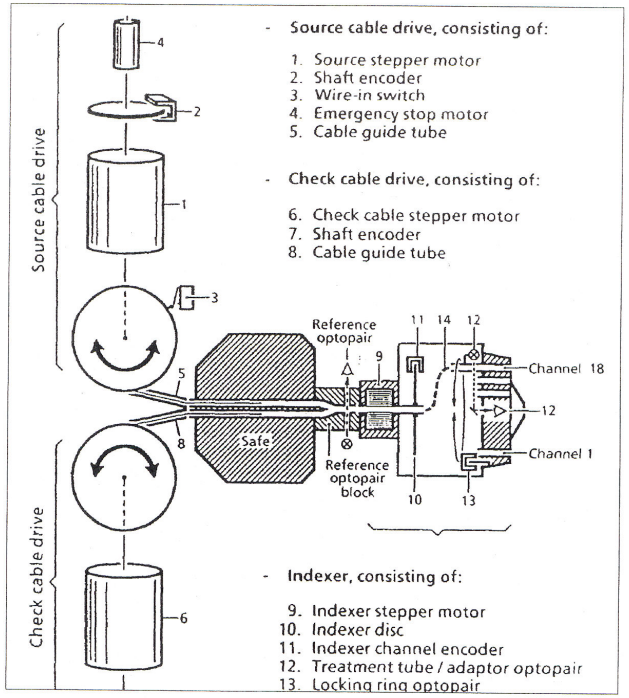


Figure 4. Schematic diagram of a single stepping-source remote afterloading device. (Courtesy of Nucletron Corporation, Columbia, MD.)

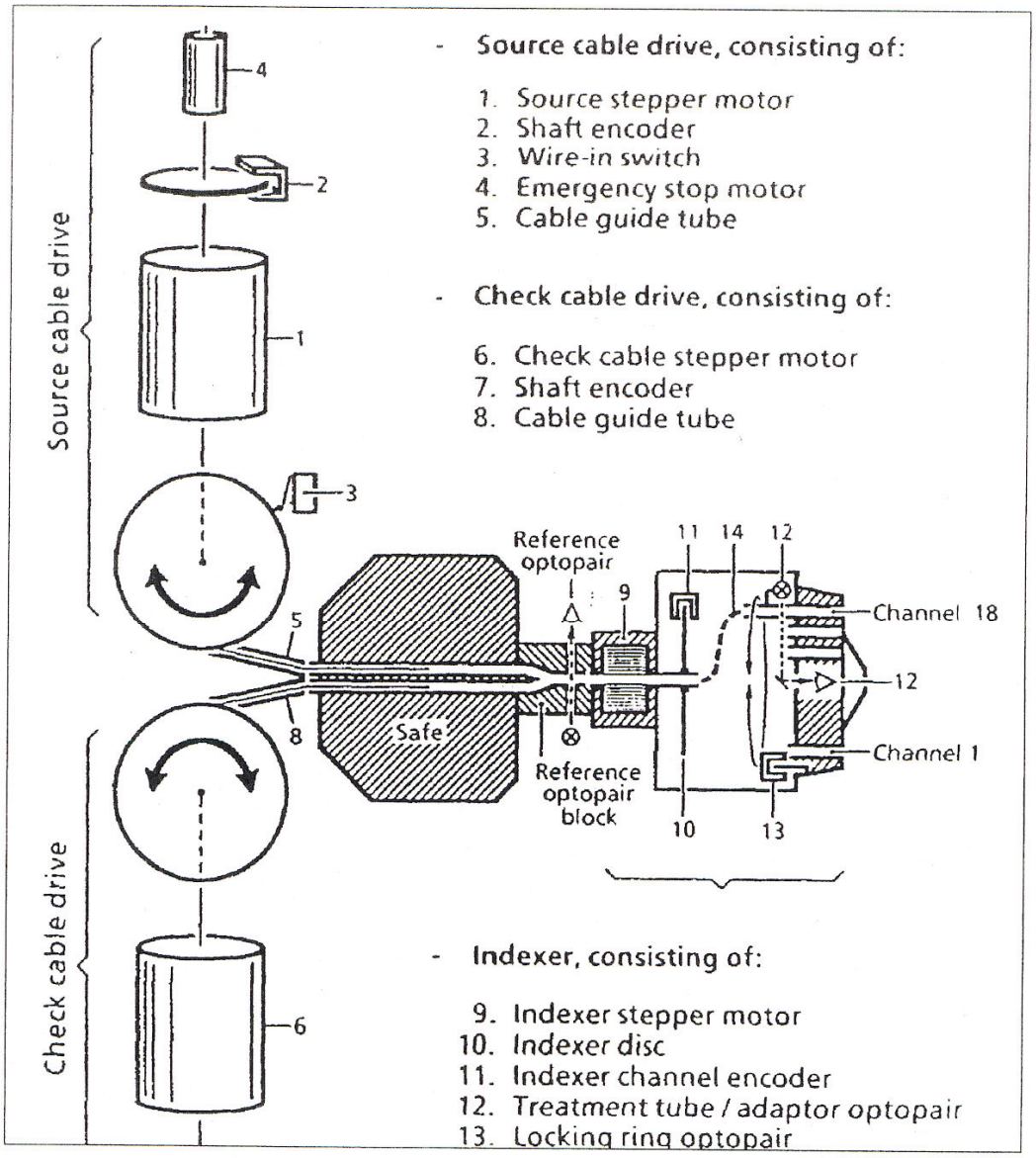


Figure 4. Schematic diagram of a single stepping-source remote afterloading device. (Courtesy of Nucletron Corporation, Columbia, MD.)

Component-Radioactive Source

The radionuclide currently used for all HDR remote afterloaders is Ir-192. Since Ir-92 has a high specific activity of about 450 Ci/g and an average gamma-ray energy of 0.38 MeV, a 10 Ci sources made out of this radioactive material can be smaller and easier to shield compared to Co-60 or Cs-137 (both of which have higher energy gamma rays).

Component -Shielded Safe

- A stepping-source remote afterloader uses an Ir-192 source of 5 to 10 Ci to provide a dose rate of up to 700 cGy/min (at 1 cm from the source). A shielded safe made of tungsten or depleted uranium houses the source when it is not in use.

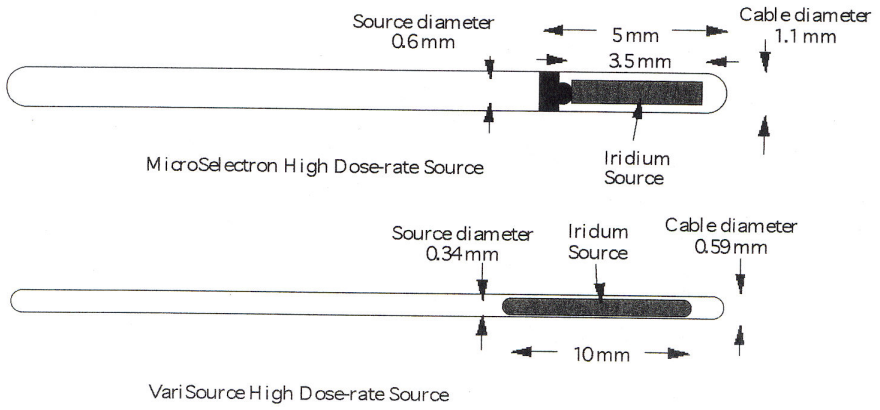
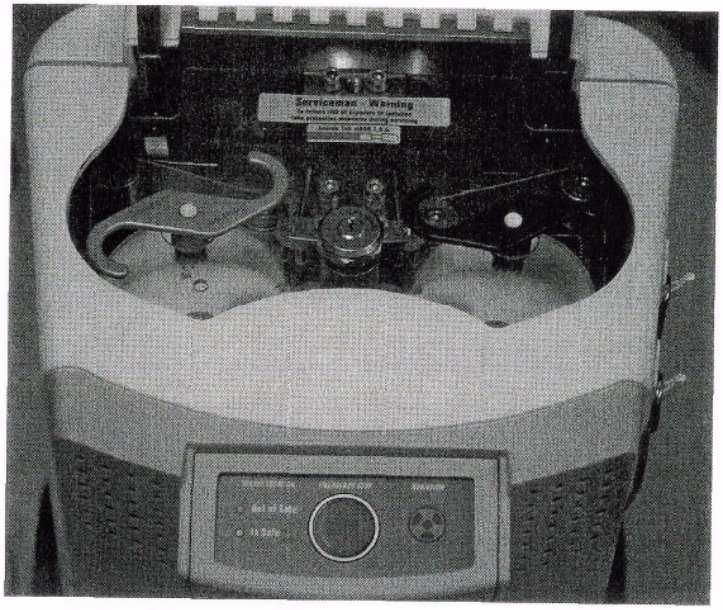


Figure 5. Schematics of the two types of sources used in stepping-source remote afterloaders.

Component- Source Drive Mechanism

The drive mechanism causes the source cable to advance from the shielded safe along a path constrained by transfer tubes to the first treated dwell position in the applicator attached to the first channel.

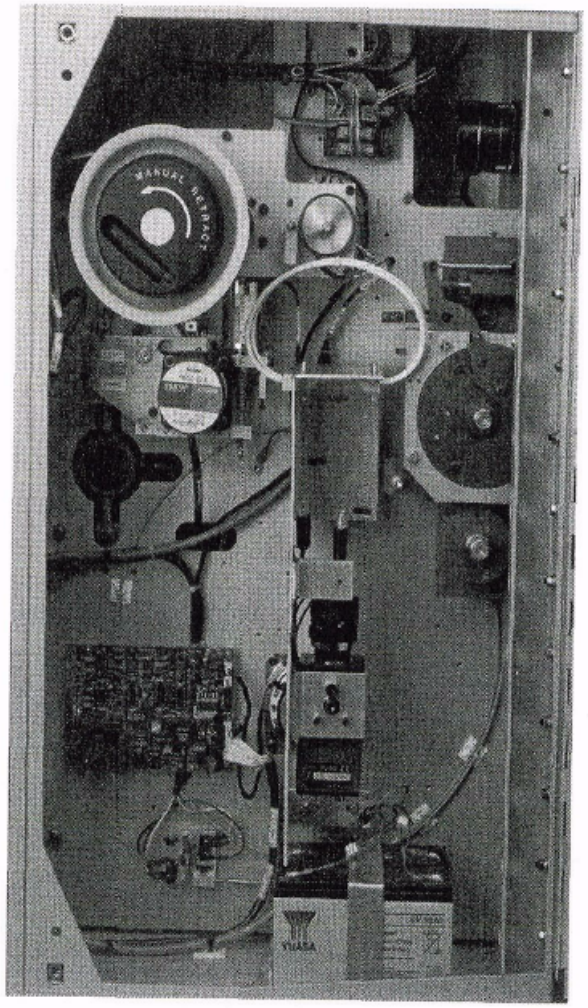
Component-**Indexer**



A view of the access panel of the microSelectron treatment unit. The emergency off button
(in the center of the box at the bottom of the picture) on the unit is to withdraw the source into the shielded safe.

Also shown are the manual retraction cranks for the radioactive source cable on either side of the keyhole in the middle, for the source on the left and the check cable on the right.

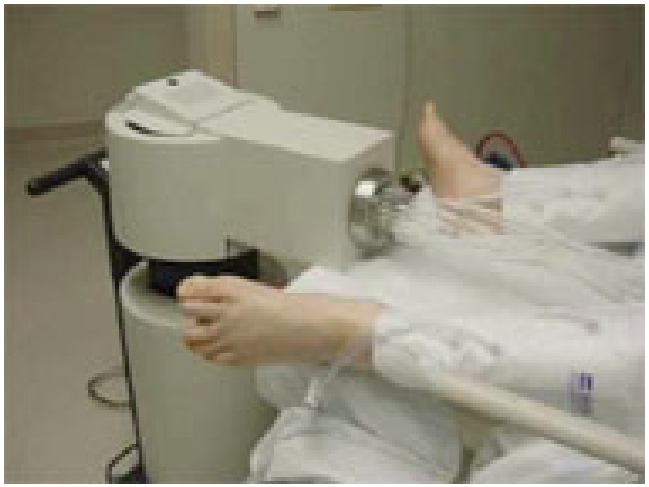
Component-**Indexer**



The back panel of the VariSource™ showing the crank for manual source retraction in an emergency.

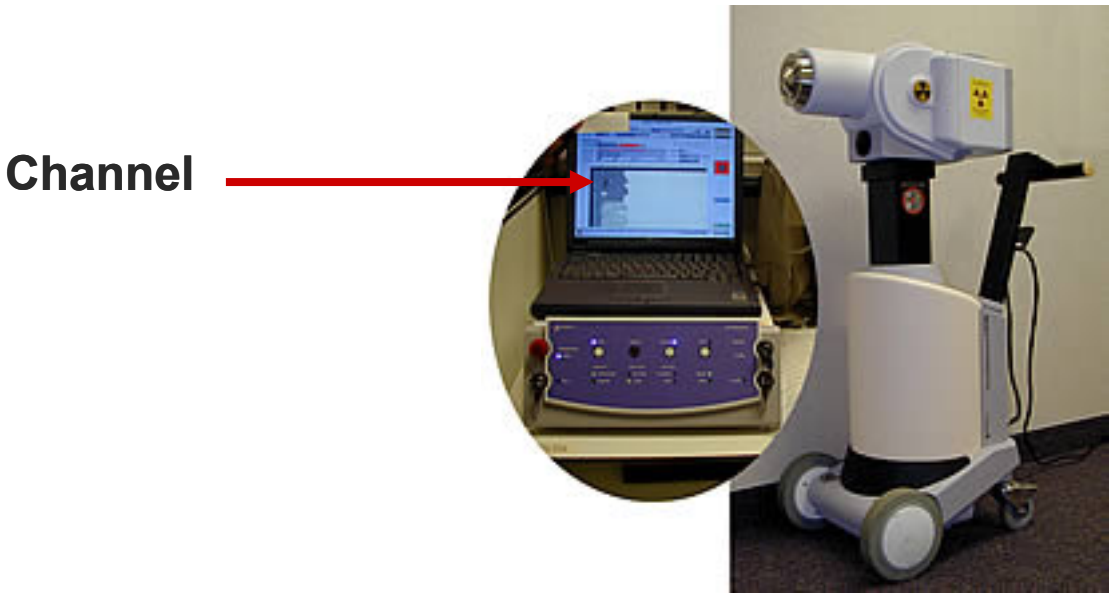
Component-Transfer Tubes

As the name suggests, transfer tubes are long flexible tubes that act as a conduit to transfer the source from the remote afterloader to the applicators or catheters for treatment. One end of the transfer tube is attached to the indexer of the treatment unit, while the other end is attached to the interstitial, intracavitary or transluminal applicators.



Component - Treatment Control Station

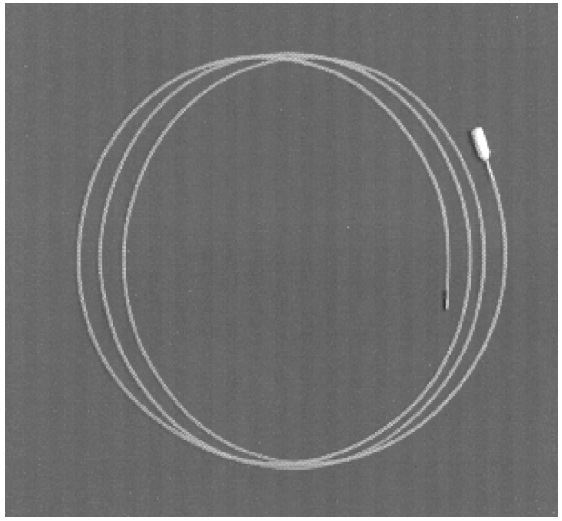
The treatment control station allows the user to select the dwell positions and dwell times for each channel .

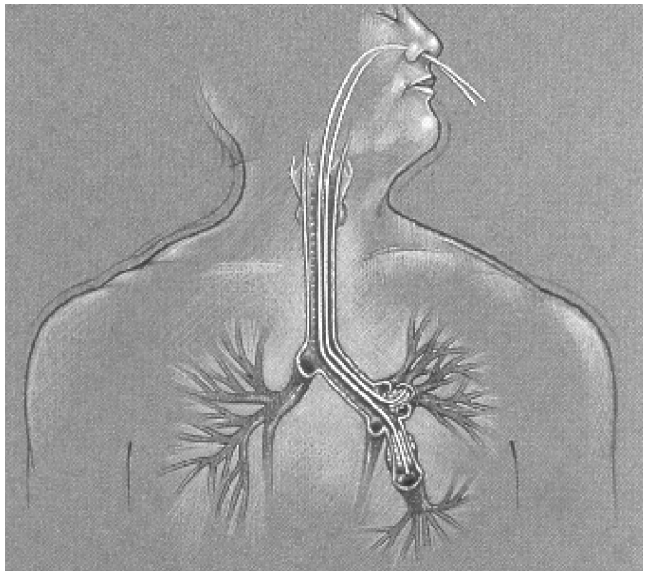


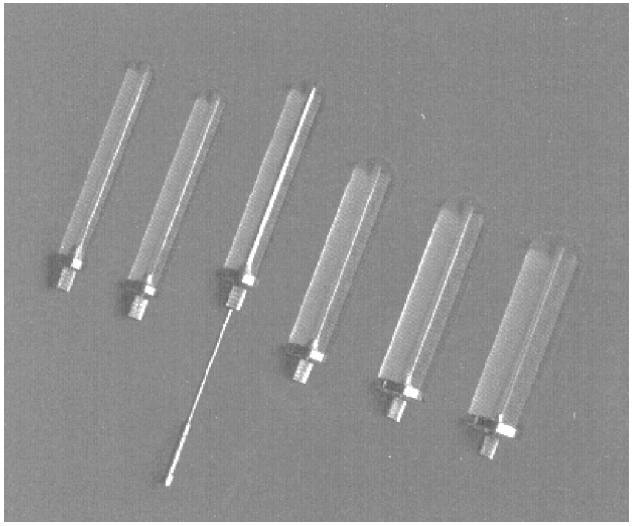
Component -Treatment Control Panel

The treatment control station transfers the data to the treatment control panel. A hard or soft START button initiates the execution of the treatment according to the program. In addition, there is an INTERRUPT button, which when pressed retracts the source and stops the timer, allowing the user to enter the treatment room without receiving radiation exposure. A RESUME or START button resumes the treatment from the time and the dwell position where it was interrupted. A master EMERGENCY OFF button initiates the high-torque DC emergency motor to retract the source

Patient Applicators







In order to deliver the source precisely to the target area, a number of different types of catheters and applicators have been developed. Three such applicators are shown above.

Patient Applicators

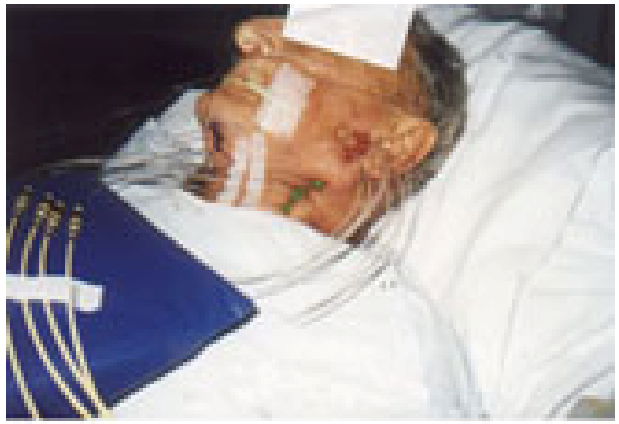
With respect to safety, the applicator must be coupled to the afterloader guide tube in such a way that no obstruction or constriction of the source wire occurs.

Two important criteria for these applicators are that safety considerations not be neglected, and that patient comfort be maximized for compliance during the treatment.

Patient Applicators

Some of the suitable tumor sites for HDR brachytherapy are as follows:

- Abdomen
- Bile duct
- Brain
- Breast
- Cervix
- Colon
- Endobronchial
- Endometrium
- Esophagus
- Head and Neck
- Pancreas
- Prostate



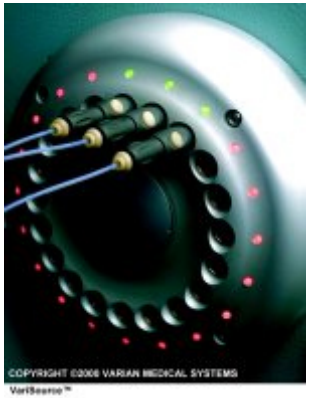
Head and Neck Brachytherapy Implant

Patient Applicators

- Almost all applicators designed for LDR manual afterloading have been adapted for HDR use with a mechanism to connect them to a transfer tube from the afterloader device.

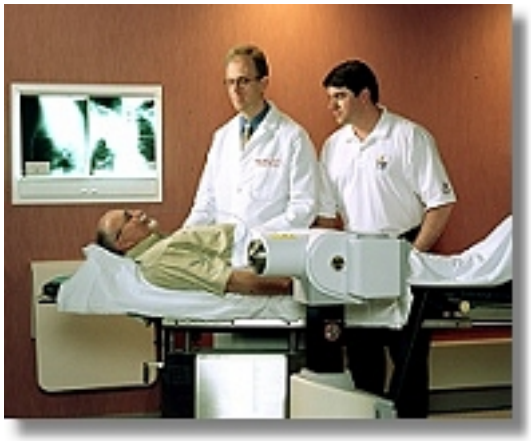
Patient Applicators

- The connection has mechanical interlocks to ensure that the applicator is correctly positioned and connected. The interlocks prevent wrong connections.



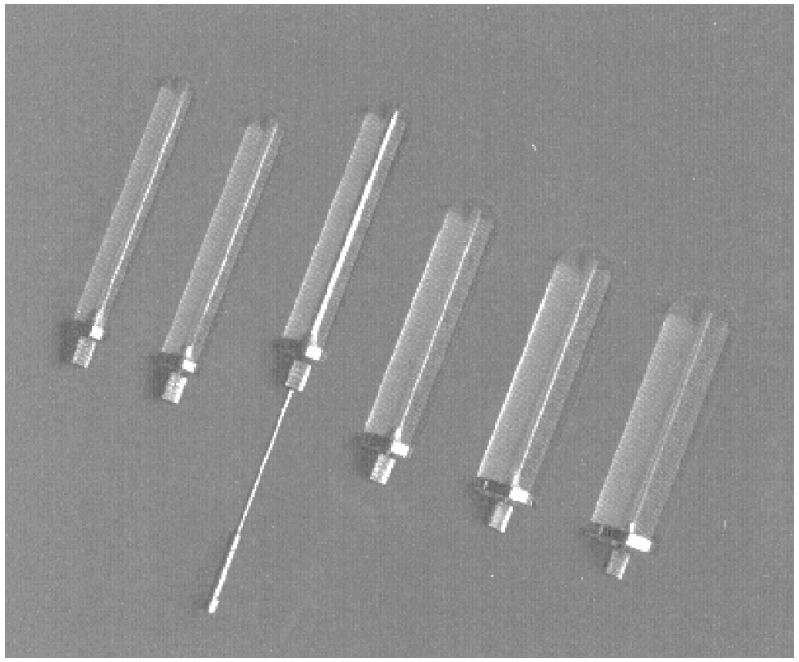
Patient Applicators

- The applicator, transfer tube, and afterloader device are a closed system to avoid the possibility of the source becoming dislodged in the patient or exiting into the air before reaching the target region.



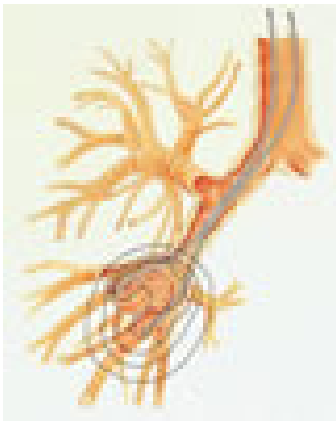
Intracavitary

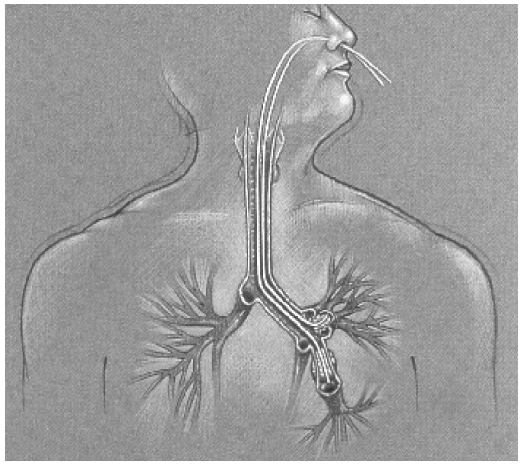
- Intracavitary applicators use specific transfer tubes designed to be the same overall length but to have different interlocks for each treatment channel to avoid connection errors..



Intraluminal

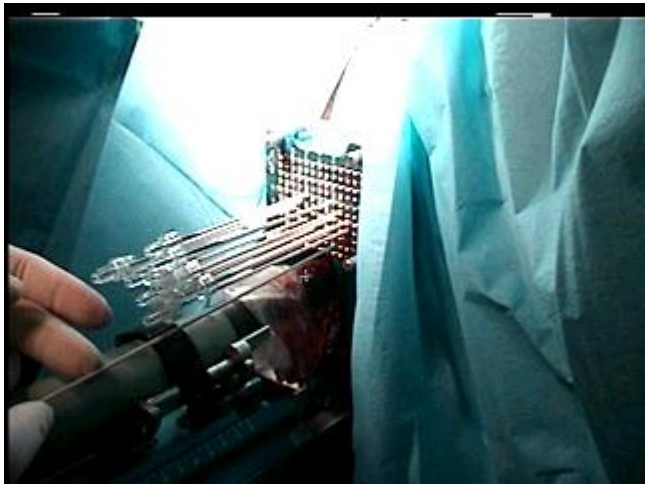
- Intraluminal applicators usually connect directly with the treatment unit using a specific adapter. These applicators can be 5 or 6 French diameter, blind ended, flexible tubes (disposable); or they can have a specific design (esophageal applicator).





Interstitial

- Interstitial applicators can be rigid or flexible. The rigid stainless steel needles are of different lengths and require specific transfer tubes. The needles can be reused after sterilization. Using a template for the implantation with a fixed predetermined geometry allows us of standard dose distribution. The thin, flexible disposable plastic tube require different transfer tubes



Characteristics of major applicators

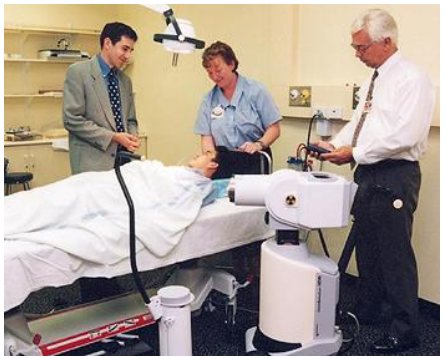
Category	Type	Dosimetry	Reusable	Clinical Use
Intracavitary	Ring Applicator	Preplan	Yes	Gynecological
Intracavitary	Fletcher type	No preplan	Yes	Gynecological
Interstitial	Rigid templates	Preplan	Yes	Interstitial/Molds
Interstitial	Neddles	No preplan	Yes	Interstitial
Interstitial	Plastic tubes	No preplan	No	Interstitial
Intraluminal	Lumen Catheter	Preplan	No	Lung/Bile Duct/Esophagus
Intraluminal	Esophageal	Preplan	Yes	Esophagus

Safety Features of Remote Afterloaders

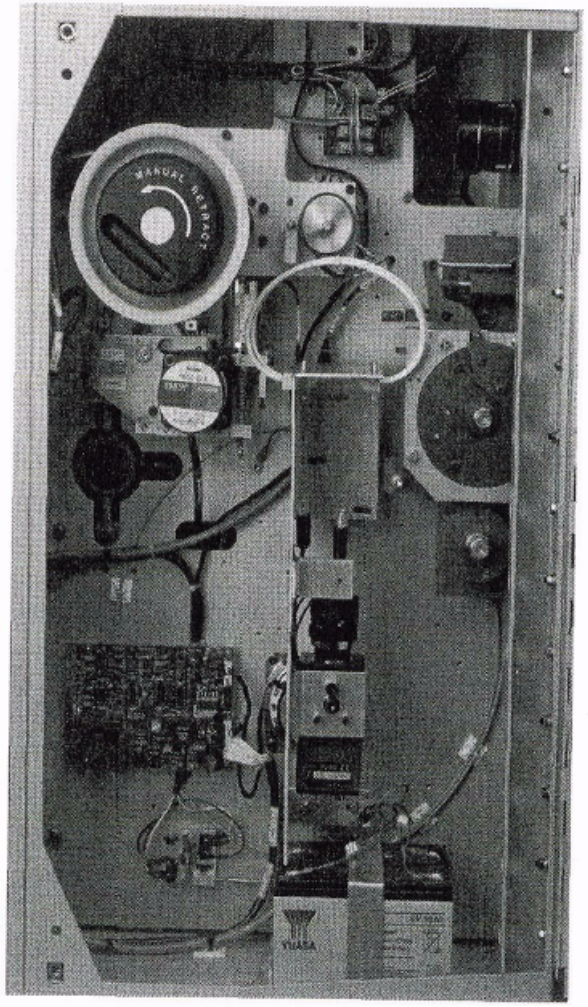
HDR remote afterloaders are complicated devices containing very high activity radioactive sources. Because of the high dose rate and the short treatment times, serious accidents can happen quickly. All these units have many safety features and operational interlocks to prevent errant source movement or to facilitate rapid operator response in the event of a system failure. Manufacturers make sure the all new installations have all the safety features described in 10 CFR Part 35.615.

Emergency Switches

Numerous EMERGENCY OFF switches are located at convenient places and easily accessible, in case a situation arises. One EMERGENCY OFF switch is located on the control panel. Another EMERGENCY OFF button is located on the top of the remote afterloader treatment head. Vendors usually install one or two emergency switches in the walls of the treatment room. In the event a treatment is initiated with someone other than the patient in the treatment room, that person can stop the treatment and retract the source by pressing the EMERGENCY OFF button.



Emergency Crank



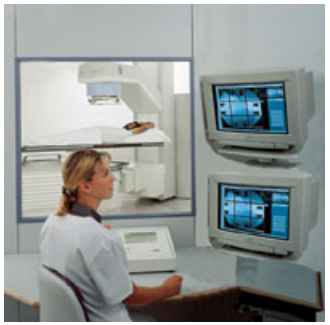
- All treatment units have emergency cranks to retract the source cable manually if the source fails to retract normally and the emergency motor also fails to reel in the source.. Using the crank requires the operator to enter the room with the source unshielded.

Door Interlock

- Interlock switches prevent initiation of a treatment with the door open. When a treatment is in progress, opening the door interrupts the treatment. This safety feature protects the medical personnel from radiation exposure in the event somebody enters the treatment room without the knowledge of the operator. If a door is inadvertently opened during the treatment, the treatment is interrupted and the source returns to the safe. The treatment can be resumed at the same point where it was interrupted by closing the door and pressing the START or the RESUME button at the control panel.

Audio/Visual System

All HDR suites must be equipped with a closed-circuit television system or shielded windows and/or mirrors for observing the patient, and a two-way audio system to communicate with the patient during treatment.



Radiation Monitor and treatment on Indicator

- Three separate independent systems alert personnel when the source is not shielded. One radiation detector is part of the treatment unit and indicates on the control panel when it detects radiation. An independent unit, usually mounted on the treatment room wall with displays both inside and outside the room, also alerts the operator and other personnel when the radioactive source is out of the safe. A treatment on indicator outside the room, usually over the door, activates when the source is exposed, also indicating that a treatment is in progress.

Backup Battery

- In case of a power failure during the treatment, the machine is equipped with a backup battery to provide retraction of the source to its safe. The batteries should be tested with each source change.

System Failure

- In the event the radioactive source fails to retract after termination, interruption, pushing the emergency off switch, or cranking the stepper motor manually, the immediate priority is to remove the source from the patient.

Table 2 gives the exposure rates at various distances from a 10 Ci 192Ir source.

Table 2. Exposure Rates from an Exposed 10 Ci 192Ir Source

Typical situation	Distance (m)	Dose Equivalent Rates Sv/h]	Time to Receive	
			10 Sv	0.05 Sv
			(Likely injury)	(Annual body limit)
In Patient	0.01	4.6R/(mCi h) x 0.966 rem/R = 444 Sv/h	1.35 minutes	0.007 minutes 0.4 seconds 0.67 minutes
Handling with Kelly Clamps	0.1	4.44	2.3 hours	(6.8 minutes for hand limit)
Handling with Kelly Clamps	0.3	0.5	20 hours	0.10 hour 6 minutes
Standing near	1.0	0.044	9.5 days	1.1 hours
Standing far	2.0	0.011	37.5 days	4.5 hours

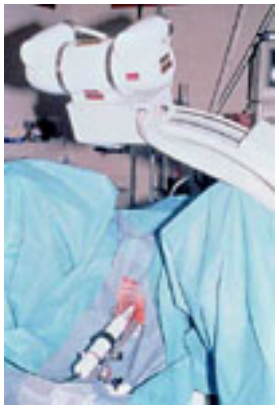
Advantages and disadvantages of HDR

- Less exposure for radiation workers
- Dose optimization
- Outpatient Treatment
- Better documentation

Advantages and disadvantages of HDR

Gynecological treatments have these additional advantages:

- **Less movement of the applicator**
- **Dose Reduction to Normal Tissue**
- **Applicator Size**



Advantages and disadvantages of HDR

Some of the disadvantages of HDR Brachytherapy are:

- Cost
- Complexity
- Compressed time frame
- Radiobiology - As the dose rate increases, the radiosensitivity (damage per unit dose) increases for both normal tissues and tumors.

Advantages and disadvantages of HDR

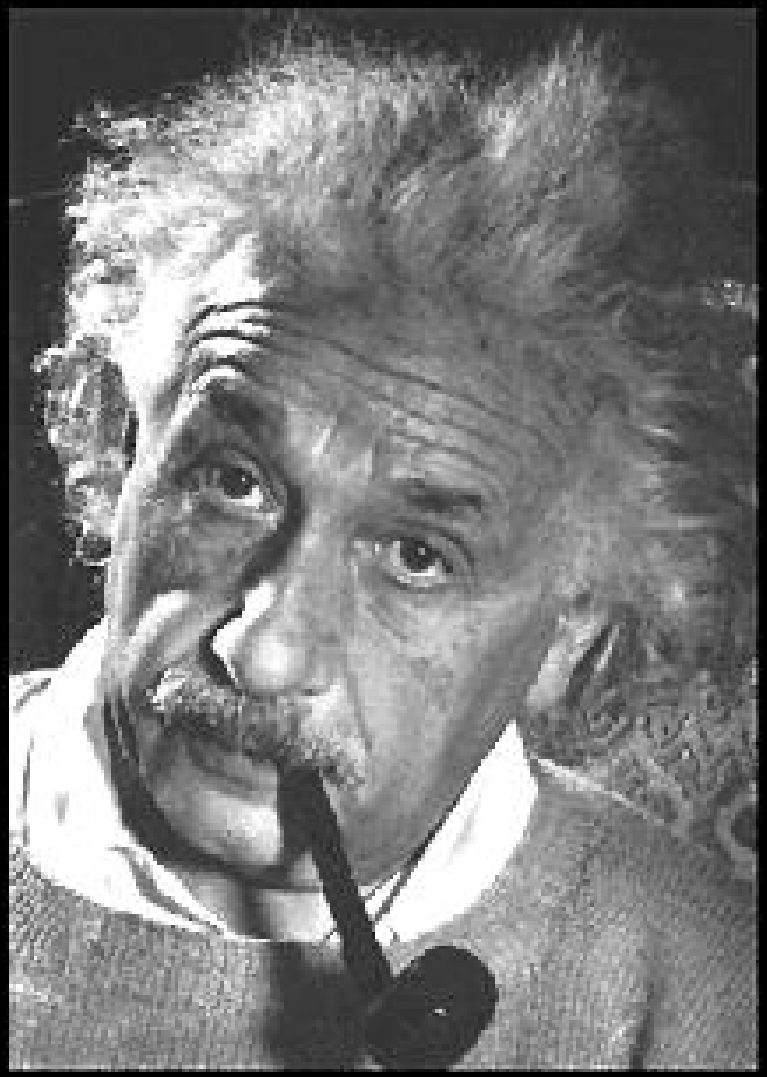
Overcoming this radiobiological handicap requires the use of the advantages of *optimization, geometry, stability,* and *dose reduction to normal tissues,* in addition to fractionation. As with external beam radiotherapy (delivered with a linear accelerator, which also operates at high dose rates) spreading the treatments over many smaller fractions delivered over several days reduces the difference in radiosensitivity between the tumor and the normal tissues.

Personnel Responsibilities and Training

- Title 10 CFR Part 35.690 addresses the requirements for **Authorized Users** of remote afterloader units. The wording of this section has created some confusion for radiation oncology departments because of the specific training required of the authorized user. First of all, the authorized user is always a physician. Secondly, this physician will satisfy training requirements.

Authorized Users

- Most authorized users will be radiation oncologists who have taken a training course from the vendor of the remote afterloader unit or from a medical physicist. All authorized users must be on the radioactive license.



The training requirements for an **Authorized Medical Physicists** are listed in 10 CFR Part 35.51

Training - Policies & Procedures

- The duties and responsibilities of the physicians, medical physicists, dosimetrists, nurses and radiation therapists are explained in the policies and procedures for the radiation oncology department or clinic. These are written with input from physicians, administrators, physicists, nurses, dosimetrists and therapists.

Responsibility

- Although each hospital or clinic may differ in some aspects, the major roles of each member of the clinical team are as follows:

The physician is personally responsible for the following:

1. Patient selection
2. Written directive for each patient's radiation dose
3. Design and approval of the treatment plan
4. Selection, insertion and removal of the treatment applicator and approval of all simulation films
5. Direction of treatment delivery
6. Safety of the patient

Physicist

- The Physicist (along with the Radiation Safety Officer) is responsible for ensuring that the remote afterloader unit is stored in a properly shielded location, and that all regulations concerning radiation safety are strictly enforced.

Physicist

- The physicist will perform the acceptance testing of the entire HDR Remote Afterloader System, including the treatment planning system. He/she is also responsible for writing quality control procedures for control of the radioactive source during initial installation and subsequent source exchanges. He/she is responsible for calibration of the source and entering this information into the treatment planning computer and the remote afterloader treatment console

Physicist

On treatment day the physicist's responsibility includes:

1. Treatment day check of safety interlocks and operational features, source position, and timer accuracy
2. Treatment planning and file management
3. Supervision along with the physician of the control console operation during delivery of the treatment
4. Survey of the patient before and after the treatment
5. Radiation safety and documentation

In addition, the authorized medical physicist is frequently involved with the calculation and administration of the radiation dose.

RSO

The Radiation Safety Officer is directly responsible for the safe use of all radioactive sources and devices. The RSO communicates with the regulatory agencies concerning safety issues and is responsible for what is written in the license concerning the HDR program. The RSO will also review the credentials of the radiation oncologist before adding him or her to the license as an authorized user. The RSO will often be involved in the design of the HDR facility and may perform the first area survey when the remote afterloader is installed. The RSO will review the installation before the first medical use to make sure that all the requirements of the license have been met. The RSO should review all procedures and emergency plans.

The Radiation Oncology Nurse is responsible for the nursing care of the patient which may include scheduling and notification of the patient. Other duties include:

1. Applicator cleaning, storage, and sterilization
2. Patient education and preparation
3. Assisting the physician with insertion of applicators
4. Care of the patient during treatment planning
5. Assisting the physician with removal of applicators
6. Documentation in patient chart

The Radiation Technology Therapist (RTT)is responsible for operation of the x-ray equipment used in preparation of the dosimetry films or the CT images used for treatment planning. These duties include:

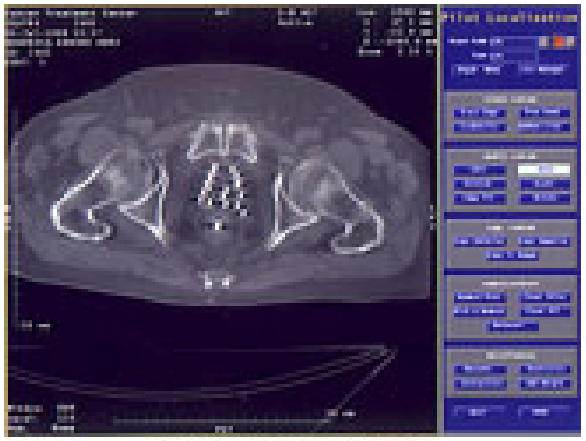
1. Transfer of the patient to and from the CT or x-ray couch
2. Checking immobilization of the applicator to prevent movement
3. Placement of markers such as a Foley balloon or rectal marker
4. Selection of technique and exposure of films as directed by the physicist
5. Labeling of films with essential information

Treatment Planning System

- A treatment planning system is supplied by a vendor, as a part of the remote afterloading system. It consists of the hardware (computer, printer, etc.) and the proprietary vendor software to perform the treatment plans. Before first medical use the physicist will test all the features of the treatment planning system to make sure it is operating as designed.

Treatment Planning System

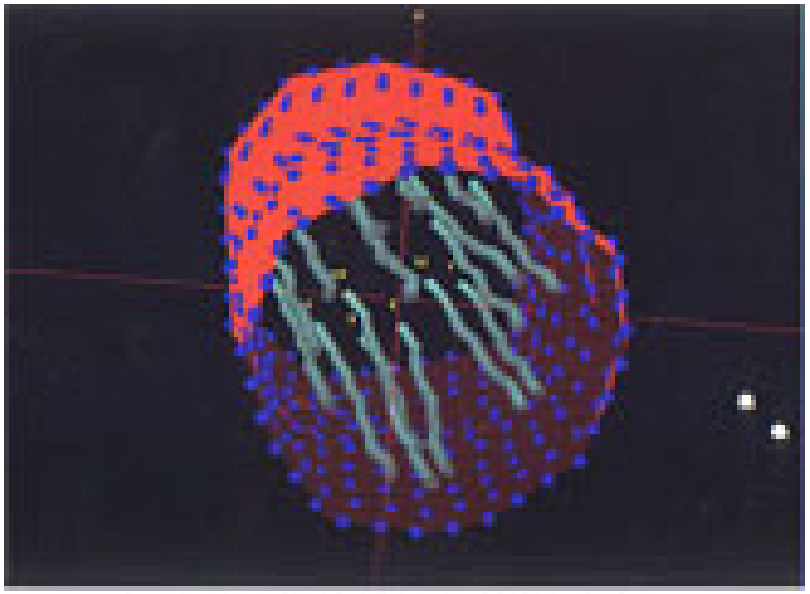
A common denominator to all is that images of the patient with the applicator in treatment position are required for treatment planning. Before taking the images (CTs or x-rays) dummy (inert) metal markers, that emulate all the possible dwell positions for the source, are inserted in the applicator. After the images are taken, and approved by the physician, the dummy markers are removed and the patient is made as comfortable as possible while the physicist uses the images to prepare the treatment plan



"HDR" Ir-192, 3D Planning and Treatment

Treatment Planning System

- The goal of the plan is to use the images to visualize the patient in 3 dimensions and to identify a target volume or organ in that dataset. Next all the possible dwell locations are identified and the planning starts. Using the tools provided in the program, the physicist attempts to find the best combination of dwell positions and dwell times to deliver the prescribed dose to the target while sparing as much normal tissue as possible. All this must be accomplished quickly and accurately.



3D Plan of Prostate (HDR) Implant

HDR QA Program

- Quality Assurance (QA) programs are established to minimize untoward events caused by the malfunction of the machine or human error. Such programs become exceedingly important in HDR brachytherapy because the planning and the treatments tend to happen very quickly, increasing the likelihood of accidents and mistakes.

HDR QA Program

- QA is performed at various intervals: some for each patient, some once each treatment day, and others with each source change. Moreover, for HDR machines, the USNRC (2003) mandates that users meet certain standards, including education and training on operating the machine, emergency procedures, radiation monitoring, pretreatment safety checks, safe and accurate delivery of the treatment, and monthly/initial calibration of the source

HDR QA Program

- Acceptance testing, which is performed upon acquiring the equipment, is different from periodic quality control testing. Acceptance testing is a comprehensive set of tests which allow the physicist to evaluate the behavior and function of the devices

Verification of dose variables

- a. Checking the strength of the source in the console computer, compared with that projected from the initial calibration based on radioactive decay.
- b. Checking the accuracy of the controlling timer

Verification of proper operation of safety features

- a. Checking the electrical interlocks at the treatment room entrance.
- b. Checking the source exposure (detector) indicator lights on the remote afterloader unit, on the control console, and in the treatment room.
- c. Checking the patient viewing monitor and intercom systems.
- d. Check that the emergency response equipment is present.
- e. Check the radiation monitors used to indicate the source position;
- f. Check the clock (date and time) in the console computer.
- g. Checking the operation of a handheld radiation detector.
- h. Checking the operation of the check cable runs and interlocks.
- i. Checking the operation of the emergency off and treatment interrupt buttons

Verification of position control (requires film and a source QA phantom).

- a. Checking that the source goes to the location programmed.
- b. Checking coincidence between the programmed positions and the respective positions indicated by imaging markers.
- c. Checking consistent movement of the source

Additional QC- Some quality control tests are performed monthly by the physicist (although this is no longer required by federal regulations).

- The tests in the daily or pre-treatment QA in addition to the following:

1. Verification of source position and step size with an autoradiograph

a. An x-ray is taken of dummy seed markers in a QA phantom to show the dwell location superimposed on the marker lines of the phantom.

b. The phantom is carefully moved to the treatment area, the dummy marker is removed and the QA phantom is connected

c. The treatment unit is connected to the QA phantom and the source is stepped through different source positions in the phantom, specifically at the location of every other marker. This produces an autoradiograph of the source that overlays every other seed in the dummy wire. The agreement should be within 1 mm.

2. Timer offset, timer accuracy and timer linearity

3. Constancy check of the chamber and calibration

a. Since this is not a full calibration, P_{ion} from the last source change is used.

QC Quarterly

More rigorous quality control tests are performed quarterly, because that is the frequency with which HDR sources are replaced. These tests are only performed by the physicist and include a calibration of the new source.

Source Change

- The half life of Iridium is approximately 74 days. Most service contracts allow for replacement of the source every quarter (approximately 90 days). At this time the 10 Curie source has decayed to about 4 Curie and the treatments take more than twice as long to deliver the same dose compared to a new source.

Calibrations

Title 10 CFR Part 35.633 requires that an authorized medical physicist perform a calibration of the HDR source:

- Before the first medical use of the unit;
- Before medical use under the following conditions:
- Following replacement of the source or following reinstallation of the unit in a new location outside the facility; and
- Following any repair of the unit that includes removal of the source or major repair of the components associated with the source exposure assembly; and
- At intervals not exceeding 1 quarter for high dose-rate, medium dose-rate, and pulsed dose-rate remote afterloader units with sources whose half-life exceeds 75 days; and
- At intervals not exceeding 1 year for low dose-rate remote afterloader units.

Calibrations

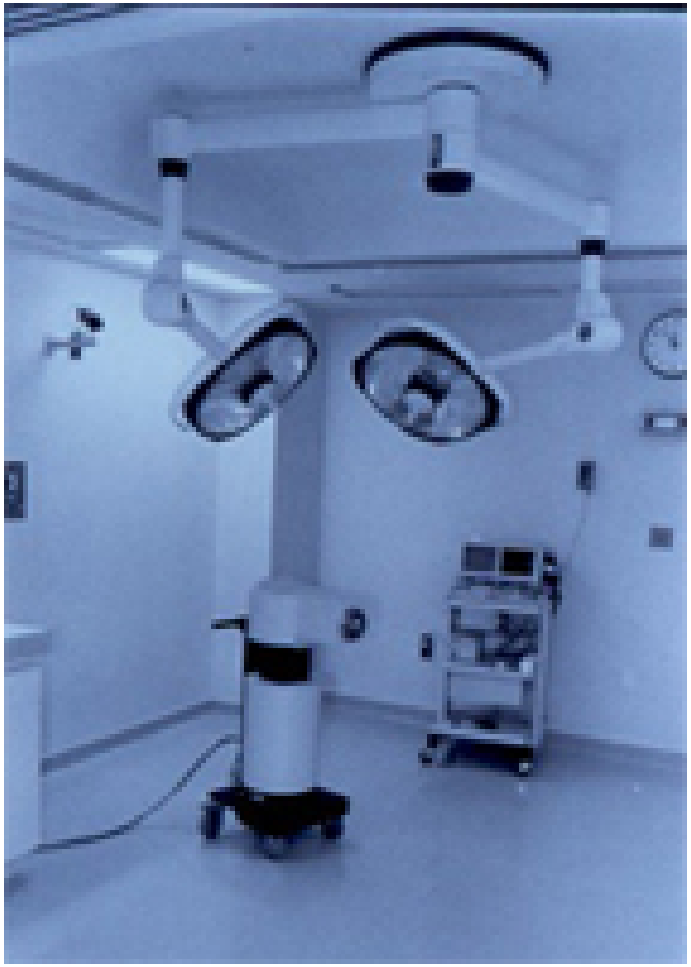
The calibration must include the following:

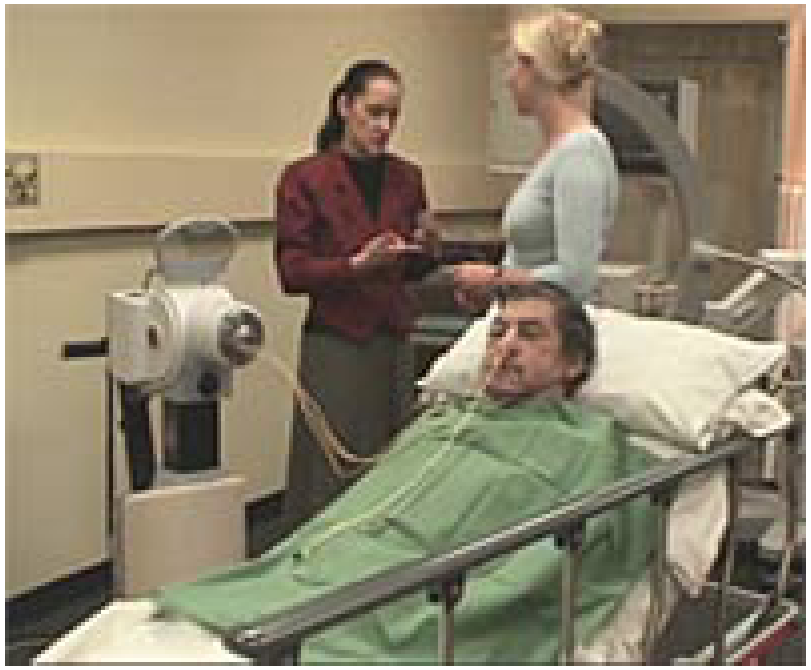
- The output within ± 5 percent;
- Source positioning accuracy to within ±1 millimeter;
- Source retraction with backup battery upon power failure;
- Length of the source transfer tubes;
- Timer accuracy and linearity over the typical range of use;
- Length of the applicators; and
- Function of the source transfer tubes, applicators, and transfer tube-applicator interfaces.

Calibrations

- The source calibration of the HDR Ir-192 is performed in accordance with the AAPM protocol TG21. The calibration quantity that is endorsed by the AAPM is air kerma strength, which is directly related to the dose in the patient.

HDR Room Design





HDR Brachytherapy Workload

The Brachytherapy workload can be calculated with:

$$W = \Gamma \, f_{med} \, A \, t$$

where:

Γ is the gamma constant (0.47 R/(Ci hr) at 1 cm
fmed is the Roentgen to cGy conversion factor (0.96 cGy/R)
A is the activity of the Ir-192 source = 10 Ci
t is
t = (no of pts/week)(ave. treatment time per pt).
and is typically 300 to 400 min/week for a busy site.

HDR Brachytherapy Workload

- An easier method is to multiply the number of treatment minutes per week by the dose rate for HDR (up to 700 cGy per minute). In many shielding calculations 10 Gy/min at 1 cm is used.
- **W = (10 Gy/min)(300 min/wk)**
- **W = 3,000 Gy/wk**

HDR Brachytherapy Workload

- At the console area, the barrier is
- **B = P D2/WUT**
- **B = (1 Gy/wk)(D2)/(3,000 Gy/wk)**

HDR Brachytherapy Workload

- If the distance, D, between the console and the unit is 5 ft, **D = 1.524 m**
- **B = (1.524)(1.524)/3000 = .0007742**
- **NTVL = log10 (1/B) = log10 (1291.7) = 3.11 TVL**
- **NTVL = (3.11)(14.7 cm concrete) = 45.7 cm concrete = 10 in concrete**

Shielding

- Proper design of a high dose rate facility will increase patient safety and comfort, provide adequate space for work and storage, and protect staff from exposure to radiation. The first requirement is radiation safety. Once a potential treatment room is identified or designed, the first consideration is adequate shielding. How much barrier material (typically concrete and/or lead) is necessary? An old cobalt room or linac room is ideal because it usually has much more shielding than is required (since they were designed to house a much more energetic source of radiation). Whether new design or old construction is used, shielding calculations need to be performed to determine what is needed. The same shielding calculations used for external beam are used for high dose rate Brachytherapy

Shielding-The same shielding calculations used for external beam are used for high dose rate Brachytherapy

$$B = P D^2 / WUT$$

B = attenuation required by the barrier
P = permissible dose (2 10-5 Gy/wk)
W = workload in Gy/wk
D= distance from the exposed source in meters
U = fraction of time that a particular wall or area is exposed to radiation (=1 for Brachytherapy)
T = fraction of time someone is on the other side of the barrier (=1 for the console area)

Shielding

Table X. Comparative TVL (cm) Shielding Data for Cesium and Iridium (from NCRP 40 & 49).

Radioisotope	Concrete	Steel	Lead
Cs-137	15.7	5.3	2.1
Ir-192	14.7	4.3	2.0

Shielding

- In Brachytherapy the radiation is (typically) inside the patient, therefore, the amount of exposure near the patient is attenuated by the patient's body. Depending on how close to the surface the radiation is (or how much tissue it has to travel through to reach the skin), the attenuation can vary from 30% (10 cm) to 65% (25 cm) for Iridium. Attenuation by the patient is commonly neglected in shielding calculations. Essentially, we assume that it is a surface application.
- Based on the assumptions made in the shielding calculations, careful consideration of the thickness of the floor and ceilings, and the nature of the occupied areas directly below and above, is needed to determine if supplemental shielding is required.

License Requirements for the Room

- 10 CFR, Part 35.12 addresses the requirements for a new license or license renewal. Part of this requirement is a diagram of the facility. One of the most important elements of the room design is the door. The door must be installed in such a manner that it controls access to the treatment room. That means it can be locked when not in use and can be observed by the operator when it is in use.

License Requirements for the Room

Furthermore the door must have an electrical interlock that will:

- prevent the operator from initiating the treatment cycle unless the treatment room entrance door is closed;
- cause the sealed source to be shielded promptly when the door is opened; and
- prevent the sealed source from being exposed following an interlock interruption until the door is closed and the source “on-off” control is reset at the console.

Security

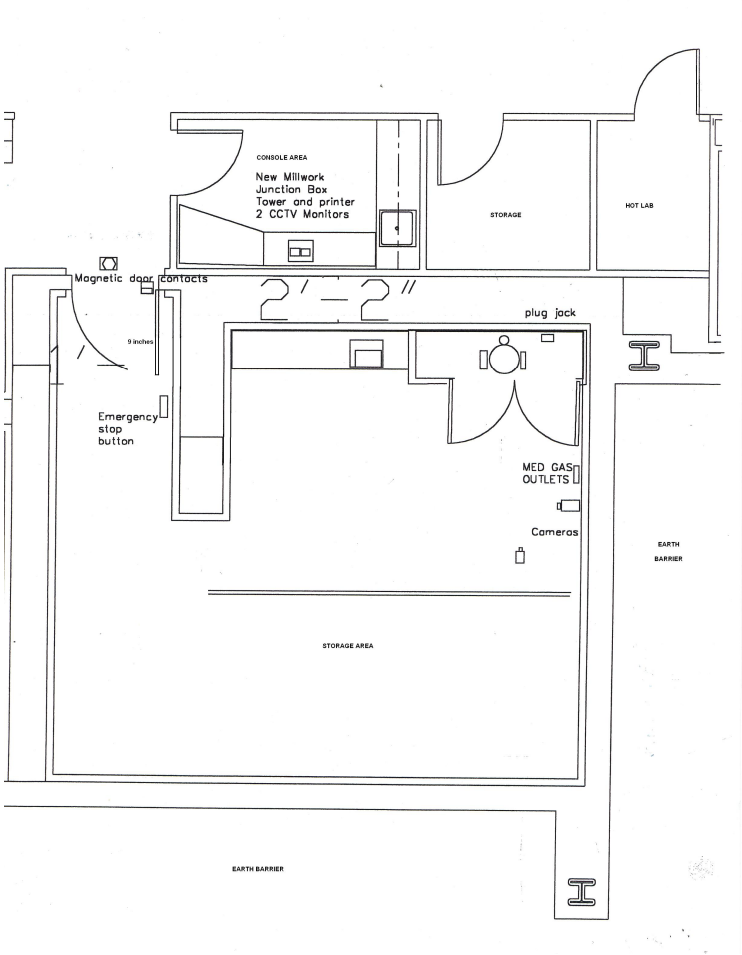
- Security of the sources and the remote afterloader is a major concern. The remote afterloader must be stored behind a locked door. Sources are exchanged quarterly and a new source arrives a few days before the source change is scheduled. This 10 Curie source must be stored in a hot lab or a locked (and properly labeled) room. The decayed source (about 4 Curie) must also be stored until it is shipped back to the manufacturer

Storage

- Storage space is required for the dosimetry equipment used for QA and for the many applicators, transfer tubes and additional apparatus used for treatments. An area to wash the applicators once they are removed from the patient is desirable.

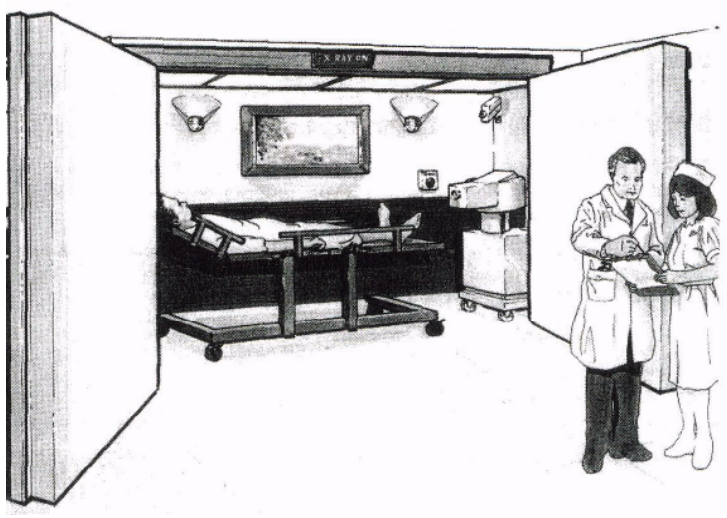
Room Design

- This room has the advantage of a maze that shields anyone entering the room from the remote afterloader unit. It also provides protection for the therapist when he or she is taking x-rays of the patient on the treatment table in the center of the room.



Room

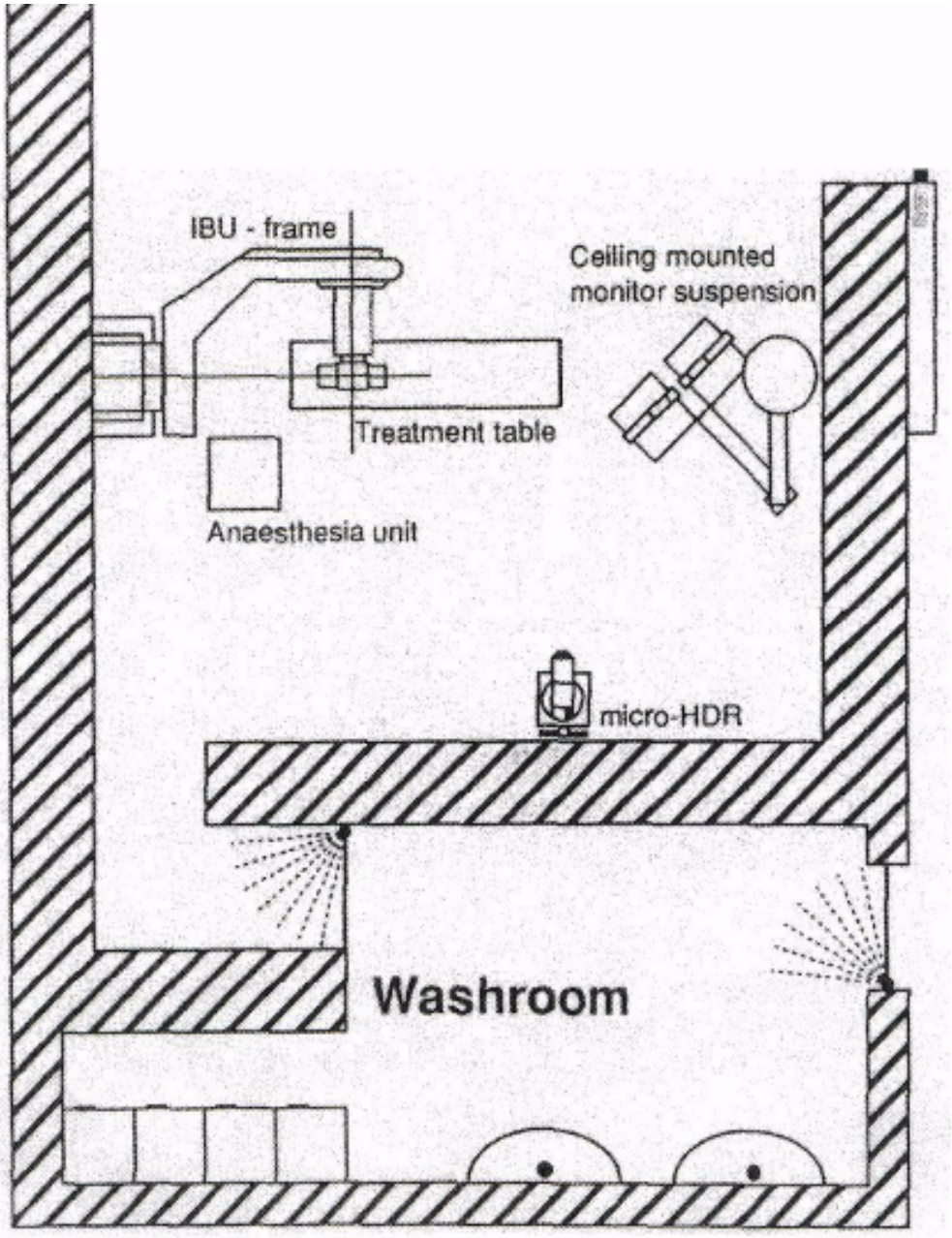
- If your facility has space for HDR, but no vault, NELCO offers a pre-fabricated vault, Figure 9, that can be installed in a space about 100 sq. ft. (7 ft deep by 10.5 ft wide by 8.5 ft high). The 50,000-pound unit, designed for 2-hour weekly source exposure time, has all necessary features of an HDR vault and can be installed in 3 weeks.



Pre-Fab HDR Suite

Integrated brachytherapy unit

- Nucletron features an integrated brachytherapy unit, designed to perform patient preparation, applicator insertion, imaging, isodose computation, delivery, and verification in the unit. The imaging equipment allows fluoroscopy from all directions. The unit is designed for those centers with large brachytherapy services.



Integrated brachytherapy unit

Mobile HDR Facilities

- A mobile HRD remote afterloader unit can service several facilities on the same license or on separate licenses. Each location in the facility where the HDR unit is used must satisfy the same safety and regulatory provisions as a permanent location. Federal technical requirements for a mobile service (USNRC 2002) are described in 10 *CFR* 35.647.
- Two types of vans are available: The "mobile vault" full-service van that contains not only the HDR remote afterloader and ancillary equipment but also the fully shielded treatment vault, and the van that transports only the HDR remote afterloader and limited ancillary equipment

Mobile HDR Facilities

- Applicable transport regulations must be rigorously adhered to and those transporting must have received hazard materials (HAZMAT) training. The van must have antitheft alarms; the HDR remote afterloader cannot be left in the van overnight. The van must satisfy either applicable state or federal Department of Transportation requirements for the transport of radioactive materials. Docking (unloading) facilities (tailgate lifts, dock lifts, etc.) may be necessary for the safe transfer of the HDR remote afterloaders to and from the van at each treatment facility.