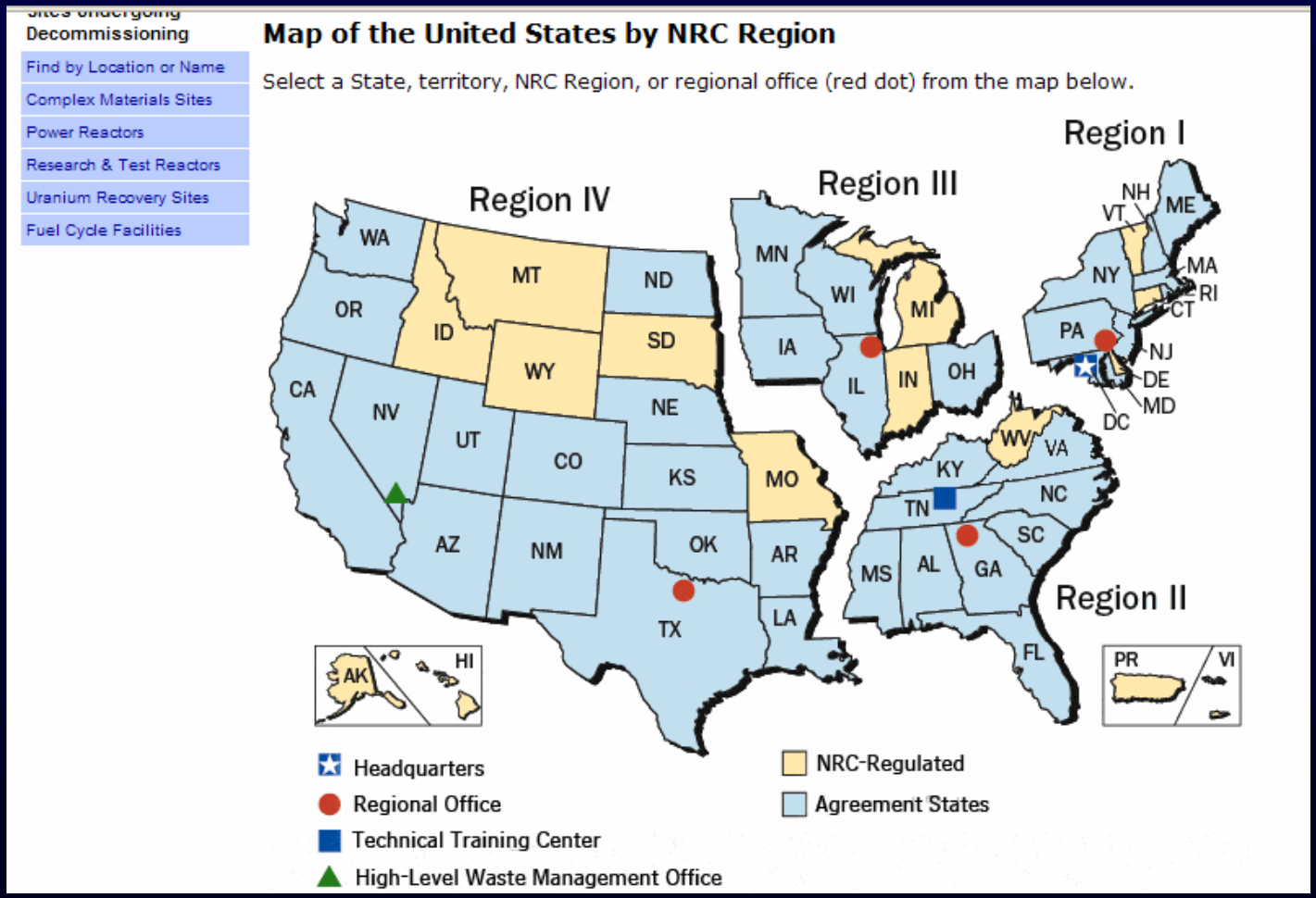
Section 3: Brachytherapy Physics

HDR Installation, Commissioning, and Procedures

NRC States


Decommissioning
Find by Location or Name
Complex Materials Sites
Power Reactors
Research & Test Reactors
Uranium Recovery Sites
Fuel Cycle Facilities
Map of the United States by NRC Region
Select a State, territory, NRC Region, or regional office (red dot) from the map below.
Region I
Region II
Region III
Region IV
WA
OR
CA
ID
NV
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RI
CT
NJ
DE
MD
DC
AK
HI
PR
VI
Headquarters
Regional Office
Technical Training Center
High-Level Waste Management Office
NRC-Regulated
Agreement States

HDR definition

- NRC definition of a remote afterloader:
  - A brachytherapy device that remotely delivers a dose rate in excess of 12 Gray per hour to a point or surface where dose is prescribed
- 10 CFR 35.2

Required Equipment

- HDR Unit
- Applicators
- TPS
- Well chamber
- Electrometer
- Survey meters
- Other safety equipment

Where will the unit reside?

- Dedicated suite
- Shared with Linac/simulator
- Depends on patient load, financial constraints, spatial constraints
- Close to other imaging rooms for ease of CT/MR acquisition

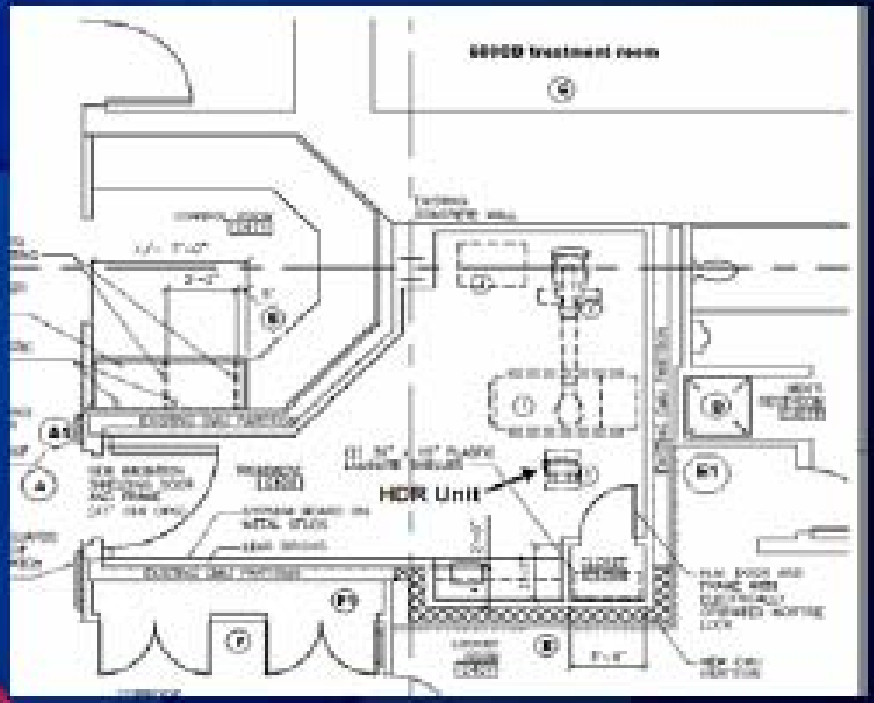
Shielding

- LDR
  - Where will the patient stay during treatment?
  - Shielded hospital rooms
  - Vacating nearby rooms
  - Portable shields
- HDR
  - Shielded vault
    - Typically 0.3-0.6 m concrete or 4-5 cm of Lead
  - Proximity to offices, etc

Room Shielding

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

- B – barrier transmission factor
- P – max permissible weekly dose
- d – distance from source to point of interest
- W – workload
- T – occupancy factor



Dictated by the NCRP, 20 μGy/hr.

Aver # pt's per week x air kerma rate @ 1 m.

#HVL = -ln(B); #TVL = -log(B)

P. McGinley, Shielding Techniques for Radiation Oncology Facilities, 2nd Edition, Medical Physics Publishing, 2002.

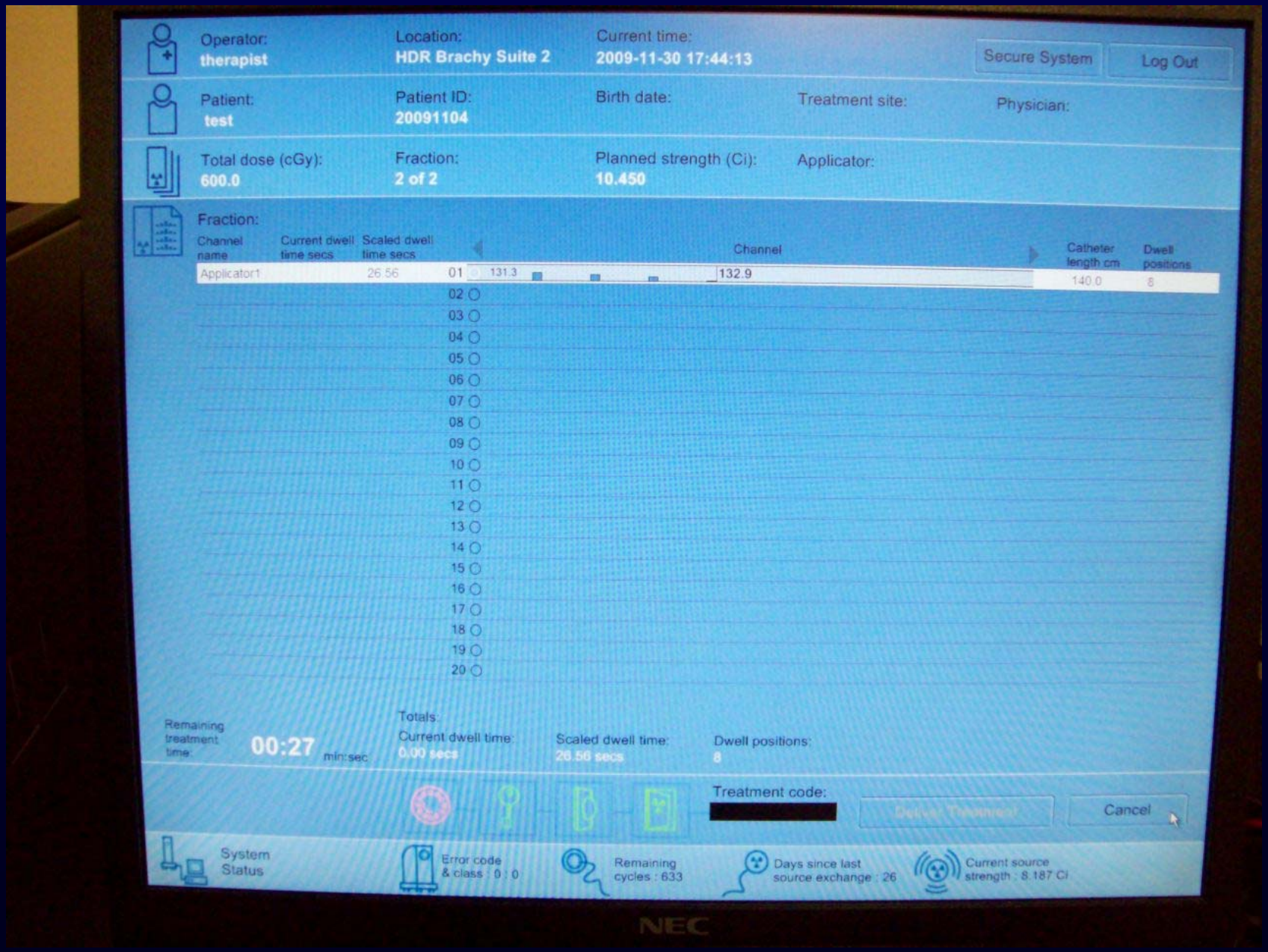
NRC Licensing

- According to 10CFR35, the licensee must provide the following:
  - Facility diagram w shielding
  - Information on equipment
  - Training and experience of the RSO, AU, and AMPs
  - Radiation safety precautions and instructions
  - Methodology for measurement of dosage
  - Calibration, maintenance, and repair of instruments and equipment necessary for radiation safety

Commissioning of the Varian VariSource 200 RAU

- Survey of RAU
- Verification of vendor's stated source strength (Physics residents please refer to Goetsch article: Calibration of 192Ir high-dose-rate afterloading systems. *Med Phys*, *18*(3), 462-467.)
- Positional accuracy
- Timer test
- Interlocks, beam-on lights, audio-visual
- Room survey (Check the room shielding)
- QA procedures (daily/source exchange)
- Emergency Procedures (AU and AMP directly responsible, but all personnel trained)
- Training (Emergency and Operation)

Safety features


Operator:
therapist
Location:
HDR Brachy Suite 2
Current time:
2009-11-30 17:44:13
Secure System
Log Out
Patient:
test
Patient ID:
20091104
Birth date:
Treatment site:
Physician:
Total dose (cGy):
600.0
Fraction:
2 of 2
Planned strength (Ci):
10.450
Applicator:
Fraction:
Channel name
Current dwell time secs
Scaled dwell time secs
Channel
Catheter length cm
Dwell positions
Applicator1
26.56
01
131.3
132.9
140.0
8
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
20
Remaining treatment time:
00:27
min:sec
Totals:
Current dwell time:
0.00 secs
Scaled dwell time:
26.56 secs
Dwell positions:
8
Treatment code:
Cancel
System Status
Error code & class : 0 : 0
Remaining cycles : 633
Days since last source exchange : 26
Current source strength : 8.187 Ci
NEC

Daily QA

- Functionality of safety interlocks
- Emergency equipment
- Detectors/survey equipment functional
- Camera and Intercom equipment
- Correct date, decay factor, time

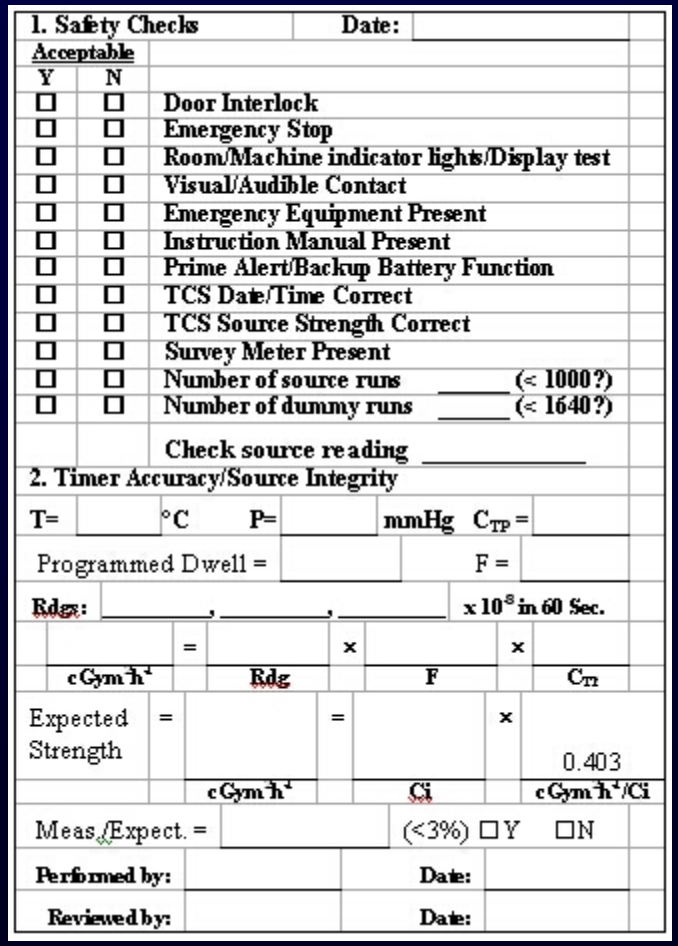
Source Exchange Parameters

- Source calibration (within 5%)
- Source positional accuracy (within 1 mm)
- Safety Checks
  - Emergency stops
  - Door
  - Lights/warnings/alarms
- Timer accuracy/linearity
- Applicator/transfer tube lengths and condition
- Other tests:
  - Catheter misconnect
  - Obstruction detection
  - Back up battery test

Source positional accuracy

QA (After Commissioning…)

- Frequency of tests (daily, source exchange, repair)
- Types of tests
- Specified in Title 10 Code of Federal Regulations (CFR) Part 35 entitled Medical Use of Byproduct Materials (Section 600 pertains to RAU)
- www.nrc.gov



1. Safety Checks		Date:	
Acceptable			
Y	N		
☐	☐	Door Interlock	
☐	☐	Emergency Stop	
☐	☐	Room/Machine indicator lights/Display test	
☐	☐	Visual/Audible Contact	
☐	☐	Emergency Equipment Present	
☐	☐	Instruction Manual Present	
☐	☐	Prime Alert/Backup Battery Function	
☐	☐	TCS Date/Time Correct	
☐	☐	TCS Source Strength Correct	
☐	☐	Survey Meter Present	
☐	☐	Number of source runs _____ (< 1000?)	
☐	☐	Number of dummy runs _____ (< 1640?)	
		Check source reading _____	
2. Timer Accuracy/Source Integrity			
T=	°C	P= mmHg	C_{TP} =
Programmed Dwell =		F =	
Rdgs: _____, _____, _____		x 10^{-8} in 60 Sec.	
	=	×	×
cGym^{-2}h^{-1}	Rdg	F	C_{TP}
Expected Strength	=	=	× 0.403
	cGym^{-2}h^{-1}	Ci	cGym^{-2}h^{-1}/Ci
Meas./Expect. =		(<3%) ☐Y	☐N
Performed by:		Date:	
Reviewed by:		Date:	

TG59 – HDR program

- The nature of HDR means one goal is to minimize time the applicator remains in the patient
- This must be done carefully…
  - Develop formal, written procedures
  - Exploit redundancy
  - Explore quality improvement techniques
  - Teamwork, efficiency, experience

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TABLE XI. Essential physics and QA duties during applicator insertion.

System tested	Test end point	Test methodology
Applicator identity	Applicator type and dimensions (e.g., cylinder or colpostat diameter) consistent with clinician's intent	Hand requested applicator to physician, make certain physician knows which one is inserted into patient and is compatible with selected modality (HDR, LDR, Manual, etc.)
	Limitations of afterloader respected	Adequate distal margin and proximal leader to allow connection to treatment unit. Treatment volume within programmable range. Catheters not kinked or constricted during insertion.
Applicator insertion	All adapters, radiographic markers, clamps correctly assembled	Direct visualization
Location of target volume	Operating room data relevant to defining distal- and proximal-most dwell positions in each catheter identified	Ask radiation oncologist how target volume/area is identified. Record all relevant information, e.g., surgical clip location, bronchoscope insertion depth to tumor margin, radiographic landmarks, etc.
Treatment record	Inserted applicators accurately recorded	Verify diagram drawn against observations

Required reading for physics residents…

The specific review of each plan should begin with verification of input data, including:

(1) name of patient and date of treatment;
(2) source strength matches the decayed value;
(3) correct system file (including, e.g., calibration data) used;
(4) magnification factors, source-film distances, etc.;
(5) source position reconstruction algorithm used was consistent with the simulation radiograph geometry;
(6) units of all quantities;
(7) step size (or length);
(8) optimization scheme and prescription criterion chosen are consistent with implant geometry and clinical intent;
(9) dose per fraction matches the treatment prescription;
(10) reconstructed implant geometry matches radiographic projections;
(11) distance from machine reference point to distal-most dwell location;
(12) dwell times and locations programmed in the treatment unit match those on the plan;
(13) Correctness of treatment unit programs recalled for treatment of subsequent fractions, including handling of decay corrections. The GammaMed HDR Treatment Planning and Treatment Delivery system handles source decay in a unique way. All treatment plans created by the GammaMed computer planning system uti-

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TABLE XIV. Critical steps in the treatment planning process. The individual listed first (primary) is responsible for executing the activity while the second individual (secondary) is responsible for verifying the procedure.

Primary/secondary individual	Activity	Methodology
Physicist/Dosimetrist	Review treatment planningprocedure	Physicist reviews with dosimetrist: which written procedure, if any, to be followed. or identifies reconstruction, optimization, dose specification procedures to be used for this case
Dosimetrist/Physicist	Active dwell positions localization	If standard pattern used (e.g., intracavitary implant), procedure type and protocol identified Channel numbers matched to radiographic image, treatment length, and first and last dwell positions in each catheter calculated. Physicist to review.
Dosimetrist	Verify plan input data	Compare patient name on prescription, radiographs, localization data, and HDR treatment schedule Confirm date/time displayed on RTP, and that displayed source strength agrees with source inventory or chart Check entered daily dose against prescription, for each catheter check length, dwell spacing, and active dwell position numbers against localization protocol or planning procedure Check radiograph orientations, distances, magnifications, and gantry angles against requirements for selected source position reconstruction algorithm
Radiation oncologist	Assess clinical adequacy of plan Accept or reject plan	Intended volume treated to desired dose Optimization goals and constraints satisfied

TABLE XV. Pretreatment physicist review of HDR treatment plan and dwell-time calculations.

End point	Check methodology
Patient identity	Compare patient names/numbers/dates printed on prescription, simulator radiographs, chart, and localization form
Input data	As described in text
Positional accuracy/ Implant geometry	Applicators modeled in treatment plan match those of operating room description and implant diagram Verify matching and localization calculations against radiographs if interstitial ortransluminal implant. Compare active dwell positions, dwell separation, and treatment length listed on computer plan to localization form or to appropriate treatment planning procedure. Compare three orthogonal dimensions of implant measured from AP and lateral radiographs to corresponding dimensions of graphic plan. Check radiograph orientations, distances, magnifications, and gantry anglesagainst requirements for selected source position reconstruction algorithm.
Plan optimization process	Appropriate optimization option used. Dose optimization and dose specification points in correct location relative to dwell positions on graphic plan. Expected isodose curve passes through dose specification points. Optimization algorithm produces expected distribution of dwell weights, coverage of target volume, and distribution/ magnitude of hot spots or peripheral/central minimum dose ratio. Implant quality parameters derived from dose-volume histograms, if available and previously validated, should be checked.
Dose calculation accuracy	(RAK)/dose ratio falls within expected range. Assuming distribution of dwell times on computer plan printout, manually calculated dose agrees with dose calculated by RTP system within expected tolerance. Doses at clinically important points of interest agree with values interpolated from isodoses. Isodose curves calculated in appropriate planes.
Clinical adequacy	Prescribed dose, applicator selected, and dose distribution consistent with Policies of Treatment for patient's disease or physicist's understanding of physician's clinical intent. Volume covered by prescription isodose surface consistent with all known target localization data. Maximum dose and dose to critical anatomic structures, including previously administered therapy, within accepted range.
Daily treatment record	Source strength, total dwell time, total IRAK, no. and type of applicators correctly entered into daily treatment record.

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TABLE XVII. Post-treatment QA checks.

End point	Individual	Methodology
Patient/personnel safety	Operator	Area monitor checked before entering the room. Enter room leading with survey instrument to confirm complete retraction of source HDR device shut down and secured after patient removed
Treatment accuracy	Operator	Fill in daily treatment record. Compare total dwell time on treatment unit printout agrees with calculation.
Chart order	Operator	All forms and checklists complete and properly filed in chart.

Why so many rules?
Aka the “Omnitron” incident

NUREG–1480

Loss of an Iridium–192 Source and Therapy Misadministration at Indiana Regional Cancer Center Indiana, Pennsylvania, on November 16, 1992

What happened?

- Patient was treated on Nov 16, 1992 and died on Nov 21.
- Patient had 5 catheters for her treatment with a 4.3 Ci source
  - Dummy wire went through all 5 catheters initially
  - Treatment wire treated 4 catheters
  - After multiple attempts to put the source wire in the 5th catheter, the treatment was aborted

Cont…

- An area monitor was observed by 3 technologists and a physician being in an “alarmed” state at multiple times when the source should have been parked
- No one conducted a radiation survey despite the availability of a survey meter
- Console indicator said “safe”
- Sent the patient back their nursing home

Cont…

- After a few days, the catheter came loose and was discarded by the nursing staff at the nursing home
- Went in a “red bag” which was picked up by disposal and sent to medical waste facility
- Source was detected on Nov 30th by the waste management system

Cont.

- No other patients had been treated in this time with the first source
- A second source broke at another facility on Dec 1. The medical physicist promptly was aware and acted appropriately to retrieve the source and no unnecessary exposures were reported
- Determined cause was degredation of the teflon in the presence of moisture which releases hydrogen flouride that erodes the nitinol encapsulation

Cont…

- Cause of death: Acute radiation exposure
- 94 other persons were irradiated
- Human error, not following procedures, lack of training, and rapid expansion of the facility from 1 to 10 centers were all attributed to the cause.

Other readings

- ICRP PUBLICATION 97 PREVENTION OF HIGH-DOSE-RATE BRACHYTHERAPY ACCIDENTS
  - More than 500 HDR accidents (including one death) have been reported along the entire chain of procedures from source packing to delivery of dose. Human error has been the prime cause of radiation events. In the present report, the International Commission on Radiological Protection concludes that many accidents could have been prevented if staff had had functional monitoring equipment and paid attention to the results.

Other reading…

NUREG/CR–6125
Vol. 2

Human Factors Evaluation of
Remote Afterloading Brachytherapy

Table 5. Distribution of Human Error in Brachytherapy

Misadministrations in Relation to RAB Functions and Tasks

Function/Task	Number of Misadministrations	Description of Human Error
I. Patient Preparation		
1. Patient scheduling, identification and tracking	1	Misidentify patient
2. Patient instruction	0	
3. Life support monitoring	0	
4. Applicator placement and stabilization	0	
5. Patient transportation	0	
II. Treatment Planning		
1. Simulation with dummy sources	0	
2. Target volume localization	1	Poor mapping of target volume to tumor
3. Radiation prescription	0	
4. Dwell position localization	2	Interpretation of imaging data inaccurate
5. Dosimetry	4	Dose calculation error
6. Treatment plan selection and approval	1	Fail to independently verify plan
III. Treatment Delivery		
1. Treatment set-up	4	Wrong treatment site Wrong number of sources loaded Wrong activity sources loaded
2. Treatment plan entry	4	Misenter plan values Wrong treatment site
3. Verify treatment data prior to treatment	1	Fail to verify plan
4. Treatment session monitoring	5	Wrong source placement in applicator Fail to detect dislodged source
5. Treatment session control	0	

IV. Post-Treatment			
1.	Source guide tube disconnection	0	
2.	Applicator removal	0	
3.	Patient transportation	0	
4.	Treatment verification	0	
5.	Record-keeping	4	Fail to account for all sources Fail to maintain adequate records
V.	Quality Assurance and Maintenance		
1.	Source exchange	1	Improper packaging of source
2.	Source calibration	1	Calibration units different
3.	Equipment and software updates	0	
4.	Troubleshooting	0	
5.	Routine quality assurance	1	Fail to perform radiation survey
Total		30	

Table 7. RAB Staff Judgments of Workload Factors

RAB Type	Treatment Planning: Time Pressure	Treatment Planning: Mental Effort	Treatment Planning: Stress	Treatment Delivery: Time Pressure	Treatment Delivery: Mental Effort	Treatment Delivery: Stress	Mean
HDR	2.0	2.6	2.1	1.7	2.3	1.8	2.1
LDR	2.0	2.2	1.5	2.0	2.2	1.8	1.9
Mean	2.0	2.5	2.0	1.8	2.3	1.8	

Note: Responses were made using a 3-point rating scale. A score of 1 corresponds to a perceived low level of the workload factor, 2 corresponds to a moderate level, and 3 corresponds to a high level.

Table 8. RAB Staff Judgments of Workload Factors by Job Category

Job Category	Treatment Planning: Time Pressure	Treatment Planning: Mental Effort	Treatment Planning: Stress	Treatment Delivery: Time Pressure	Treatment Delivery: Mental Effort	Treatment Delivery: Stress	Mean
Oncologists	2.0	2.4	1.8	1.5	1.8	1.5	1.8
Physicists	2.1	2.6	2.2	1.8	2.3	1.9	2.1
Radiation Therapy Technologists	2.0	2.5	1.8	1.9	2.4	1.7	2.1

Note: Staff judgments were made using a 3-point rating scale. A score of 1 corresponds to a low level of the indicated activity or perception, 2 corresponds to a moderate level, and 3 corresponds to a high level.

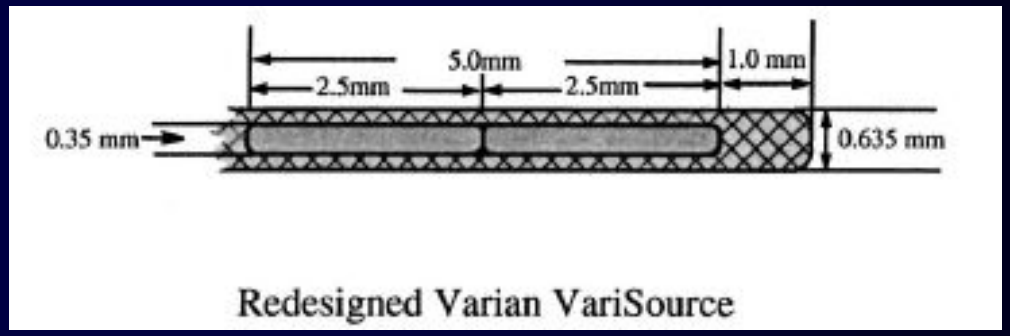
No.	Step Description	Info Input	Control Output	System Feedback	Possible Errors	L(E)
1	Receive and identify patient to be treated	Patient ID. Scheduled patient. Scheduled treatment.	Identification of patient		Mismatch patient and treatment session	Low
2	Instruct patient on treatment session event sequence and desired patient responses	Patient understanding and capabilities; Expected treatment session scenario	Treatment session events	Patient acknowledges instruction	Fail to instruct patient	Low
3	Place patient in treatment location and attach patient support equipment	Patient support equipment needed	Location of patient		Fail to attach all patient support equipment	Low
4	Move afterloader unit into treatment position		Locate trolley source head within range of patient		Do not position afterloader properly	Low
5	Activate afterloader brake	Proximity to patient	Press Brake switch	Brake Lock light illuminates	Do not activate brake	Low
6	Adjust source head elevation and orientation	Proximity to patient	Press Head switch	Head raises or lowers; Up or Down light on	Do not orient source head properly	Low
7	Connect patient's applicators to appropriate afterloader channels with source guide tubes	Map of afterloader channel – applicator connections desired	Connect each applicator to its correct source guide tube	Source guide tubes snap into seated position of applicators	Mismatch source guide tubes to patient applicators	Med

About the Varian VariSource 200

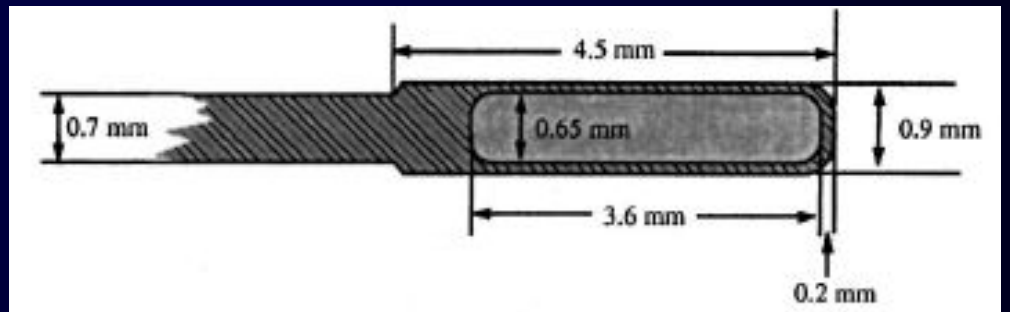
- 20 channels
- Step size of 2-99 mm, 1 mm increments
- One active source, one dummy source
- 1000 active runs
- 1640 dummy runs
- Crank located on the side for retracting active wire

About the HDR Source

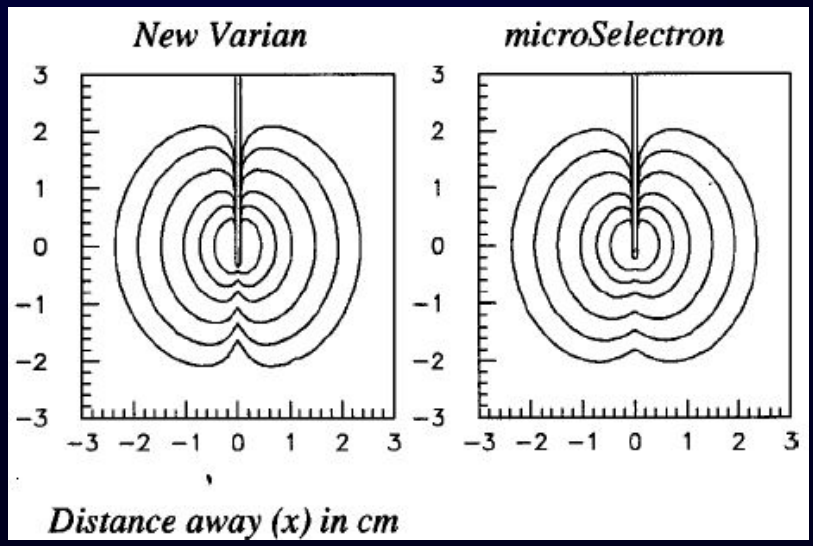
- Refer to source as the "wire"
- Ni-Ti wire
- 0.1 cm Ni-Ti encapsulation
- 2 - 0.25cm Ir-seeds
- Greater anisotropy at the distal tip of the source



Redesigned Varian VariSource

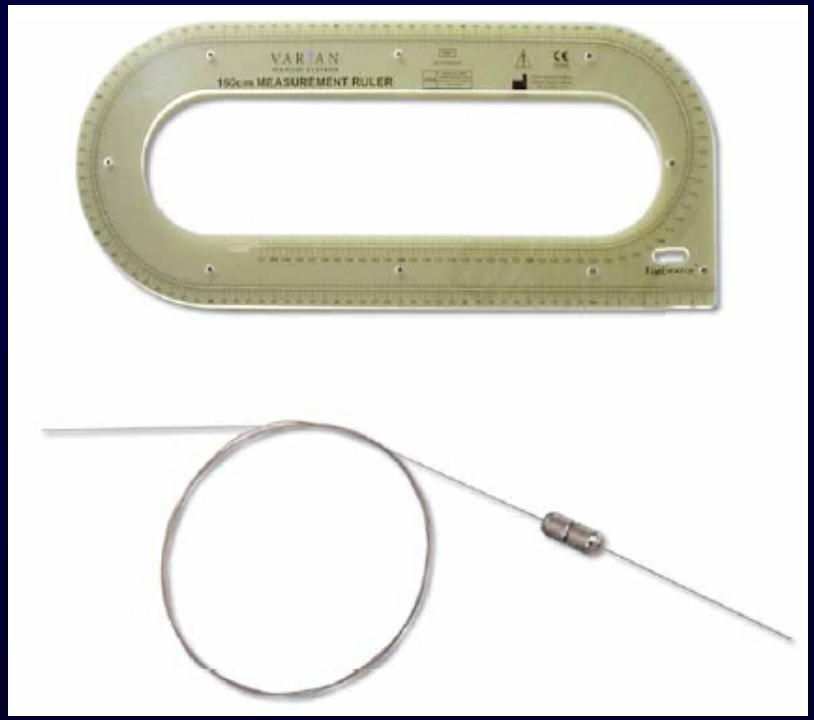


Redesigned Nucletron MicroSelectron



Commissioning of the Applicators + TGTs

- Measurement of treatment length inside applicator + TGT
- Ruler using a dummy wire
- Called the SPS (source position simulator) for Nucletron

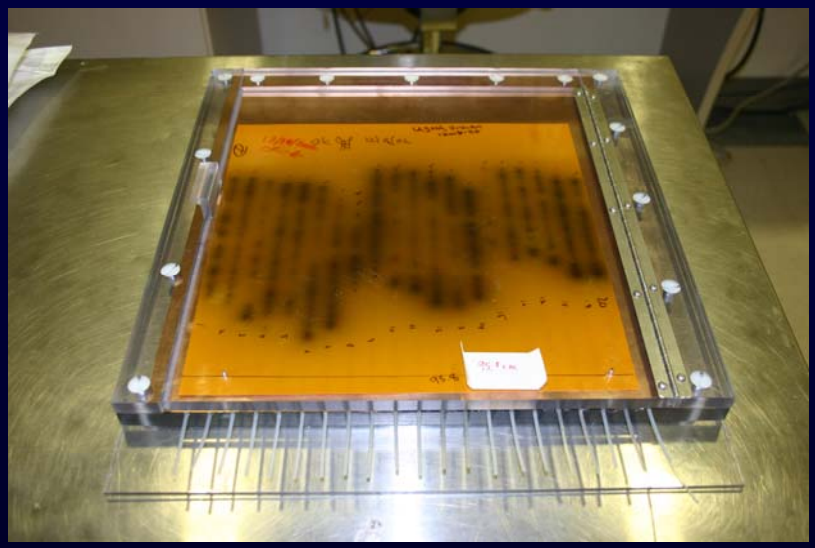


Audioradiography

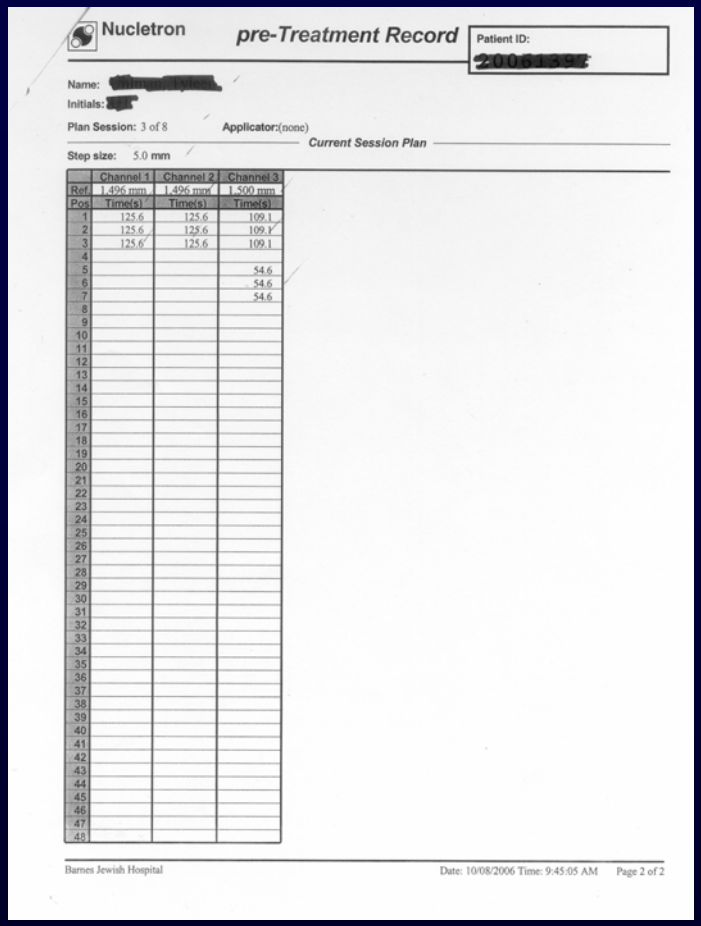
- Examine distribution of radioactivity in the source itself
- Records position of the source relative to the end of the transfer cable
- Record relative position of each source in a source train
- Check the reproducibility of source positions when inserted into catheters, needles, or applicators
- Every new device should be autoradiographed prior to use and as routine QA

Commissioning of Autoradiograph Jigs for Varian

- Verify programming of interstitial and GYN intracavitary treatments
- Verifying integrity of TGTs
- Verify positional accuracy of source



Utility of the Autoradiograph



Nucletron **pre-Treatment Record** Patient ID: [redacted]

Name: [redacted]

Initials: [redacted]

Plan Session: 3 of 8 Applicator:(none)

Current Session Plan

Step size: 5.0 mm

Ref. Pos	Channel 1 1.496 mm Time(s)	Channel 2 1.496 mm Time(s)	Channel 3 1.500 mm Time(s)
1	125.6	125.6	109.1
2	125.6	125.6	109.1
3	125.6	125.6	109.1
4			
5			54.6
6			54.6
7			54.6
8			
9			
10			
11			
12			
13			
14			
15			
16			
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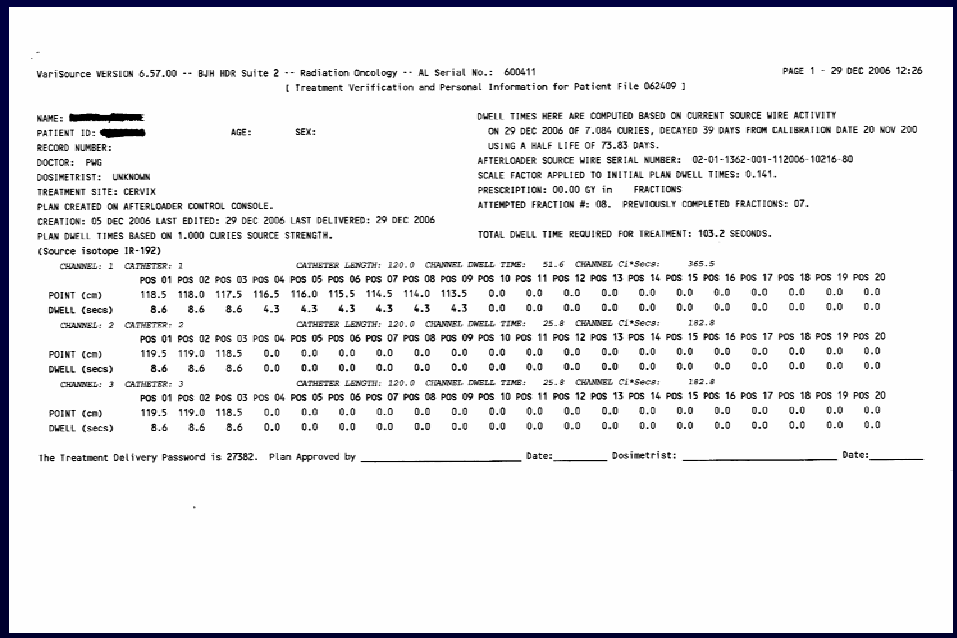
Barnes Jewish Hospital Date: 10/08/2006 Time: 9:45:05 AM Page 2 of 2



VariSource VERSION 6.57.00 -- BJH HDR Suite 2 -- Radiation Oncology -- AL Serial No.: 600411 PAGE 1 - 29 DEC 2006 12:26

[Treatment Verification and Personal Information for Patient File 062409]

NAME: [redacted]

PATIENT ID: [redacted] AGE: SEX:

RECORD NUMBER:

DOCTOR: PWG

DOSIMETRIST: UNKNOWN

TREATMENT SITE: CERVIX

PLAN CREATED ON AFTERLOADER CONTROL CONSOLE.

CREATION: 05 DEC 2006 LAST EDITED: 29 DEC 2006 LAST DELIVERED: 29 DEC 2006

PLAN DWELL TIMES BASED ON 1.000 CURIES SOURCE STRENGTH.

(Source Isotope IR-192)

DWELL TIMES HERE ARE COMPUTED BASED ON CURRENT SOURCE WIRE ACTIVITY
ON 29 DEC 2006 OF 7.084 CURIES, DECAYED 39 DAYS FROM CALIBRATION DATE 20 NOV 200
USING A HALF LIFE OF 73.83 DAYS.

AFTERLOADER SOURCE WIRE SERIAL NUMBER: 02-01-1362-001-112006-10216-80

SCALE FACTOR APPLIED TO INITIAL PLAN DWELL TIMES: 0.141.

PRESCRIPTION: 00.00 GY in FRACTIONS

ATTEMPTED FRACTION #: 08. PREVIOUSLY COMPLETED FRACTIONS: 07.

TOTAL DWELL TIME REQUIRED FOR TREATMENT: 103.2 SECONDS.

CHANNEL: 1 CATHETER: 1 CATHETER LENGTH: 120.0 CHANNEL DWELL TIME: 51.6 CHANNEL Ci*Secs: 365.5

	POS 01	POS 02	POS 03	POS 04	POS 05	POS 06	POS 07	POS 08	POS 09	POS 10	POS 11	POS 12	POS 13	POS 14	POS 15	POS 16	POS 17	POS 18	POS 19	POS 20
POINT (cm)	118.5	118.0	117.5	116.5	116.0	115.5	114.5	114.0	113.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DWELL (secs)	8.6	8.6	8.6	4.3	4.3	4.3	4.3	4.3	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

CHANNEL: 2 CATHETER: 2 CATHETER LENGTH: 120.0 CHANNEL DWELL TIME: 25.8 CHANNEL Ci*Secs: 182.8

	POS 01	POS 02	POS 03	POS 04	POS 05	POS 06	POS 07	POS 08	POS 09	POS 10	POS 11	POS 12	POS 13	POS 14	POS 15	POS 16	POS 17	POS 18	POS 19	POS 20
POINT (cm)	119.5	119.0	118.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DWELL (secs)	8.6	8.6	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

CHANNEL: 3 CATHETER: 3 CATHETER LENGTH: 120.0 CHANNEL DWELL TIME: 25.8 CHANNEL Ci*Secs: 182.8

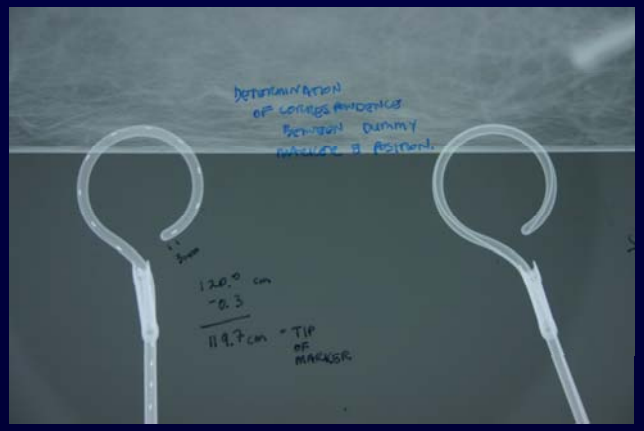
	POS 01	POS 02	POS 03	POS 04	POS 05	POS 06	POS 07	POS 08	POS 09	POS 10	POS 11	POS 12	POS 13	POS 14	POS 15	POS 16	POS 17	POS 18	POS 19	POS 20
POINT (cm)	119.5	119.0	118.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DWELL (secs)	8.6	8.6	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

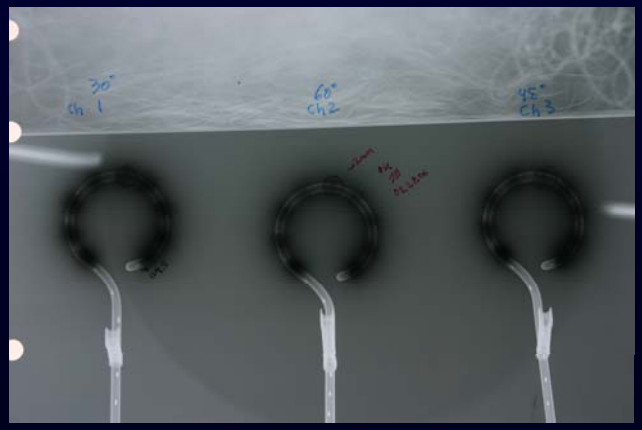
The Treatment Delivery Password is 27382. Plan Approved by _____ Date:_____ Dosimetrist: _____ Date:_____

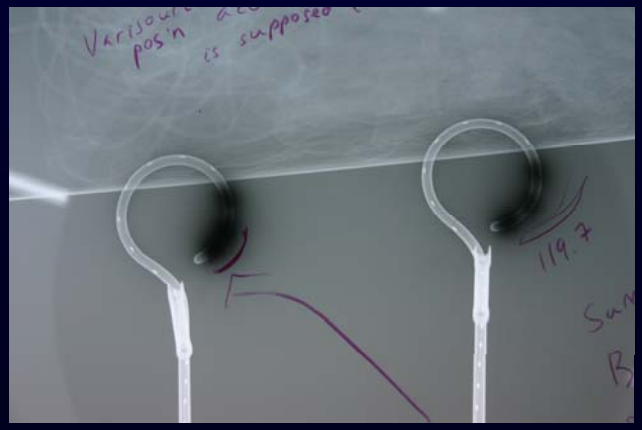
- Positional accuracy check of a treatment plan prior to patient treatment
- Check plan entry (varying step size, more manual entry, specify each dwell position, no zero dwell times allowed, less graphical representation of treatment layout)
- Check TGT integrity (less durable)

Commissioning of the Applicators + TGTs

- Correlate position inside the applicator to dwell positions
- Dummy markers are useful for this
- Check of positional accuracy of source inside applicator (double-exposure)
- Mark treatment positions on images

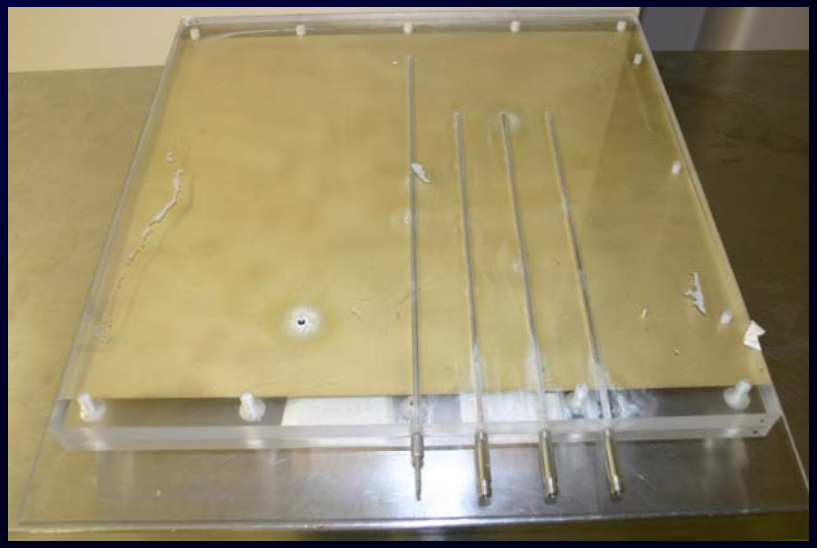




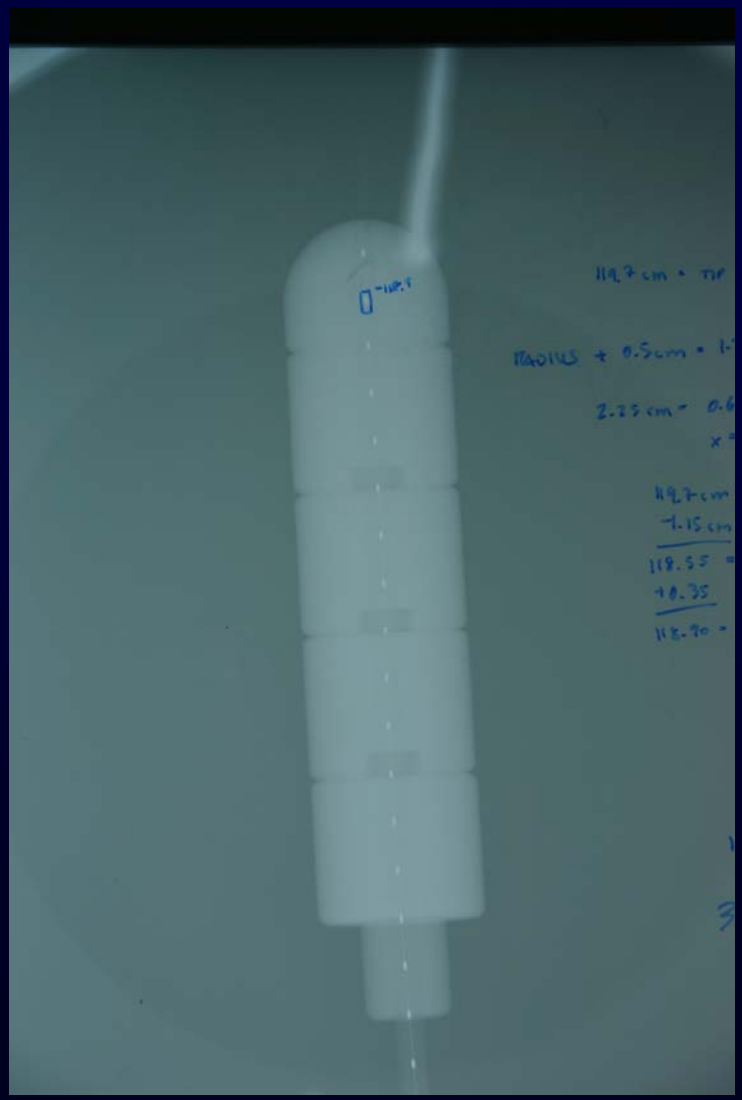


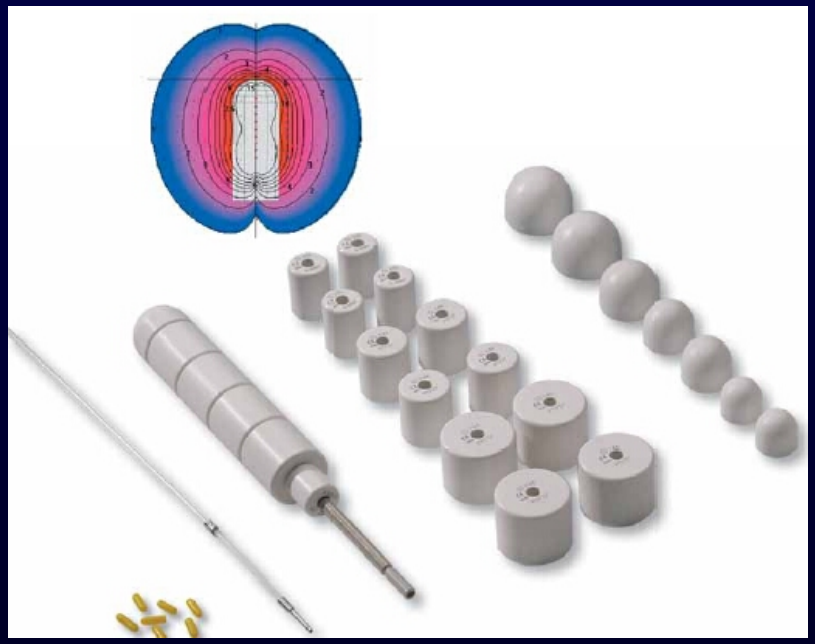
Construction of the GYN Autoradiograph Jigs

- Film is sandwiched between slabs of lucite
- 3 straight tandems for T&O treatments
- Applicator probe for VC, ring treatments
- We are not accounting for curvature of applicator (this should be done at time of commissioning)

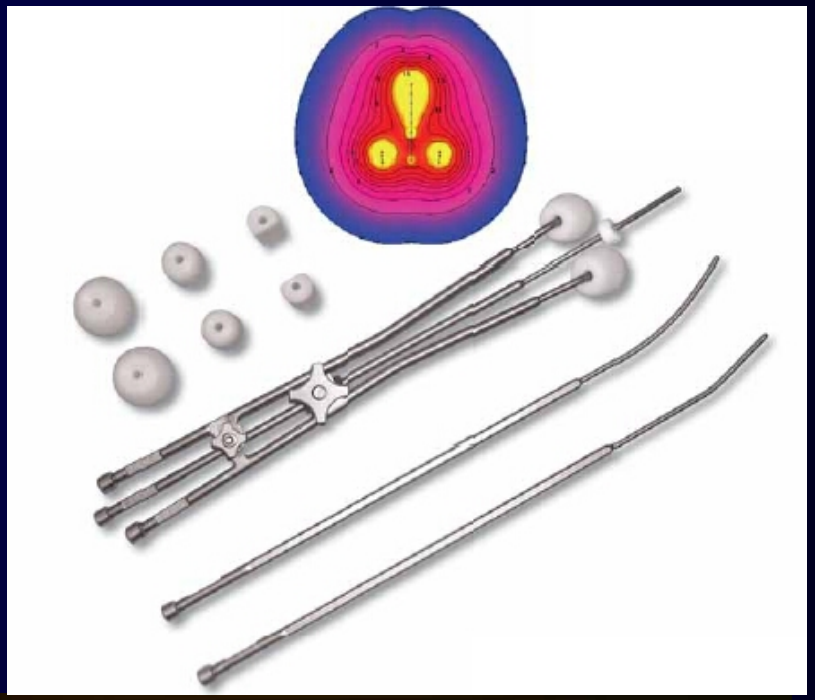


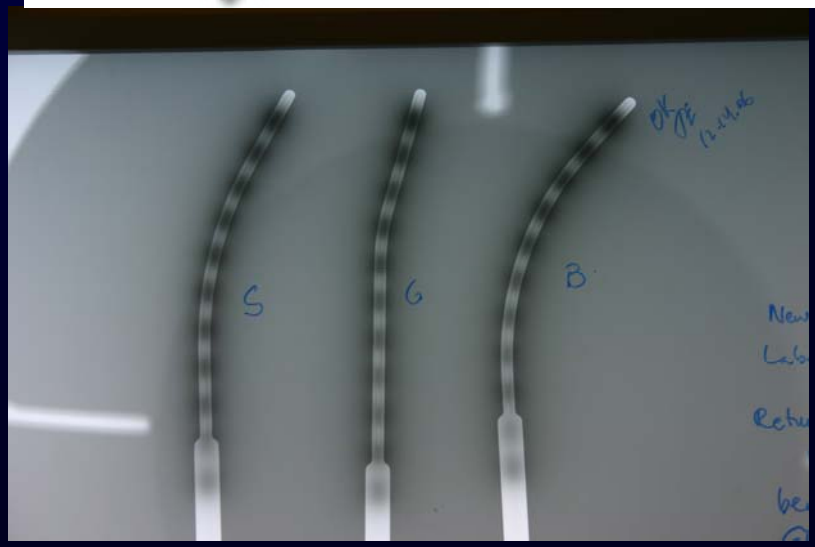
Vaginal Cylinder Commissioning





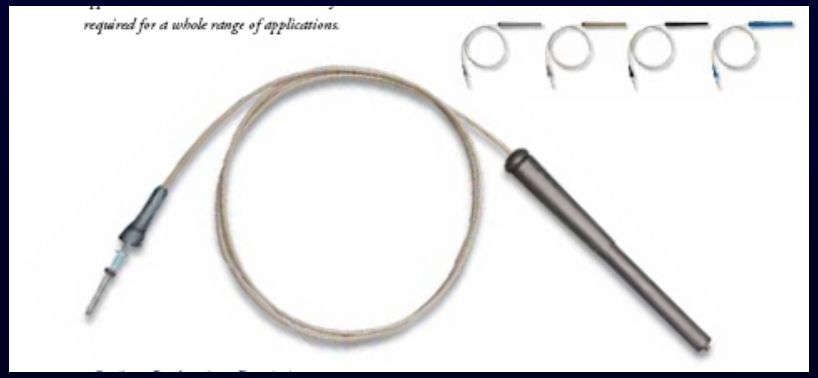
Tandem and Ovoid Commissioning





Tandem and Ovoid TGTs

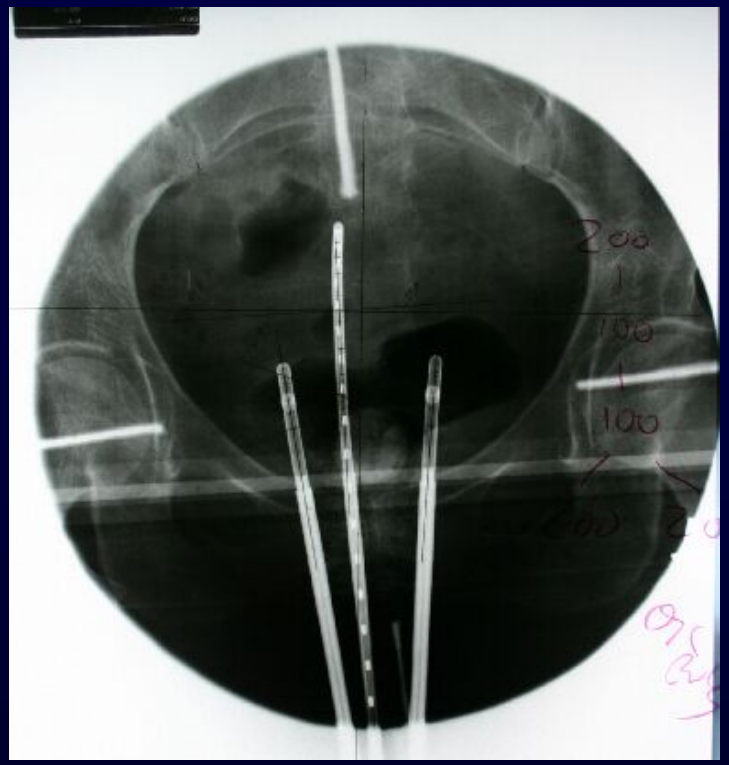
- Different colors
- Coded on machine end
- No coding on patient end
- Closed system
- Can treat with TGT not fully inserted into applicator (ovoids)

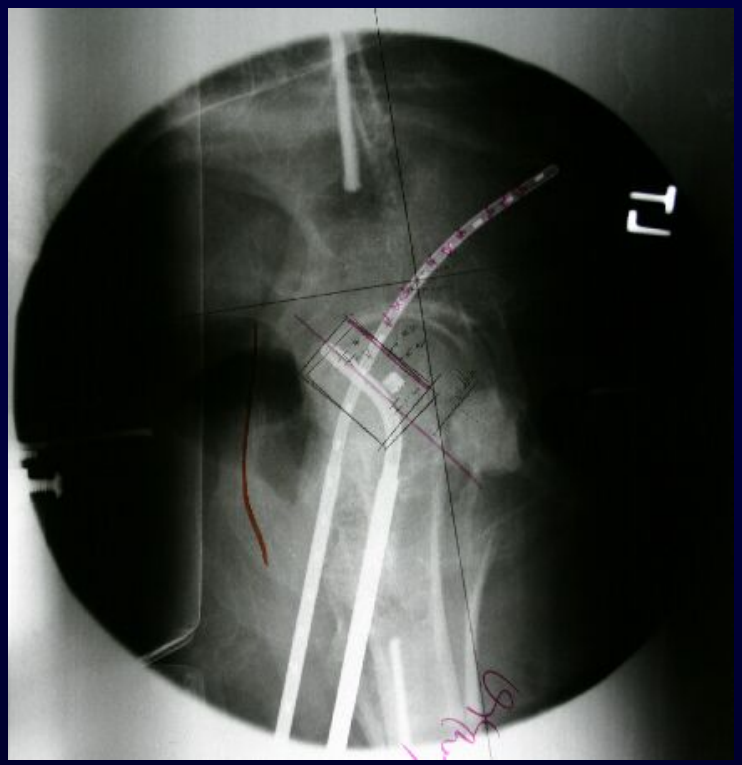


General Flow of HDR Treatments

- Applicators placed
- Images are acquired
  - Applicator placement verified
  - Treatment positions are indicated
- Rx is specified on written directive
- Dwell times are calculated (using TPS/dwell time calc sheets)
- Manually verify dwell times
- Isodoses generated on TPS/Plan printed and checked
- Dwell times/positions are communicated to the console and checked vs. plan
- Patient is connected to the machine
- In the treatment room: treatment connections, patient identification, presence of emergency equipment, audiovisual
- Deliver treatment with AU and AMP present
- At end of treatment, verify source retraction, and perform a final survey.

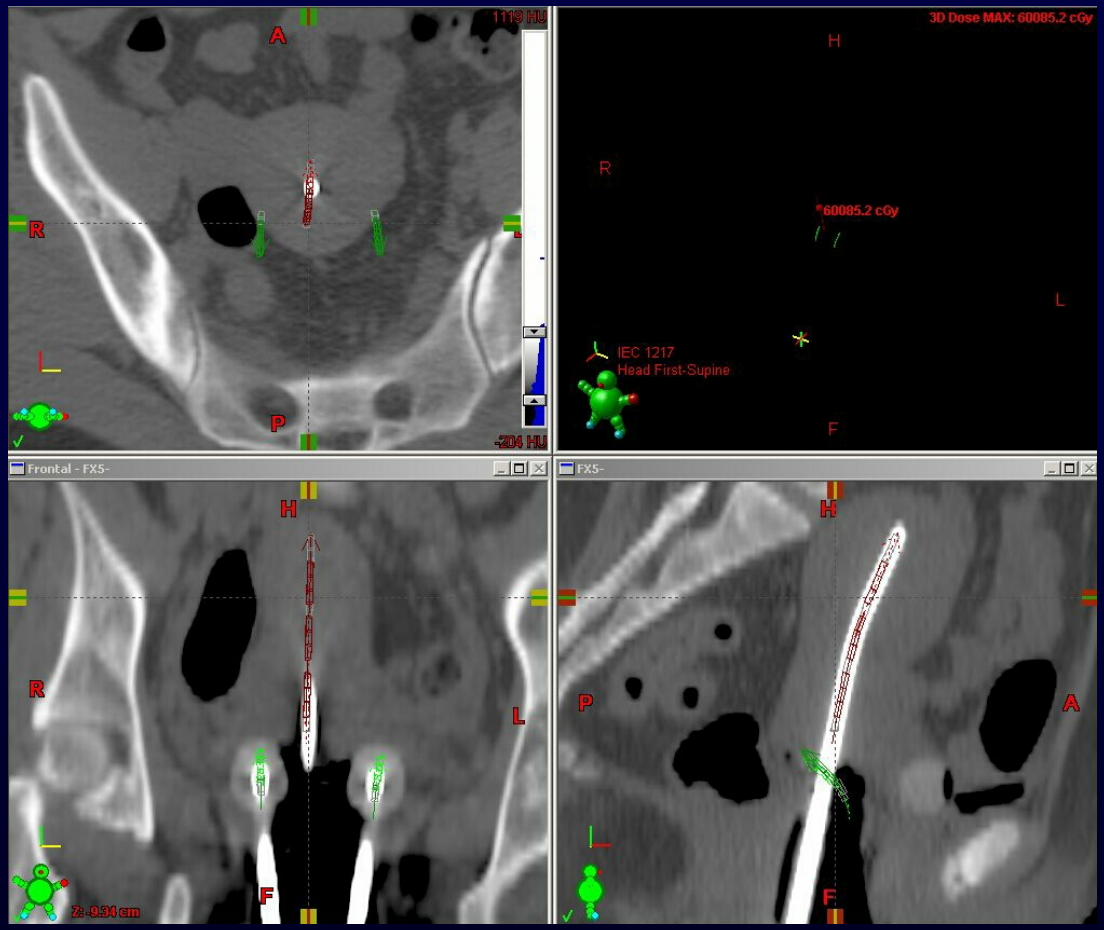
Traditional: 2D Imaging





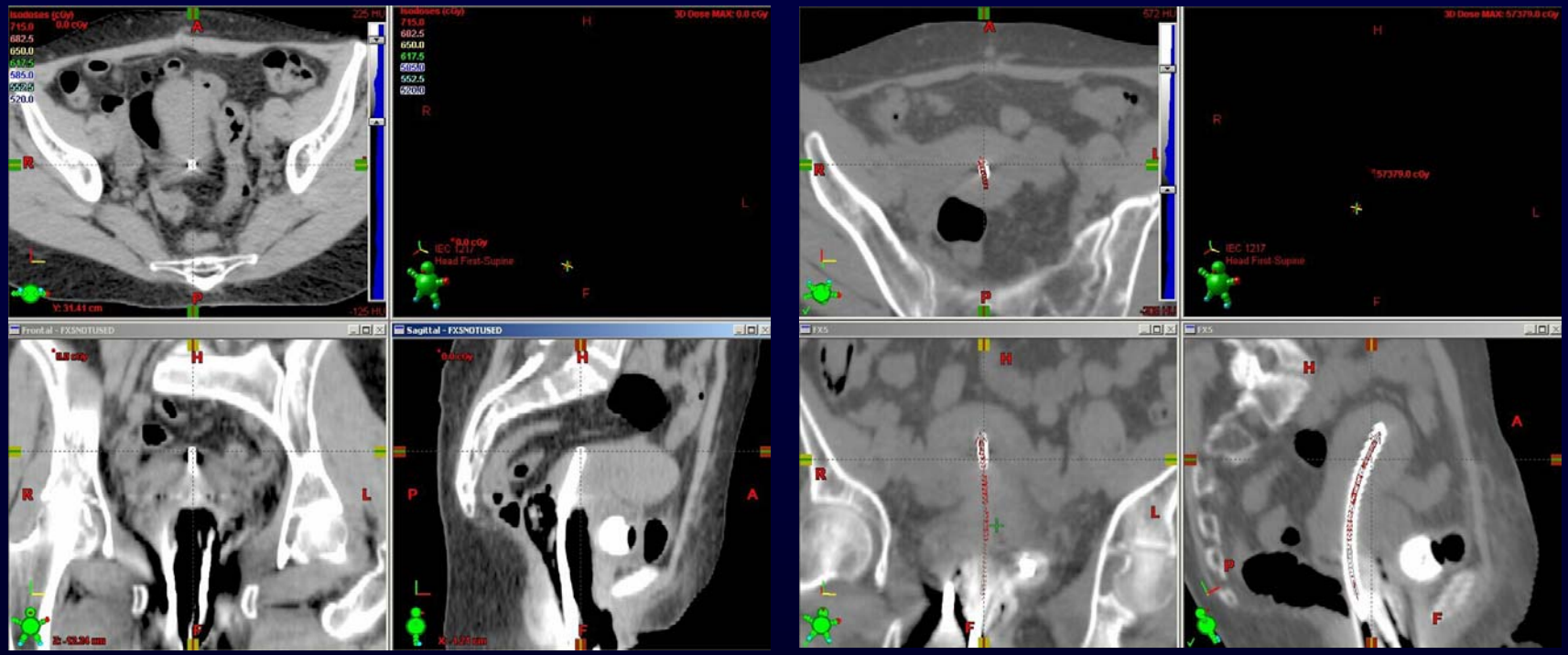
- Orthogonal films taken after implant
- Check of applicator placement relative to bony anatomy
- Identification of treatment positions
- Post-implant dosimetry

Current: 3D Imaging for Most Patients



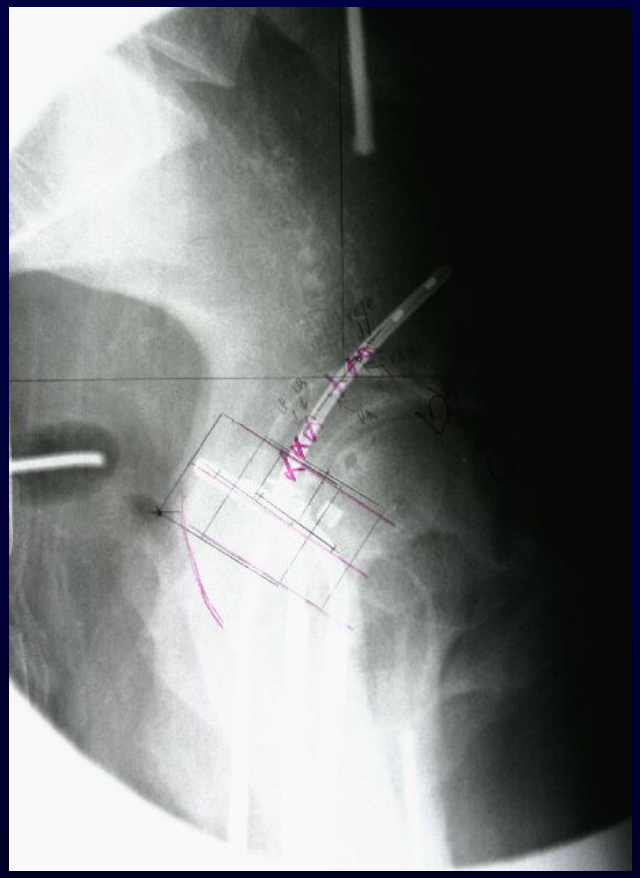
- Have multiple views
- Have soft tissue information

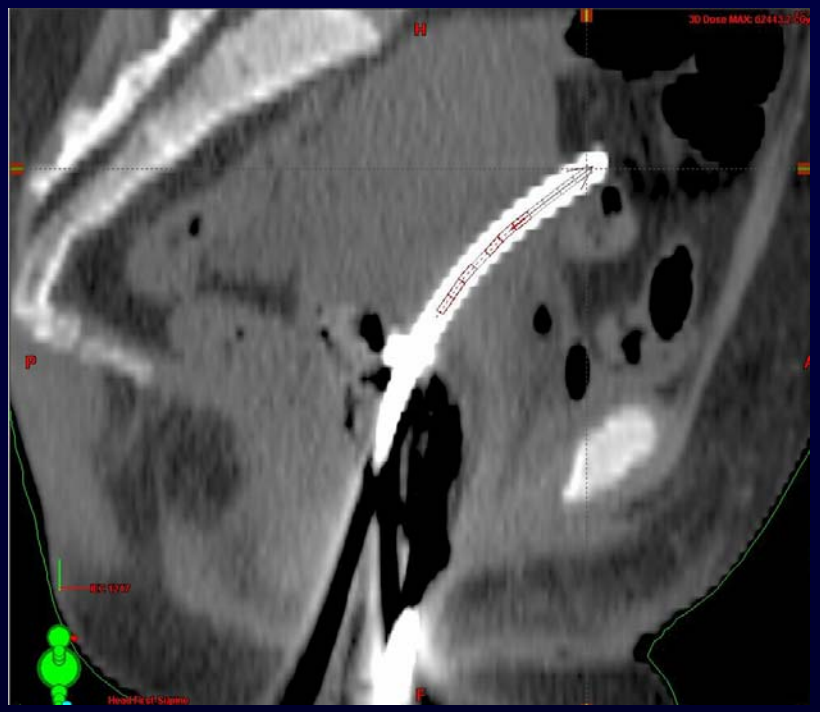
Applicator Placement Check



Applicator placement check relative to the soft-tissue anatomy prior to treatment

2D vs. 3D:
Identification of Treatment Dwells



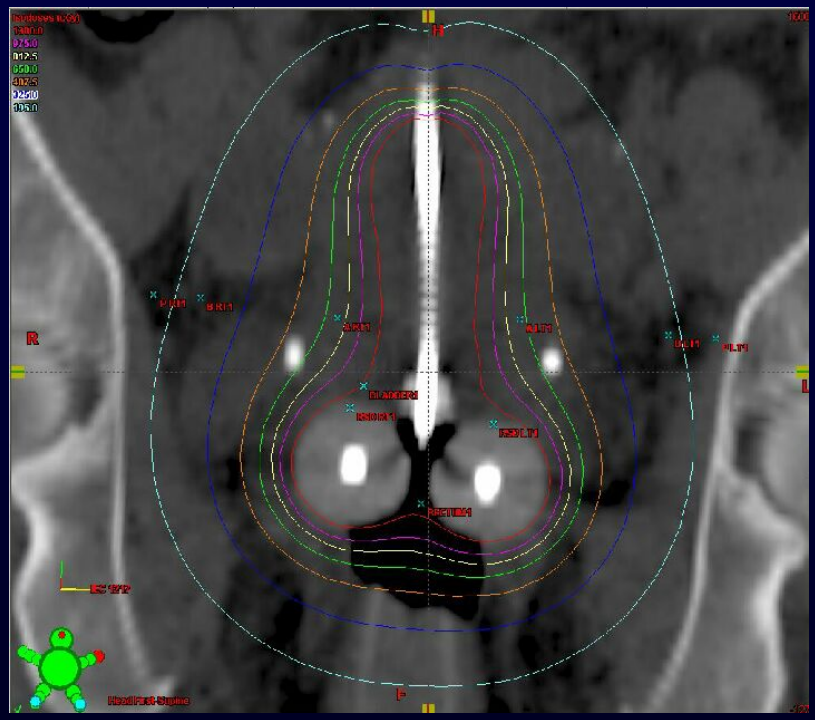


•Identification of treatment positions relative to applicator and soft-tissue anatomy

2D Dosimetry → 3D Dosimetry

2D Orthogonal Radiographs

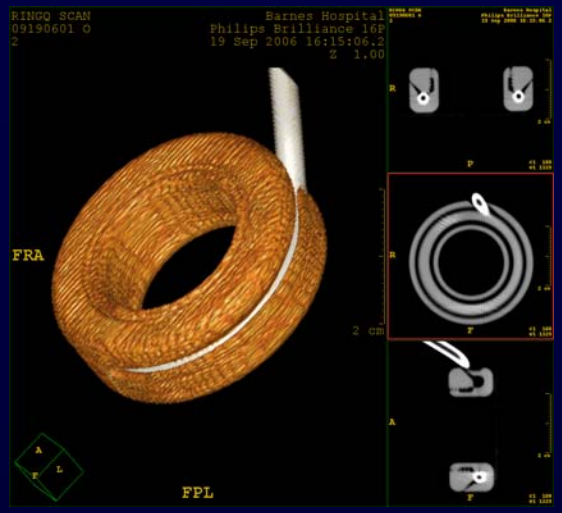
CT Volumetric Datasets

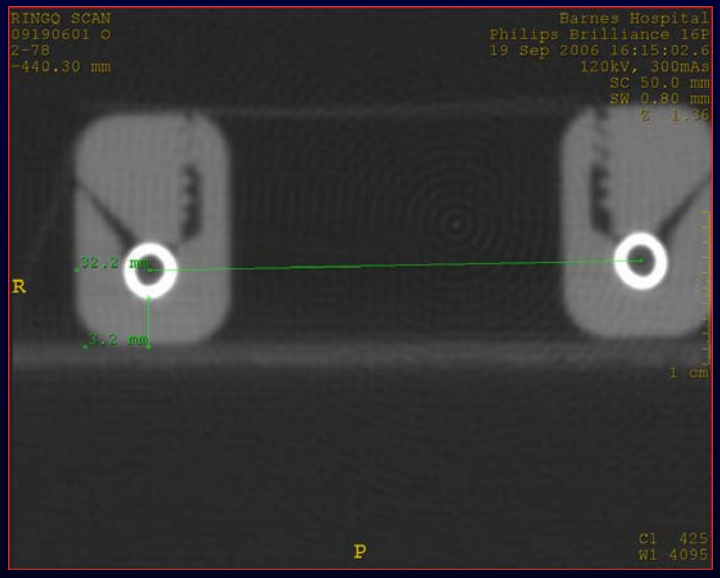


- Discontinued 2D-based post-implant dosimetry
- All HDR GYN dosimetry currently done on CT or MR images

Commissioning of the Applicators: Vaginal Ring

- Measurement of applicator dimensions using calipers, x-ray, CT
- Check of applicator integrity (radiographic)





Commissioning of the Varian BrachyVision TPS

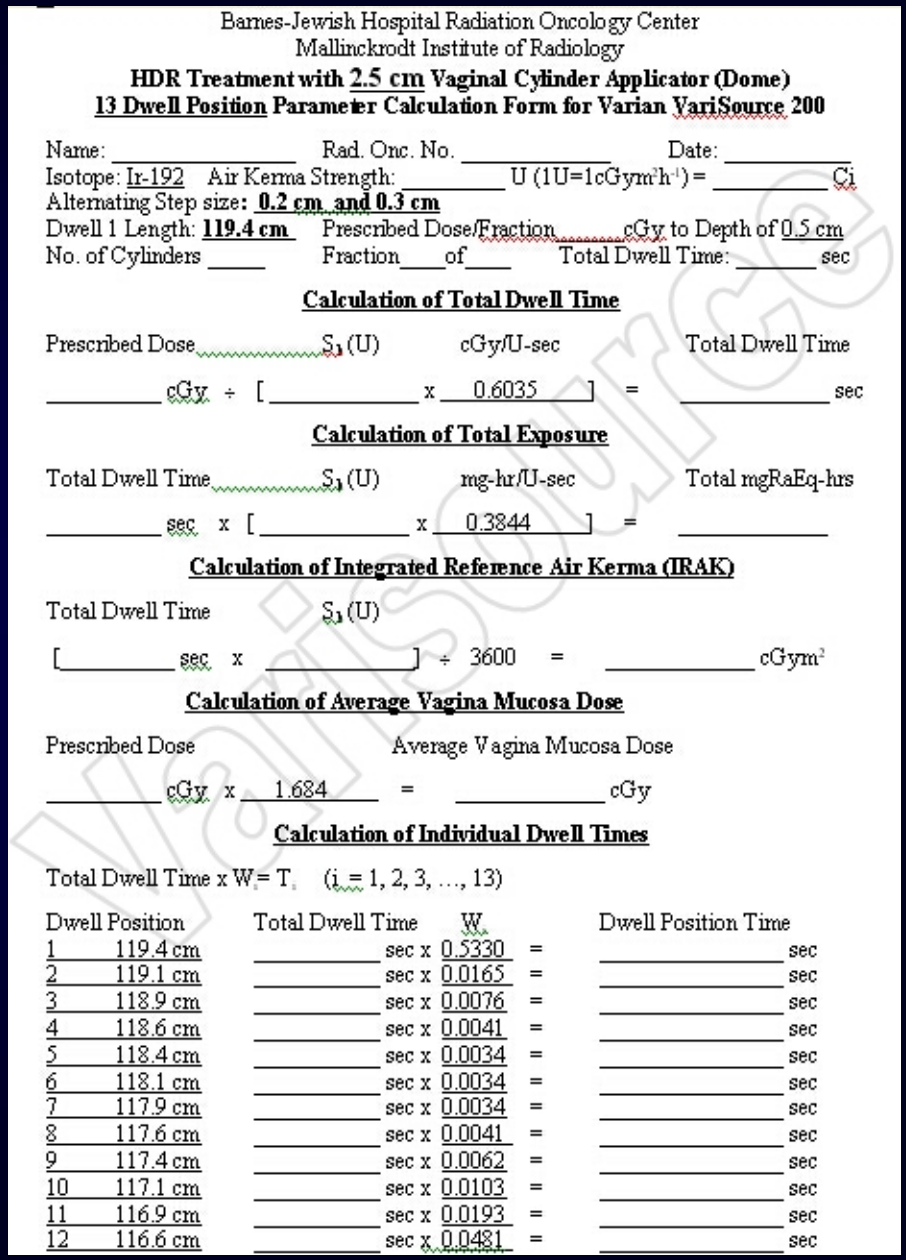
- Verification of dosimetric data in TPS (“TG-43” dosimetry parameters)
- Dose calculation accuracy
  - Single source (TPS vs. Manual Calculation)
  - Dual source
- DVH/Isodose display accuracy
- Reconstruction accuracy (from films)
- Data transfer integrity (image import, plan export)

Commissioning of the Treatment Protocols

- Development of planning procedures
  - Cylinders/rings on AP/LAT x-rays
  - T&O on CT images
  - APBI on CT images
- Development of forms
  - Dwell time calculation forms (ring, cylinder, T&Os)
  - Prescription forms
  - Catheter Length Measurement forms

Development of Dwell Time Calc Forms (example Vaginal Cylinder)

- Use plan to calculate different factors
- This was done for each size cylinder
- Dwell time forms were generated for the ring



Barnes-Jewish Hospital Radiation Oncology Center
Mallinckrodt Institute of Radiology

HDR Treatment with 2.5 cm Vaginal Cylinder Applicator (Dome)
13 Dwell Position Parameter Calculation Form for Varian VariSource 200

Name: _____ Rad. Onc. No. _____ Date: _____
Isotope: Ir-192 Air Kerma Strength: _____ U (1U=1cGym^{2}h^{-1}) = _____ Ci
Alternating Step size: **0.2 cm and 0.3 cm**
Dwell 1 Length: **119.4 cm** Prescribed Dose/Fraction _____ cGy to Depth of 0.5 cm
No. of Cylinders _____ Fraction ____ of ____ Total Dwell Time: _____ sec

Calculation of Total Dwell Time

Prescribed Dose S_k (U) cGy/U-sec Total Dwell Time

_____ cGy ÷ [_____ x 0.6035] = _____ sec

Calculation of Total Exposure

Total Dwell Time S_k (U) mg-hr/U-sec Total mgRaEq-hrs

_____ sec x [_____ x 0.3844] = _____

Calculation of Integrated Reference Air Kerma (IRAK)

Total Dwell Time S_k (U)

[_____ sec x _____] ÷ 3600 = _____ cGym^2

Calculation of Average Vagina Mucosa Dose

Prescribed Dose Average Vagina Mucosa Dose

_____ cGy x 1.684 = _____ cGy

Calculation of Individual Dwell Times

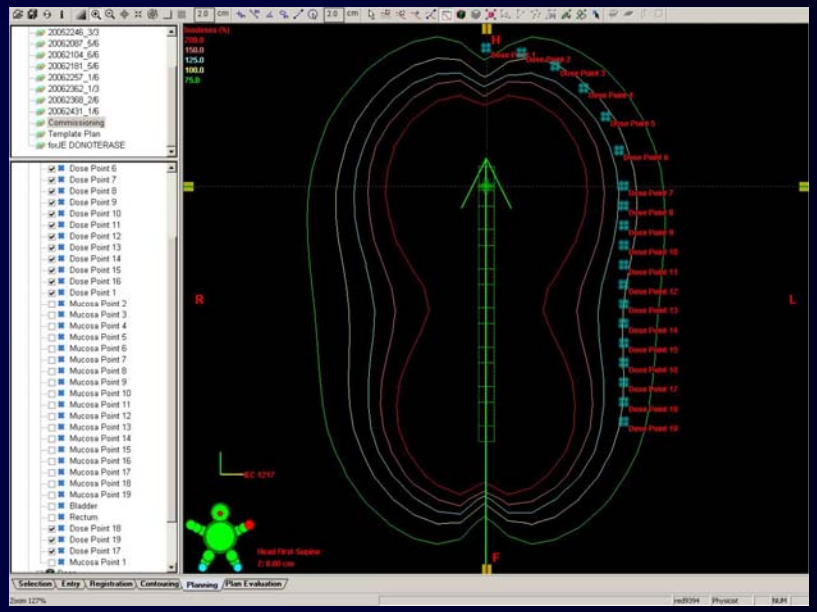
Total Dwell Time x W = T$_i$ (i = 1, 2, 3, …, 13)

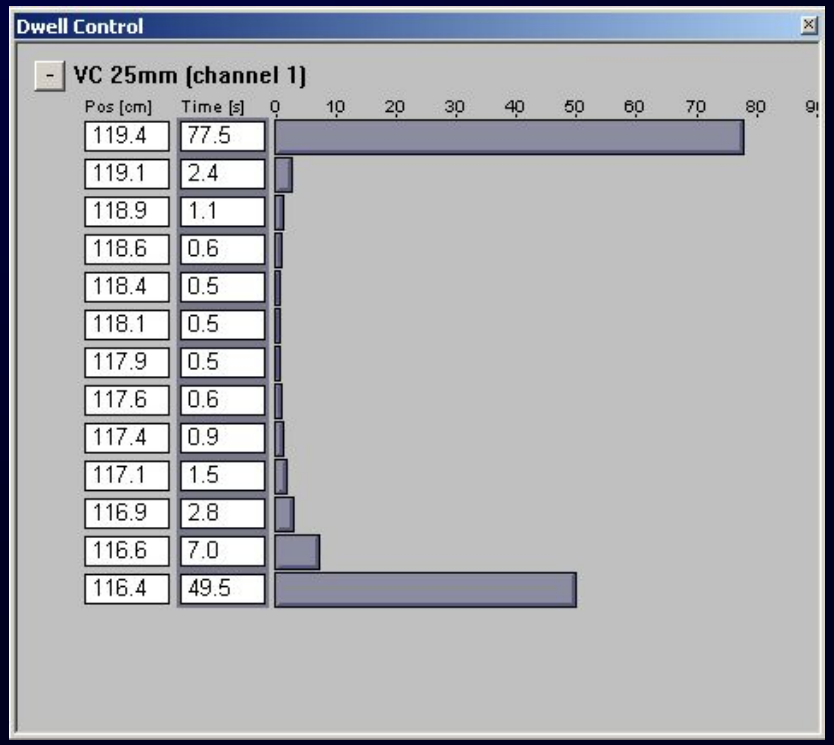
Dwell Position		Total Dwell Time	W		Dwell Position Time
1	119.4 cm	_____ sec x	0.5330	=	_____ sec
2	119.1 cm	_____ sec x	0.0165	=	_____ sec
3	118.9 cm	_____ sec x	0.0076	=	_____ sec
4	118.6 cm	_____ sec x	0.0041	=	_____ sec
5	118.4 cm	_____ sec x	0.0034	=	_____ sec
6	118.1 cm	_____ sec x	0.0034	=	_____ sec
7	117.9 cm	_____ sec x	0.0034	=	_____ sec
8	117.6 cm	_____ sec x	0.0041	=	_____ sec
9	117.4 cm	_____ sec x	0.0062	=	_____ sec
10	117.1 cm	_____ sec x	0.0103	=	_____ sec
11	116.9 cm	_____ sec x	0.0193	=	_____ sec
12	116.6 cm	_____ sec x	0.0481	=	_____ sec

VariSource

Development of Dwell Time Calc Forms (Vaginal Cylinder)

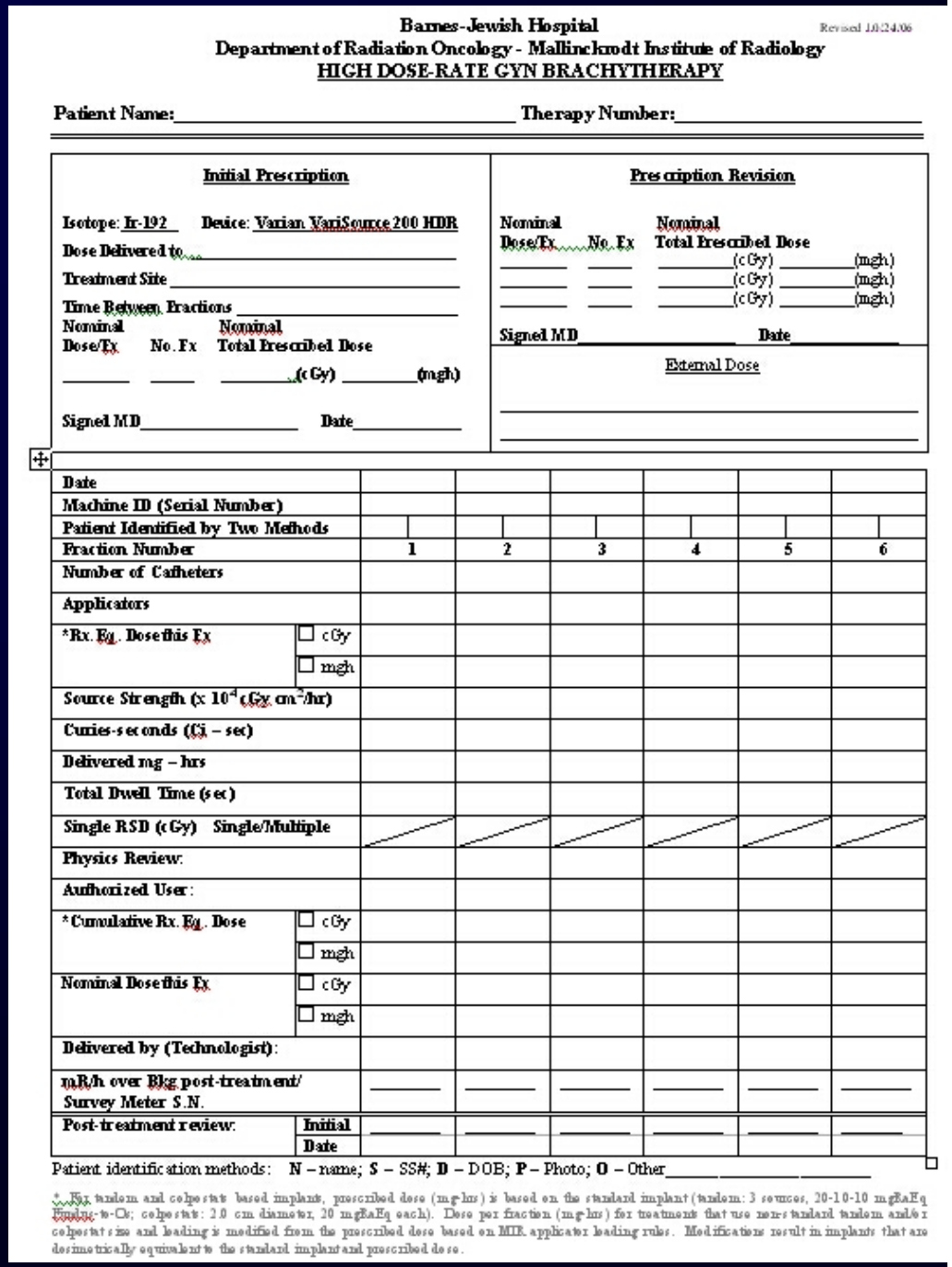
- Standard treatment geometry and Rx depth → Template Plan
- Enter treatment geometry into TPS
- Enter dose points
- Optimize dwell times
- Obtain dwell times
- Calculation form for varying Rx dose and source strength





Development of Prescription Forms

- Written Directives
- Must specify radionuclide, treatment site, dose per fraction, number of fractions, and total dose
- Must be signed and dated by AU
- Revisions allowed: written revisions must be signed and dated by AU before next fraction, oral revisions (in case of emergency) must be documented within 48 hours
- Title 10 CFR Part 35.40



Barnes-Jewish Hospital Revised 10/24/06
Department of Radiation Oncology - Mallinckrodt Institute of Radiology
HIGH DOSE-RATE GYN BRACHYTHERAPY

Patient Name:_____ **Therapy Number:**_____

Initial Prescription

Isotope: Ir-192 **Device:** Varian VariSource 200 HDR
Dose Delivered to:_____
Treatment Site_____
Time Between Fractions_____

Nominal Dose/Fx	No. Fx	Nominal Total Prescribed Dose	
_____	____	_____(cGy)	_____(mgh)

Signed MD_____ **Date**_____

Prescription Revision

Nominal Dose/Fx	No. Fx	Nominal Total Prescribed Dose	
_____	____	_____(cGy)	_____(mgh)
_____	____	_____(cGy)	_____(mgh)
_____	____	_____(cGy)	_____(mgh)

Signed MD_____ **Date**_____

External Dose

Date							
Machine ID (Serial Number)							
Patient Identified by Two Methods							
Fraction Number		1	2	3	4	5	6
Number of Catheters							
Applicators							
***Rx. Eq. Dose this Fx**	☐ cGy						
	☐ mgh						
Source Strength (x 10^{-4} cGy cm^2/hr)							
Curies-seconds (Ci – sec)							
Delivered mg – hrs							
Total Dwell Time (sec)							
Single RSD (cGy) Single/Multiple							
Physics Review:							
Authorized User:							
***Cumulative Rx. Eq. Dose**	☐ cGy						
	☐ mgh						
Nominal Dose this Fx	☐ cGy						
	☐ mgh						
Delivered by (Technologist):							
mR/h over Bkg post-treatment/ Survey Meter S.N.		_____	_____	_____	_____	_____	_____
Post-treatment review:	**Initial**	_____	_____	_____	_____	_____	_____
	Date						

Patient identification methods: **N** – name; **S** – *SS#*; **D** – DOB; **P** – Photo; **O** – Other_____

* Rx tandem and colpostat based implants, prescribed dose (mgehrs) is based on the standard implant (tandem: 3 sources, 20-10-10 mgEqH Fletcher-Suit-Delclos; colpostats: 2.0 cm diameter, 20 mgEqH each). Dose per fraction (mgehrs) for treatments that use non-standard tandem and/or colpostat size and loading is modified from the prescribed dose based on MIR applicator loading rules. Modifications result in implants that are dosimetrically equivalent to the standard implant and prescribed dose.