Installation and Commissioning of High Dose Rate Brachytherapy Units

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A Roadmap for Installing and Commissioning New Equipment
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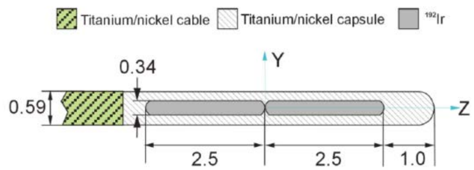
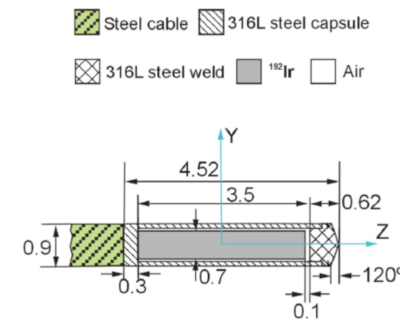
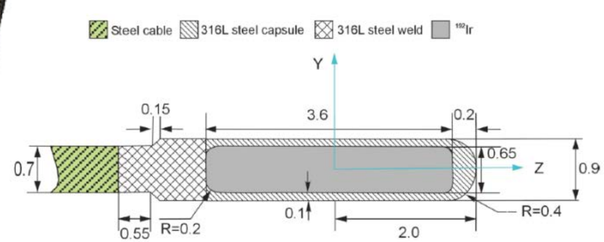
HDR Technology



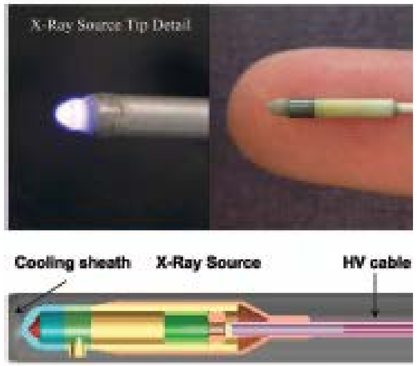
Varian HDR ^{192}Ir model VS2000 source



GammaMed HDR ^{192}Ir model Plus source



Nucletron HDR ^{192}Ir model mHDR-v2 source

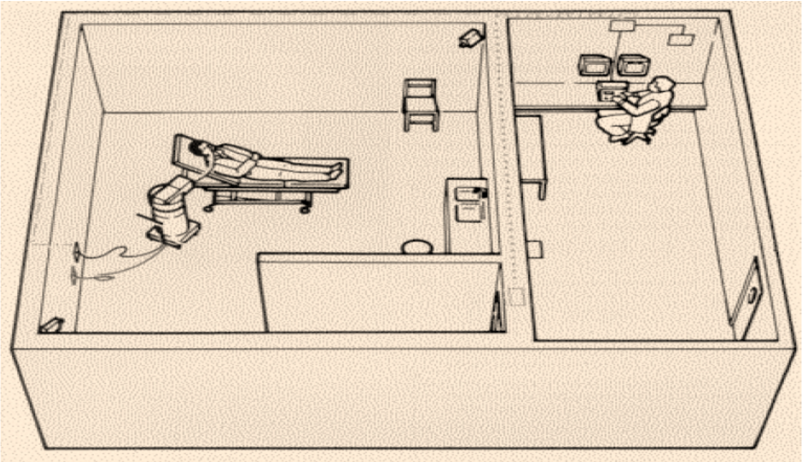


Installation Planning Guide

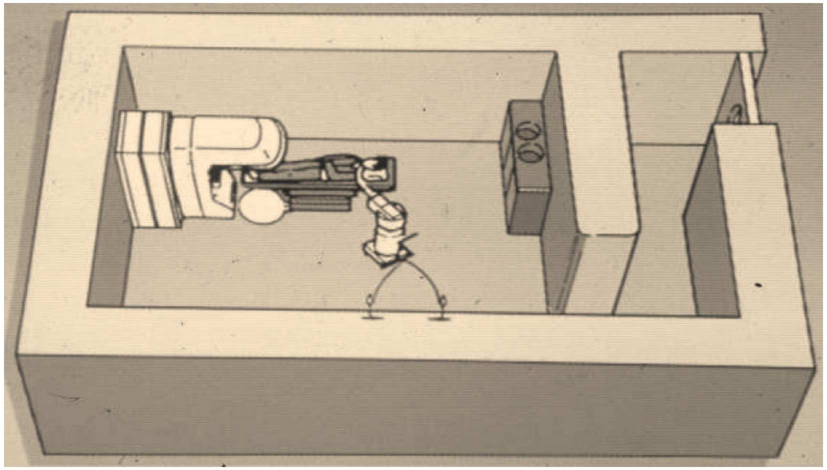
- Site Planning
- Radiation Safety / Shielding
- Purchasing
- Acceptance
- Commissioning
- Development of Quality Control Program
- Training
- Treatment

Site Planning Guide

Design Type	Advantage	Disadvantage
Dedicated vault	•Higher throughput	•Cost •Space
Shared vault with LINAC	•Reduced cost of shielding •Easy adaptation of existing facility	•Reduced use of both LINAC and HDR
Shared vault with simulator	•Combined imaging	•Reduced use of both simulator and HDR



Dedicated Vault

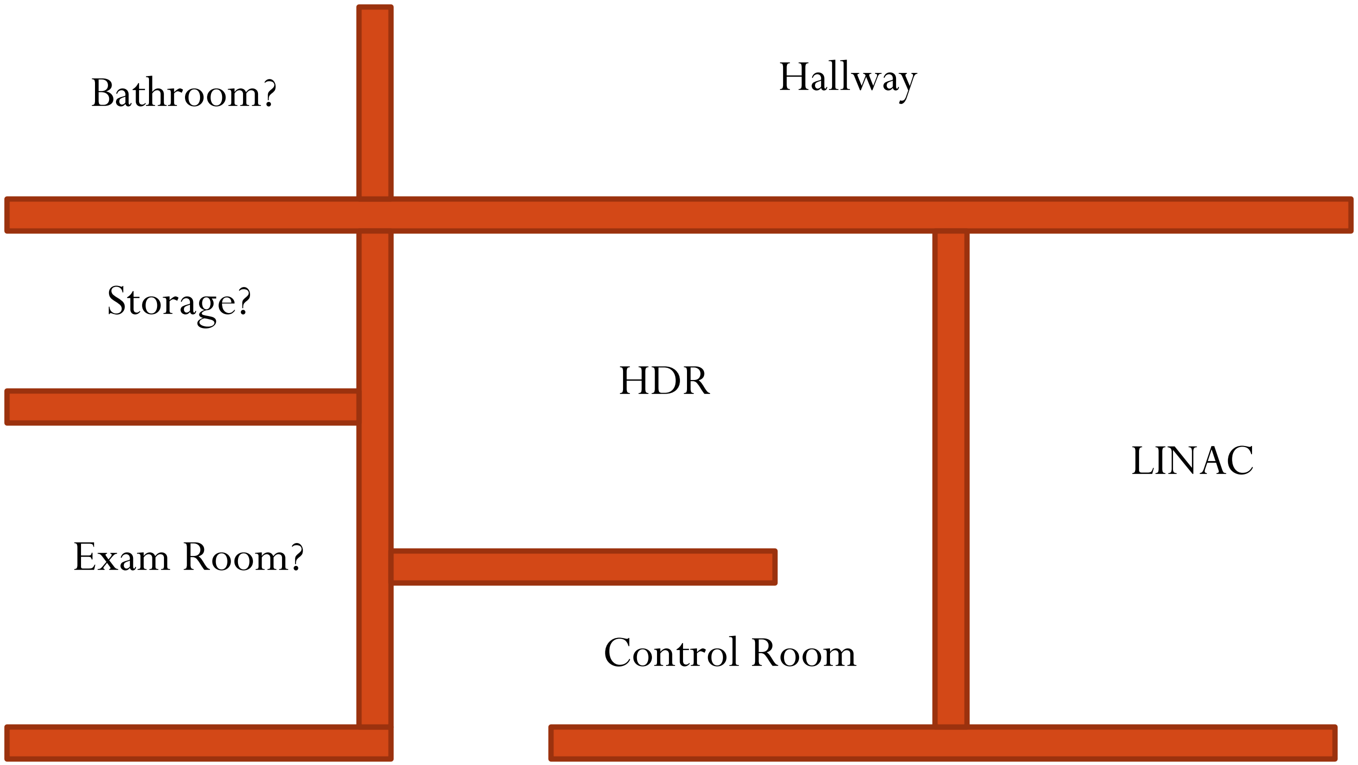


Shared Vault

Site Design Example: Stanford University

- Combined vault with Varian Acuity simulator
- Issues:
  - Simulator imaging not completely used
    - Patients treated on gurney
    - Poor image quality relative to CT
  - Scheduling conflicts between simulations and HDR

Shielding: Strategic Space Organization



$$P = \begin{cases} 0.02\,\dfrac{mSv}{week} & \text{Uncontrolled Areas} \\ 0.10\,\dfrac{mSv}{week} & \text{Controlled Areas} \end{cases}$$

Shielding

$$B = \frac{Pd^2}{WT}$$

$$W = \Gamma f A t \qquad t = \frac{(dose\ per\ patient)(number\ of\ patients\ per\ week)}{(dose\ rate\ at\ 1\ cm)}$$

- Typically need 3 to 4 TVLs of shielding ~ 45-60 cm of concrete, or 4.6-6.4 cm of lead for a 10 Ci Iridium-192 source. In actuality, use a combination of materials to balance cost and space.
- Advantage of electronic brachytherapy (50 kVp): minimal shielding requirements; disadvantage: large source (due to water cooling layer) not suitable for interstitial

Source	TVL Lead	TVL Concrete
50 kVp (Xoft)	0.02 cm	1.4 cm
Iridium-192	1.6 cm	14.8 cm
Cobalt-60	4.2 cm	20.1 cm

Purchasing

- What is the intent of the program?
- Type of afterloader (conventional or electronic brachytherapy, manufacturer)?
- Applicators?
  - Gynecological
    - Cylinders, Miami, Capri
    - Tandem and Ovoid / Tandem and Ring Applicators
    - Interstitial templates (Syed-Neblet) and needles
  - Prostate:
    - Applicators (Mick)
  - Breast
    - MamoSite, SAVI, Contura
  - Skin
    - Surface moulds, Valencia/Leipzig applicators, etc.
  - Others: intraluminal, intravascular, intraop

Purchasing

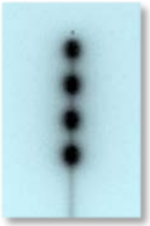
- Type of image guidance?
  - 2D?
  - 3D?
    - CT
    - MRI
  - Real-time?
    - Ultrasound
    - Fluoroscopy
- QA and safety equipment for selected modalities
  - ADCL calibrated well chamber
  - Electrometer
  - Survey meter, Geiger counter
  - Autoradiography tools
  - QA phantoms

Acceptance and Commissioning

- Acceptance:
  - Purpose of acceptance is to test that the HDR unit

1. Meets safety standards
   - Interlocks, signage, emergency functionality, radiation surveys of afterloader

2. Meets contractual specification of the unit.
   - Positional accuracy, timing accuracy, source activity, TPS functionality and integration



- Scope of acceptance tests generally determined by vendor, unless previously agreed upon

Tip: request customer acceptance procedure from vendor prior to acceptance

Acceptance and Commissioning

- Commissioning:

1. Acquire and test accuracy of all system-specific parameters in the treatment planning process

2. Entry of acquired data into to TPS and testing of dossimetric accuracy and end-to-end (E2E) process

3. Development of operational and quality control procedures

4. Training of all staff involved

Tip: Image guidance system, e.g. ultrasound, should ideally be commissioned prior to afterloader for E2E testing

Acceptance and Commissioning

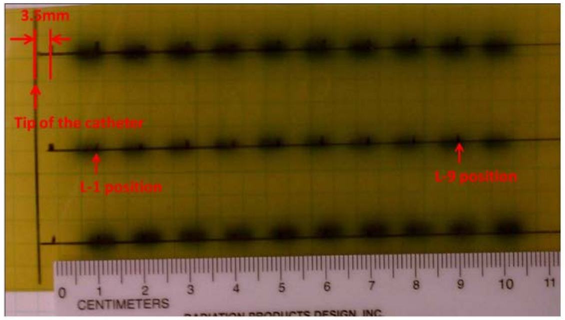
Literature to consult during acceptance and commissioning:

- Procedural
  - AAPM TG-56: Code of practice for brachytherapy physics
  - AAPM TG-41: Remote afterloading technology
  - ACR Practice Guidelines and Technical Standards
- Dosimetry
  - AAPM TG-43 and 43U1
  - AAPM ESTRO HEBD (2012): Dose calculation for high energy photon-emitting brachytherapy sources
  - AAPM TG-186 (2012): Dose calculation beyond TG-43
- TPS
  - AAPM TG-53: Quality assurance of treatment planning system
- Image Guidance
  - AAPM TG-128: QA for brachytherapy ultrasound

Design of Quality Assurance Program for HDR

1. Safety: NRC 35.643 Periodic spot-checks for remote afterloader units (http://www.nrc.gov/reading-rm/doc-collections/cfr/part035/part035-0643.html)

2. Positional < 1mm. Daily check with PVT, autoradiography gold standard



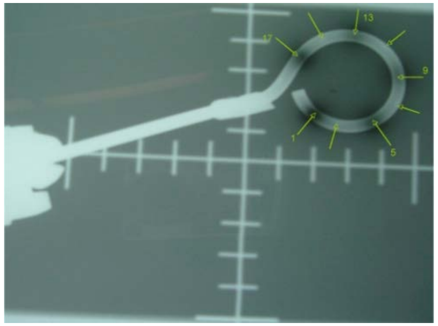
3. Timer < 2%

4. Dosimetry: calibration <3%, TPS < 2%

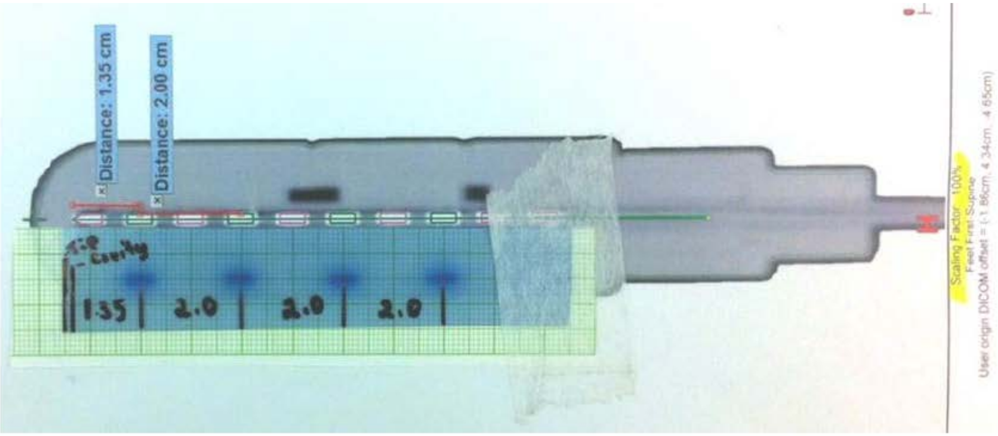
5. Treatment: Pre/post patient survey
    a. Written directive must contain name, the radionuclide, treatment site, dose per fraction, number of fractions, and total dose

Design of Quality Assurance Program for HDR

6. Applicator QA: initially then annually



7. Planning system QA (TG-53), annual or each version upgrade



8. Image guidance QA (TG-128)

Design of Quality Assurance Program: Daily

TG-56:
Core daily QA

Table V. Core daily quality assurance tests for a remote afterloading facility.

Test endpoint	Test methodology	System type
dose delivery accuracy	• Verify date, time and source strength in treatment unit and planning computer.	• all
	• Verify source strength and timer accuracy against a tertiary standard (see text).	• HDR/PDR
overall system function	• Run system through a complete cycle of simulated treatment: - programming; - source ejection; - source retraction at end of timer countdown.	• all
	• Verify treatment status indicator lights and critical source control functions.	• all
	• Correct function of dedicated fluoroscopy/imaging system if present.	• HDR
patient/public/staff safety	• Correct function:	
	- door interlock;	• HDR/PDR
	- area radiation monitor;	• HDR/PDR
	- audio/visual system communication;	• HDR/PDR
	- portable survey meter;	• all
	- audible/visual error and alarm condition indicators;	• all
	• Safety equipment available: - emergency instructions; - emergency equipment (forceps, emergency safe, surgical supplies); - operator's manual; - survey meter.	• all
	• Measure hourly/weekly radiation levels after patient loaded and portable shields positioned	• PDR/LDR
verify positional accuracy within 1 mm	Many possible tests: - primary positional accuracy test for a single catheter; - deviation of ion chamber response placed near a programmed dwell position; - multiple-channel autoradiograph of every active dwell position used in the patient treatment and compare programmed position to expected; - visually check that relative position of source tip in a ruled catheter reproduces from day-to-day.	• all
	• Autoradiograph patient-specific configuration of sources loaded into intermediate safe of device.	• all fixed and programmable source-train units
temporal accuracy	• Many possible tests: - time duration of "source ejected" light; - perform a spot check of radiation output for a timed interval using tertiary calibration standard jig; - compare source arrival and departure times on printed treatment documentation with a clock or stop watch;	• HDR/PDR
	- for LDR, subtract treatment interruptions from overall treatment time and compare to programmed time.	• LDR (optional)

Design of Quality Assurance Program: Quarterly

TG-56:
Core quarterly QA

Table VI. Additional core quarterly quality assurance tests for a remote afterloading facility.

General endpoint	Specific tests/endpoints	System type
personnel safety	Head/machine survey with source retracted[a]	• all
patient safety	•Important interlocks and emergency response systems function: obstructed applicator, missing applicator, door, unlocked indexer ring, displacement, power/air pressure loss, backup battery system.	• all
	•Emergency source handling tools, shielded storage container, and supplies for emergency applicator removal available and functioning.	• all
calibration of optical and pneumatic source position/status detection systems; any other preventive maintenance or inspections	•As specified by vendor.	• all
correct operation of all applicators, transfer tubes and source localization dummies	•Examine all dummies for kinks or bends that may shorten their axial displacement through applicator assembly. Check integrity of all transfer tube-applicator interfaces.	• all
positional accuracy: single stepping source	•Verify that radioactive source position agrees with dummy marker within 0.5 mm previously tested against dwell position markers used in simulation.	all HDR/PDR single-stepping source devices
	• Confirm check cable operation.	
	• Obtain multiple channel autoradiograph with unique dwell sequence in each channel: verify that dwell position spacing, assignment of dwell sequence to programmed channel, and relative indexer length to dwell 1 are correct within 1 mm.	
	•Confirm accuracy of daily positional test protocol.	
	•Transfer tube length (if stability through time is not confirmed and positional accuracy is influenced by tube length).	
positional accuracy: multiple-source machines	•Device positions source train in specified treatment location.	• all
	•Source trains delivered to programmed channels within 1 mm of intended location.	• all
	•Source trains correctly sorted and composed.	• programmable source train
	•Source inventory correct.	• all
	•Source trains stored in correct locations in user accessible storage location.	• fixed source-train devices
source calibration	Measure source air kerma strength using a 'secondary' standard as described in Sec. III.	HDR/PDR
redundant source calibration checks	•Difference between measured and vendor-specified air kerma strength is within expected margin.	• HDR/PDR
	•Use tertiary source strength standard (e.g., daily/monthly output checking system) to confirm primary calibration within 5%. Different electrometerand detector to be used.	
• spot check of absolute timer accuracy	Various techniques available (Williamson, 1991 and 1994).	• all LDR
• timer accuracy and linearity measurement		• HDR/PDR
miscellaneous	•Update source strength in treatment planning computer initialization file, treatment unit and quarterly inventory.	• all
	•Have a second physicist independently review the quarterly report.	• HDR/PDR

[a]In addition, NRC requires a complete facility survey whenever an HDR or PDR source is replaced.

Thank You!