Buyer Beware – Third party products
Linac and TPS commissioning
Treatment planning &
Brachytherapy sources

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Objectives

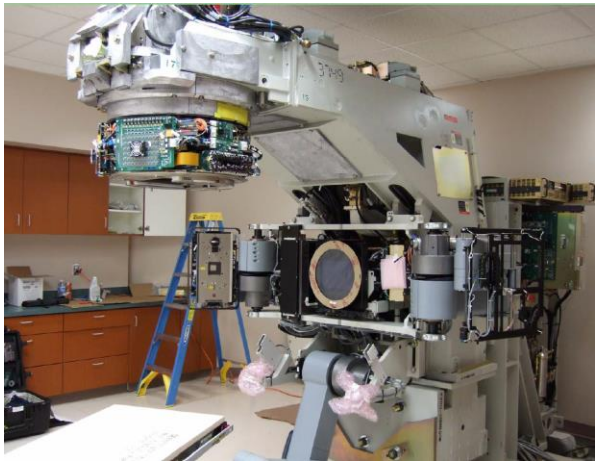
- Why a session on buyer beware of third party services and products?
  - Increased use of third party services and products
- An increasing level of complexity
  - More complex treatment planning systems (TPS), delivery systems and treatment techniques
- Serious incidents involving TPS, treatment delivery systems, treatment planning and brachytherapy
- Many AAPM TG/MPPG recommendations available for qualified medical physicist (QMP) to use

Motivation

- Therapist makes a mistake
  - Affected – One Fraction
- Physician makes a mistake
  - Affected – One Patient
- Physicist makes a mistake
  - Affected – All patients treated through the duration of the mistake
- Linac or Treatment Planning System (TPS) mistake
  - Affected – All patients planned or treated until the mistake is caught

Qualified Medical Physicist (QMP) Responsibilities

- The QMP is responsible for acceptance testing, commissioning, calibration, and periodic QA of therapy equipment
- In particular, the QMP must certify that the therapy units and planning systems are performing according to specifications, generate beam data, and outline written QA procedures which include tests to be performed, tolerances, and frequency of the tests



TPS Linac Commissioning Timetable Third-Party vs. TG 106/MPPG 5a

Agenda	Third Party Website	Estimation (TG-106)
Acceptance Testing	Pre	Pre
Linac Commissioning	2 Days	30 Days
Data Processing for TPS	1 Day	6 Days
TPS Beam Modeling	2 Days	9 Days
TPS Validation	1 Day	5 Days
Data Review and Data Book Generation	Post	Post
TOTAL DAYS	**6**	**50**

TG-106 states approximately 4 – 6 weeks plus additional time for validation, baselines, etc.

MPPG5a states approximately 6-8 weeks for 2 photon and 5 electron energy linac, assuming 1.5 to 2 FTE working 12 to 16 hours per day!!!

Beam Matching & Golden Beam Data

- Some vendors provide beam matching services or provide a reference dosimetry dataset called "golden beam data"
- Issues that could arise from vendor provided services:
  - Consistent reproducibility of manufacturing procedures for all linear accelerators
  - On-site changes to the beams (energy and/or profiles) will not be reflected in the golden beam data
  - Individual machine variation of non-physical wedges (EDW)
  - Commissioning process may uncover potential problems that may not otherwise be discovered
- Golden beam data could be useful as a reference to verify site's commissioning results

Linac and TPS Commissioning – QMP Responsibility

- If a linac or TPS has been commissioned by a third- party, it is the duty of the site's QMP to ensure that all work has been performed appropriately and correctly
- The QMP should verify commissioning and validate accuracy of dose calculation through machine specific QA, compute and compare plans on old and new TPS, IMRT/VMAT QA on numerous test cases, IROC end-to-end phantoms, OSLD services to verify linac output and if possible inter-institutional comparisons
- The QMP should consolidate all tests, data and results performed by third-party vendors and generate linac and TPS commissioning reports and data-books

MPPG 5a: TPS Commissioning & QA

- QMP understand TPS algorithms and has received proper training
- Appropriate CT calibration data acquired
- Review of raw beam data collected
- Beam modeling completed per vendor recommendation
- Photon and electron beam models including heterogeneities evaluated qualitatively and quantitatively
- IMRT/VMAT validation and end-to-end phantom tests
- Baseline QA and routine QA established
- Commissioning report generation

Smilowitz et al, AAPM MPPG5a, JACMP 16 (5): 14-34 (2015)

MPPG5a: Recommendations for Small Field Dosimetry Validation

- Since small field dosimetry is often extrapolated by TPS, verification measurements for small fields and MLC are recommended
- Intra-leaf and inter-leaf transmission/leakage and leaf gap should be measured with appropriate detectors
- Leaf-end penumbra and small field PDD's should be obtained with a small detector to avoid volume averaging effects
- Small field output factors should be measured for beam modeling/verification

Smilowitz et al, AAPM MPPG5a, JACMP 16 (5): 14-34 (2015)

VMAT/IMRT Validation Tolerances

Measurement Method	Region	Tolerance
Ion Chamber	Low gradient target region	2% of prescribed dose
	OAR region	3% of prescribed dose
Planar/Volumetric Array	All regions	2%/2mm*, no pass rate tolerance, but areas that do not pass need to be investigated
End-to-End	Low gradient target region	5% of prescribed dose

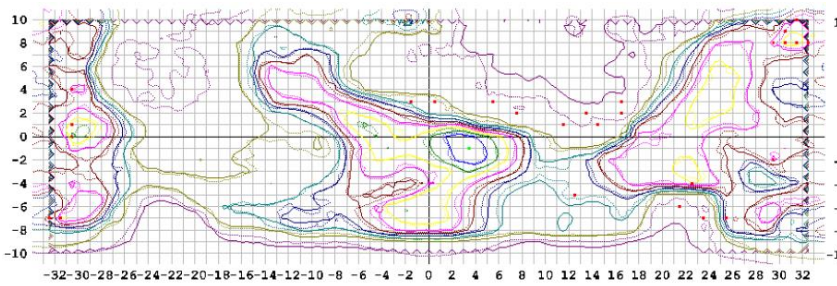
*Application of a 2%/2 mm gamma criterion can result in the discovery of easily correctable problems with IMRT commissioning that may be hidden in the higher (and ubiquitous) 3%/3 mm passing rates

Smilowitz et al, AAPM MPPG5a, JACMP 16 (5): 14-34 (2015)

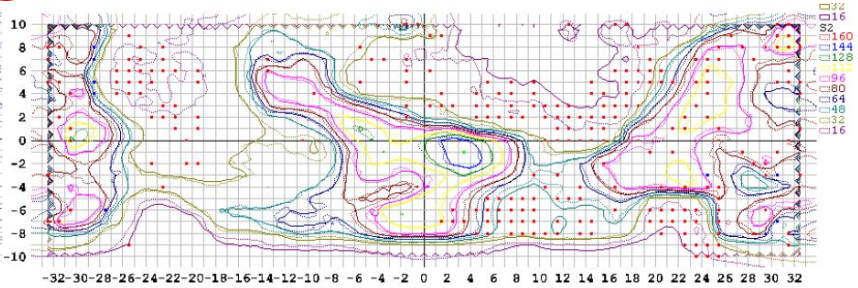
Gamma Criteria Tolerance and Passing

Clinical Site	Γ (5%/3mm)	Γ(3%/3mm)	Γ(2%/2mm)
Prostate Fossa	99.1	98.4	91.0
Bottom of Tongue	99.9	98.5	82.1
Throat	99.3	98.0	89.9
Esophagus	99.7	97.9	79.6
Parietal Brain	99.6	98.1	92.8

Esophagus Case

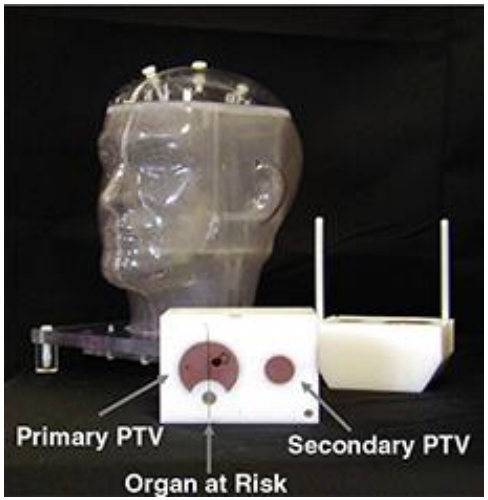


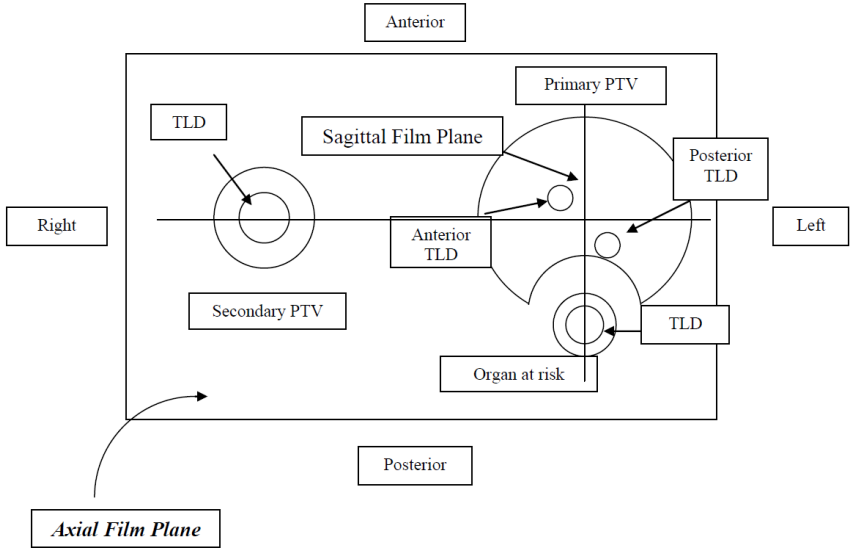
Gamma 3%/3mm

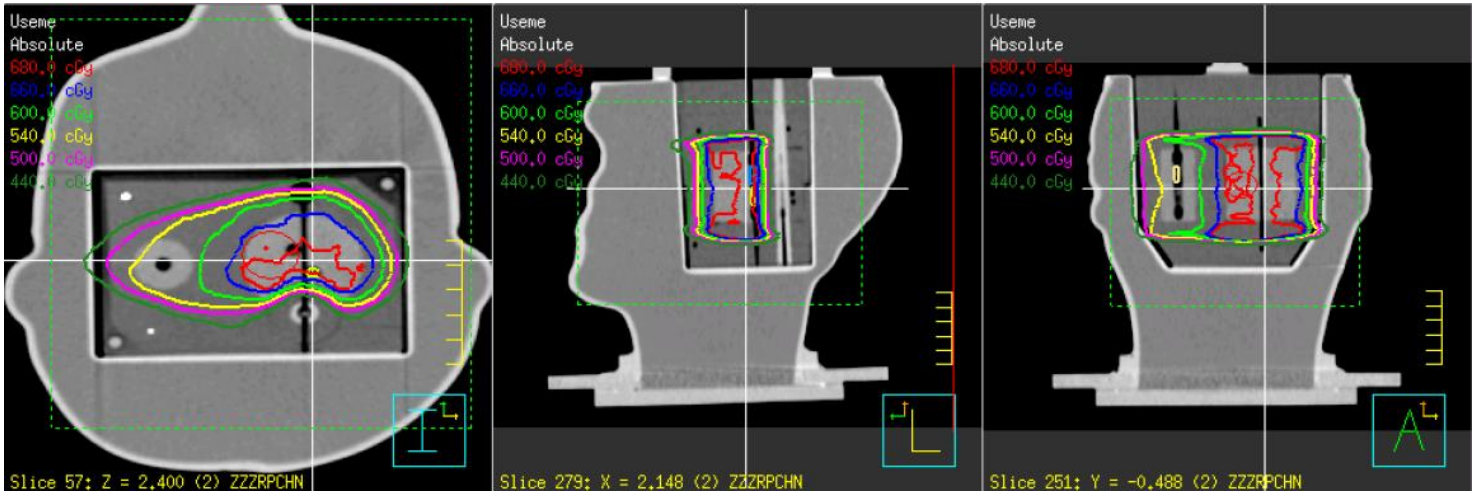


Gamma 2%/2mm

IROC Anthropomorphic Head & Neck IMRT Phantom End to End Test







IROC H&N Phantom TLD & Film Results
MDACC Varian Truebeam

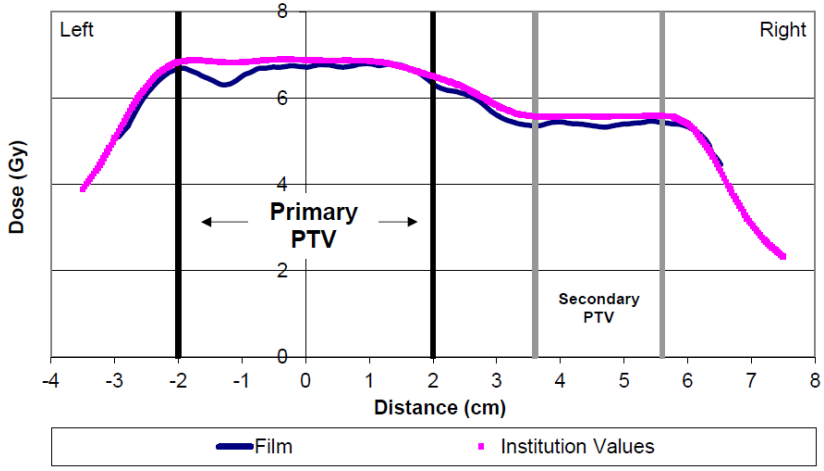
Summary of TLD and film results:

Location	IROC-H vs. Inst.	Criteria	Acceptable
Primary PTV sup. ant.	0.99	0.93 – 1.07	Yes
Primary PTV inf. ant.	0.98	0.93 – 1.07	Yes
Primary PTV sup. post.	0.96	0.93 – 1.07	Yes
Primary PTV inf. post.	0.95	0.93 – 1.07	Yes
Secondary PTV sup.	0.97	0.93 – 1.07	Yes
Secondary PTV inf.	0.97	0.93 – 1.07	Yes

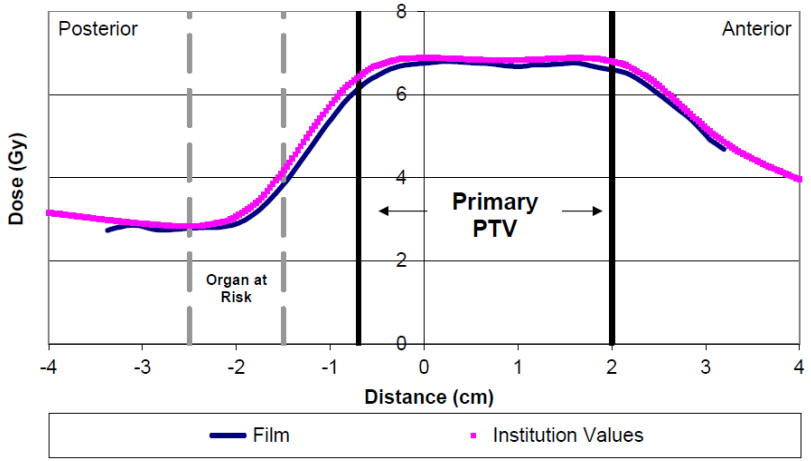
Film Plane	Gamma Index*	Criteria	Acceptable
Axial	100%	≥85%	Yes
Sagittal	100%	≥85%	Yes

*Percentage of points meeting gamma-index criteria of 7% and 4 mm.

Right Left Profile

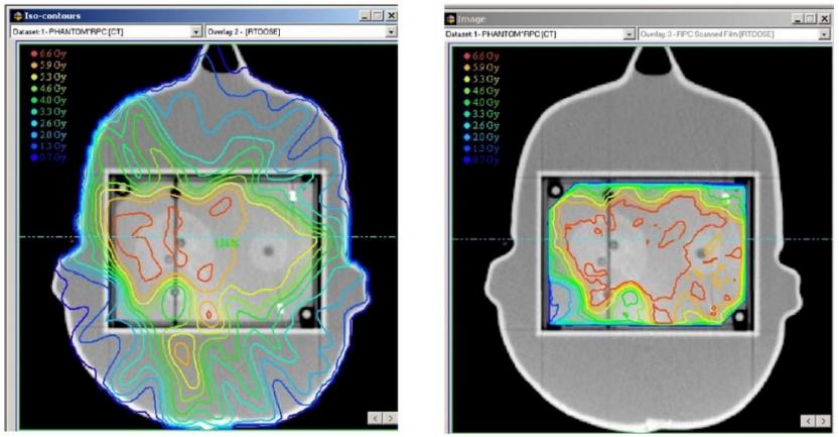


Anterior Posterior Profile



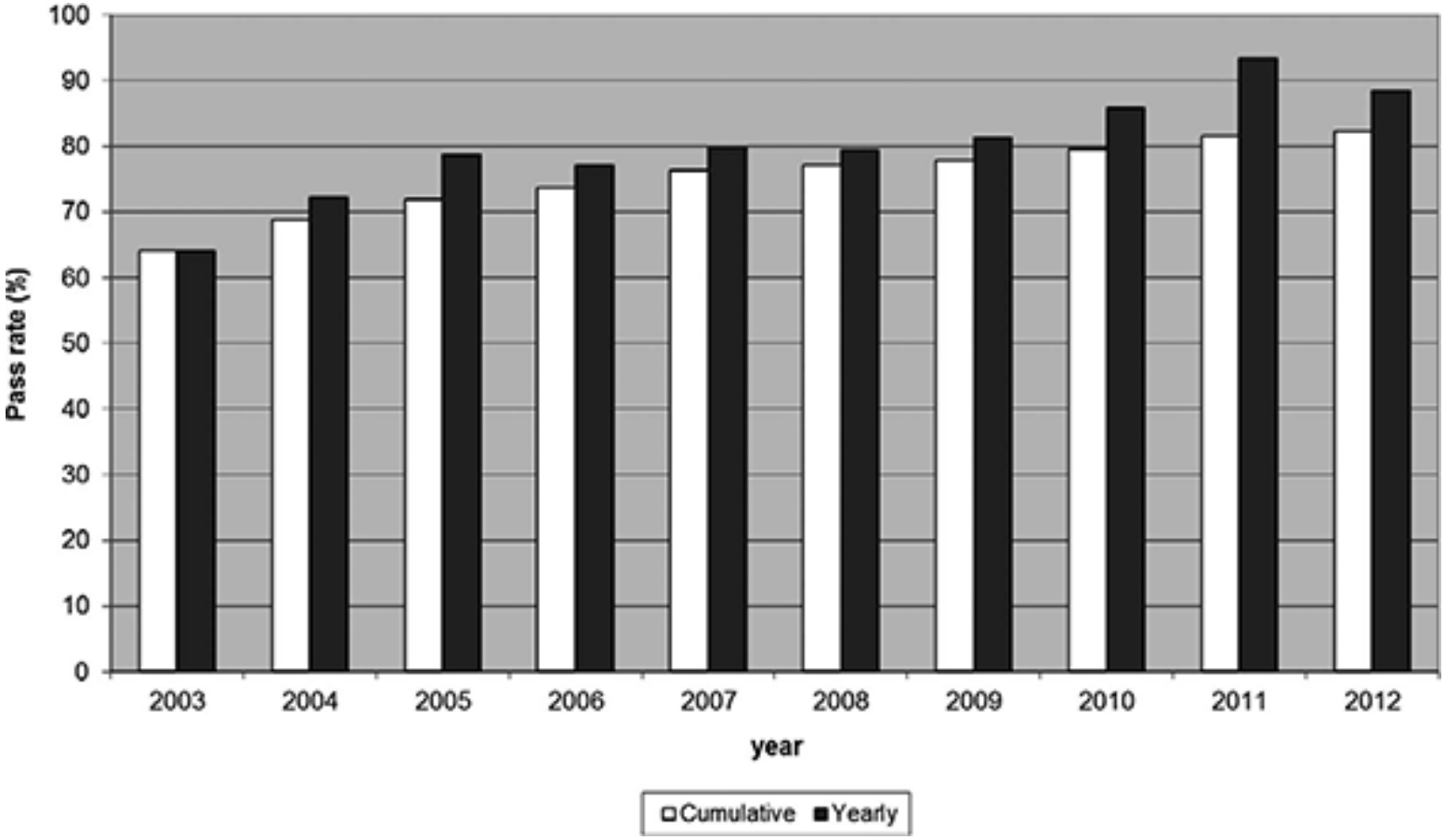
IROC Phantom 2001-2011 results

- Irradiated 1139 times by 763 institutions
- Only 82% of institutions passed the end-to-end test with the Head and Neck phantom on the first irradiation (Passing criteria was 7% for TLD in PTV and DTA of 4 mm in high dose gradient area (≥85% pixels pass) between PTV and OAR)



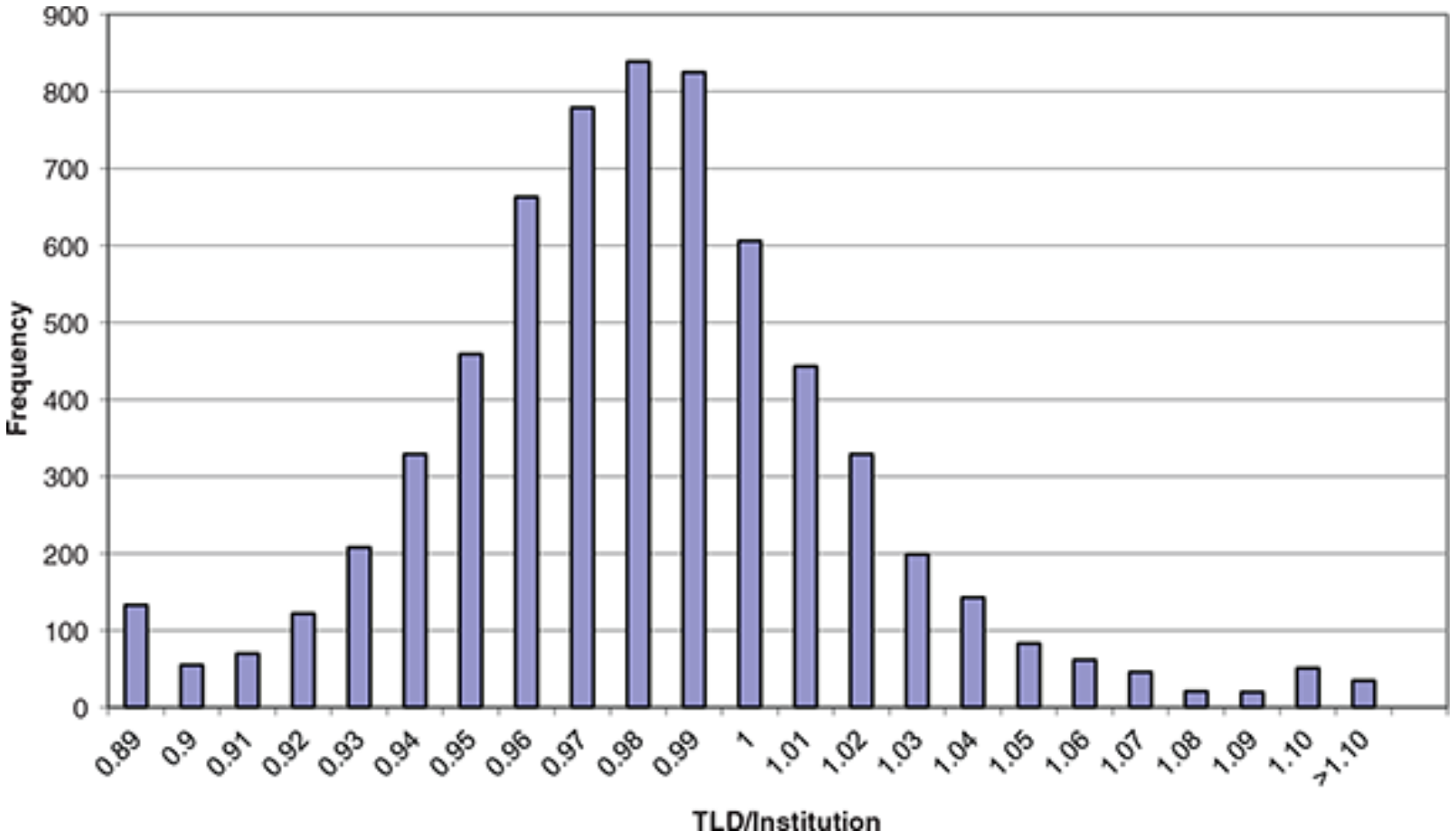
Molineu et al, Med Phys 40 (2): 022101-1 (2013)

Cumulative and Passing Rate Over Time



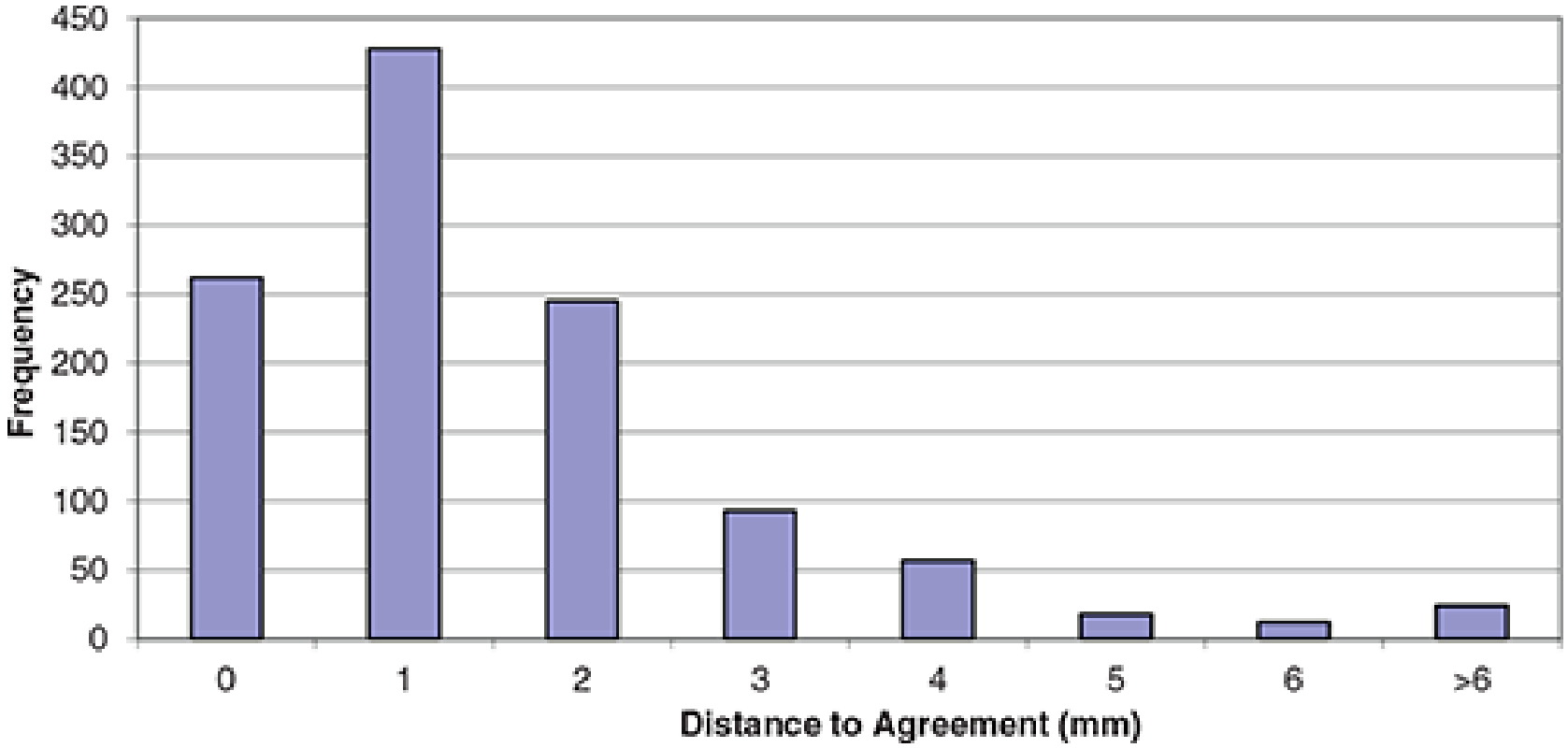
Molineu et al, Med Phys 40 (2): 022101-1 (2013)

TLD/Institution ratio for all PTV TLD Results



Molineu et al, Med Phys 40 (2): 022101-1 (2013)

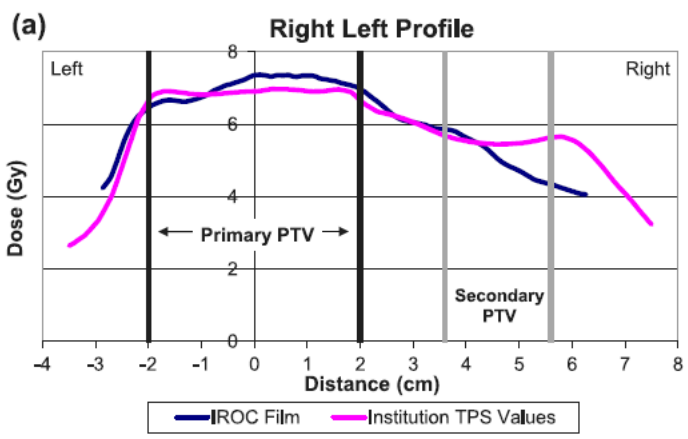
Distance to Agreement Values for All Irradiations

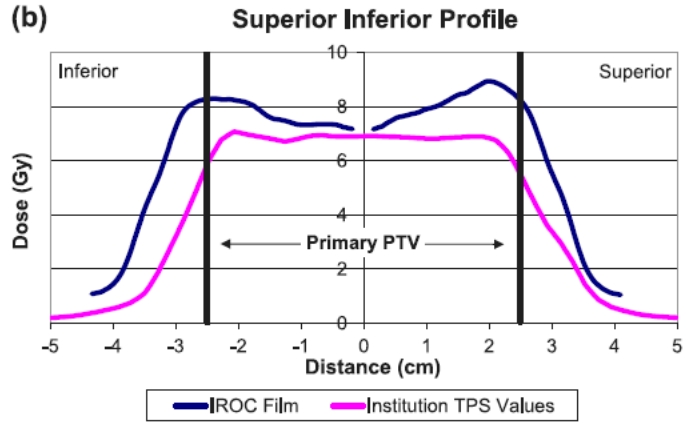


Molineu et al, Med Phys 40 (2): 022101-1 (2013)

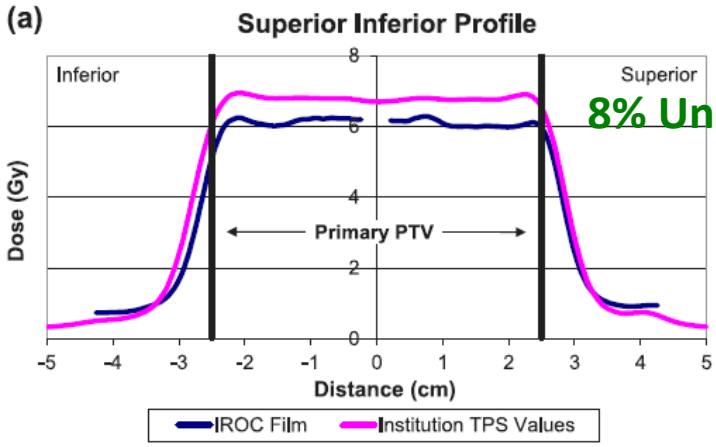
Global (non-systematic) & Systematic Error

Global Error

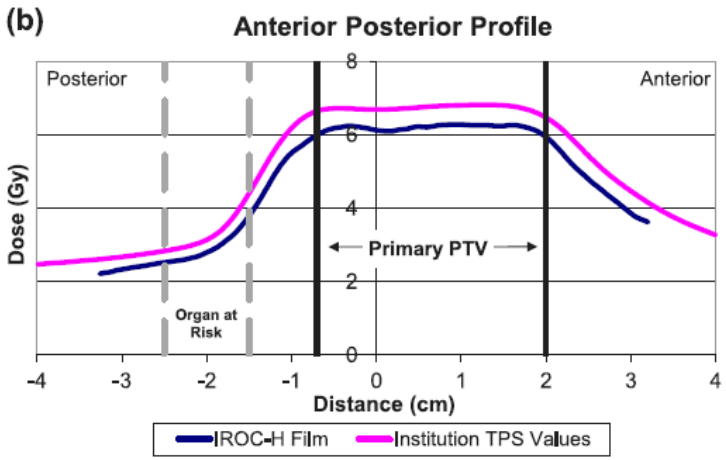




Systematic Error



8% Underdose



Carson et al, Med Phys 43 (12): 6491-96 (2016)

Causes of Failure

- Some linac TPS combinations performed better than other combinations
- Most detectable errors are systematic and dosimetric (60%)
- Causes of failure include:
  - Incorrect data entry into the TPS - output factors, pdd's, etc.
  - Inexact beam modelling
  - MLC leaf modeling
  - Software and hardware failures
  - Inexperienced QMP's and dosimetrists
  - IMRT implementation incorrect
  - Gross setup errors
  - Systematic and nonsystematic errors

Improvement – Carson et al predict that if IROC tightened criteria to 5%/4 mm, 77% of institutions would meet criteria today

Molineu et al, Med Phys 40 (2): 022101-1 (2013)

Treatment Planning - Third Party Products and Services

- Treatment intent, disease stage, previous treatments
- Patient positioning and immobilization
- Image acquisition, registration and input into TPS
- Anatomy delineation & image fusion (if necessary)
- Beam setup, technique (IMRT/VMAT/3DCRT, etc.) and dose calculation
- Dose constraints/goals
- Plan evaluation and quality

Ideally the patient should be simulated, planned and treated in one location by the same team. If not, "third party" could be Radiation Oncologist, Physicist, Dosimetrist or Therapist

Treatment Intent, Disease Stage & Previous Treatments

- Radiation oncologist, physicist, dosimetrist and therapist must have clear communication regarding the patient treatment site, intent and disease staging
- Any previous radiation treatment records for the patient should be obtained and documented
- If patient has a pacemaker, prosthesis, is pregnant, need anesthesia, etc. this information should be documented upfront and included during the entire process
- If patient has health issues, is claustrophobic, etc. this needs to also be taken into consideration
- Communication between all involved parties is key!!!!!

Patient Positioning and Immobilization

- Patient positioning and immobilization is extremely important to provide reproducible daily patient setup and minimize motion during treatment (simulation directives)
- This becomes more important if the patient is simulated, planned or treated in different locations
- The treatment site and adjacent normal tissues that need to be avoided need to be stated upfront (planning directives)
- The intended treatment technique – 3DCRT, IMRT, VMAT, SBRT, etc. needs to be defined
- Appropriate immobilization devices for the treatment site and treatment technique need to be utilized (transfer of devices, etc.)
- If bolus is needed this should be stated
- Take into account patient weight and couch weight limitations

Image acquisition, registration and input into TPS

- CT is the primary imaging modality in radiation therapy
- Adequate bore size for the patient and immobilization devices
- Ensure patient CT scan extent is sufficient
- Does the patient have metal prosthesis that could lead to severe CT artifacts? If so, is Metal Artifact Reduction reconstruction needed?
- Is 4D CT imaging needed for motion management?
- Appropriate patient isocenter marking
- Ensure connectivity between CT simulation software and TPS
- Ensure appropriate CT electron density match between scanner and treatment planning system

Anatomy Delineation & Image Fusion

- Sometimes contours are drawn by third-party
- Have the proper gross tumor volume (GTV) and clinical target volume (CTV) been delineated?
- Have the appropriate internal target volume (ITV) and planning target volume (PTV) with appropriate margins been contoured?
- Have the appropriate organs at risk (OAR) and planning organ at risk volumes (PRV) with appropriate margins been contoured?
- If possible standardized nomenclature (ICRU 83, ASTRO 2009, AAPM TG 263, NRG/RTOG) recommendations should be used
- Override density of artifacts, etc.
- Correct CT/MRI/PET fusion techniques if required

Beam Setup, Technique & Dose Calculation

- The radiation oncologist should define the treatment technique (3D CRT, IMRT, VMAT, SBRT, etc.) that needs to be used
- Appropriate machine selection with capability, field naming, isocenter location, etc.
- Appropriate IMRT/VMAT parameter choice and optimization
- Optimal dose grid size selection for calculation

Dose Constraints/Goals

- Have appropriate dose constraints been used?
- Joint AAPM/ASTRO Quantitative Analysis of Normal Tissue Effects in the Clinic (QUANTEC) published in IJROBP March 2010 is a good starting point
- Fraction size, total dose, tissue volume, etc. can affect tolerance dose

Quantec Tolerance Doses Example

Table 1. QUANTEC Summary: Approximate Dose/Volume/Outcome Data for Several Organs Following Conventional Fractionation (Unless Otherwise Noted)* (*Continued*)

Organ	Volume segmented	Irradiation type (partial organ unless otherwise stated)†	Endpoint	Dose (Gy), or dose/volume parameters†	Rate (%)	Notes on dose/volume parameters
Rectum	Whole organ	3D-CRT	Grade ≥ 2 late rectal toxicity, Grade ≥ 3 late rectal toxicity	V50 <50%	<15 <10	Prostate cancer treatment
	Whole organ	3D-CRT	Grade ≥ 2 late rectal toxicity, Grade ≥ 3 late rectal toxicity	V60 <35%	<15 <10	
	Whole organ	3D-CRT	Grade ≥ 2 late rectal toxicity, Grade ≥ 3 late rectal toxicity	V65 <25%	<15 <10	
	Whole organ	3D-CRT	Grade ≥ 2 late rectal toxicity, Grade ≥ 3 late rectal toxicity	V70 <20%	<15 <10	
	Whole organ	3D-CRT	Grade ≥ 2 late rectal toxicity, Grade ≥ 3 late rectal toxicity	V75 <15%	<15 <10	
Bladder	Whole organ	3D-CRT	Grade ≥ 3 late RTOG	Dmax <65	<6	Bladder cancer treatment. Variations in bladder size/shape/location during RT hamper ability to generate accurate data
	Whole organ	3D-CRT	Grade ≥3 late RTOG	V65 ≤50 % V70 ≤35 % V75 ≤25 % V80 ≤15 %		Prostate cancer treatment Based on current RTOG 0415 recommendation
Penile bulb	Whole organ	3D-CRT	Severe erectile dysfunction	Mean dose to 95% of gland <50	<35	
	Whole organ	3D-CRT	Severe erectile dysfunction	D90‖ <50	<35	
	Whole organ	3D-CRT	Severe erectile dysfunction	D60-70 <70	<55	
Small bowel	Individual small bowel loops	3D-CRT	Grade ≥ 3 acute toxicity§	V15 <120 cc	<10	Volume based on segmentation of the individual loops of bowel, not the entire potential peritoneal space
	Entire potential space within peritoneal cavity	3D-CRT	Grade ≥ 3 acute toxicity§	V45 <195 cc	<10	Volume based on the entire potential space within the peritoneal cavity

IJROBP 76 (3 sup)(2010)

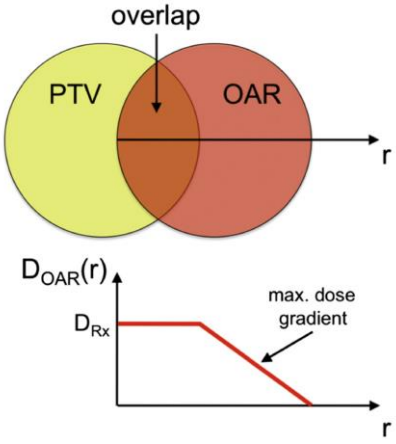
Plan Check & Evaluation

- Patient & Plan info (Patient name, MR, Radonc, Plan type)
- Setup & CT info (Immobilization, Orientation, Isocenter, CT-ED table)
- Dose Calculation Parameters (Linac properties, dose grid resolution, etc.)
- Prescription (Dose, time, fractionation, etc.)
- Contours (PTV and OAR, density overrides, DVH constraints, etc.)
- Beam Parameters (Beam info, isocenter, modality, energy, collimator, modifiers, control points, dose rate, MU Monitor unit (time) per field, etc.
- Dose Calculation (DVH, isodose lines, hot spots, max dose, etc.)
- Plan deliverability (Plan inspector, Collision check, etc.)
- Record and Verify data import
- IMRT / VMRT quality assurance
- Other (pacemaker, prosthesis, etc.)

Evaluating & Quantifying Plan Quality

- Do IMRT planning goals & constrains ensure safe plans?
- Need system that can identify sub-optimal plans (mostly manifested by insufficient OAR sparing
- In cases with minimal PTV/OAR overlap the planners might not push to provide a dose distribution that spares OAR more than the standard goal even if additional sparing was possible
- In cases with large PTV/OAR overlap the planners might expend time and effort to meet goals that are impossible to accomplish without unacceptable sacrifice of another goal

Geometry Based Dose Prediction Tool

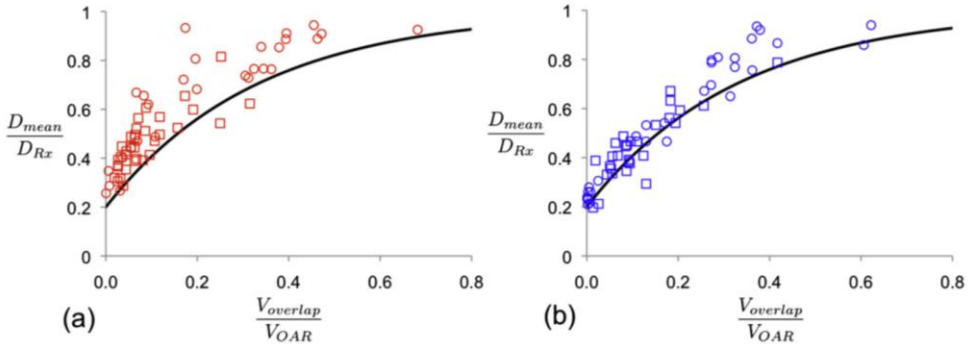


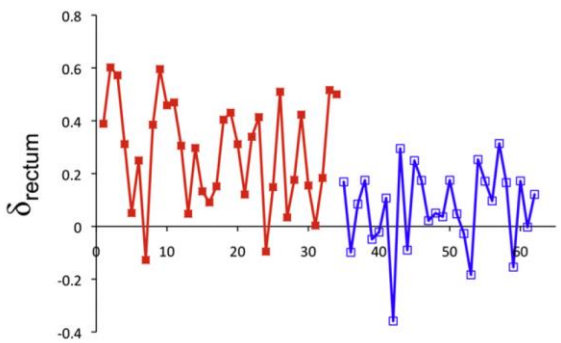
Moore et al, IJROBP 81 (2): 545-551 (2011)

Evaluating & Quantifying Plan Quality

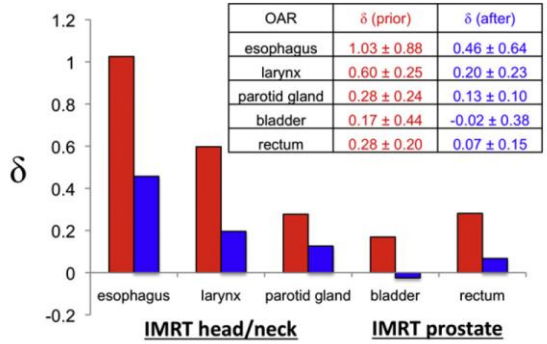
- Analyzed previous plans, then developed and implemented a model to predict OAR doses in advance for new patients
- Reduced inter-clinician treatment plan variability

$$\frac{D_{pred}}{D_{Rx}} = 0.2 + 0.8\left(1 - e^{-3V_{overlap}/V_{OARP}}\right)$$





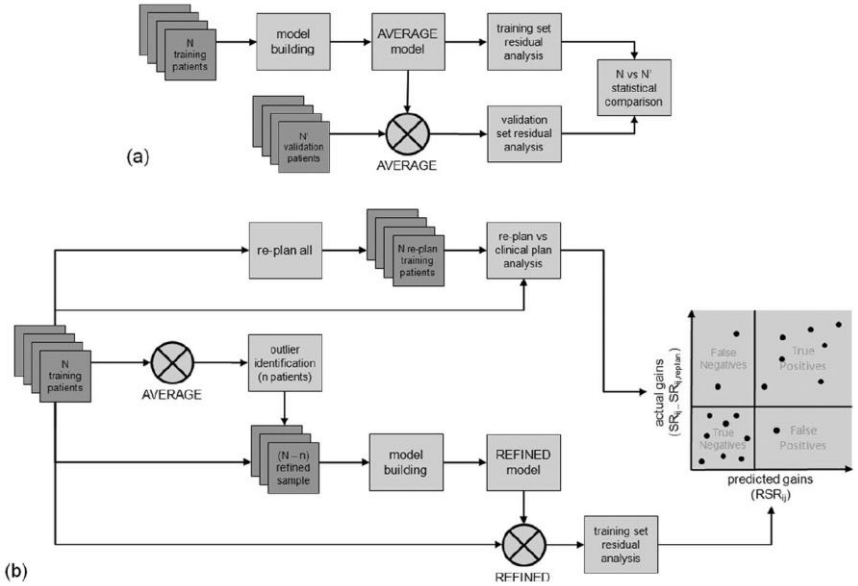
OAR	δ (prior)	δ (after)
esophagus	1.03 ± 0.88	0.46 ± 0.64
larynx	0.60 ± 0.25	0.20 ± 0.23
parotid gland	0.28 ± 0.24	0.13 ± 0.10
bladder	0.17 ± 0.44	-0.02 ± 0.38
rectum	0.28 ± 0.20	0.07 ± 0.15

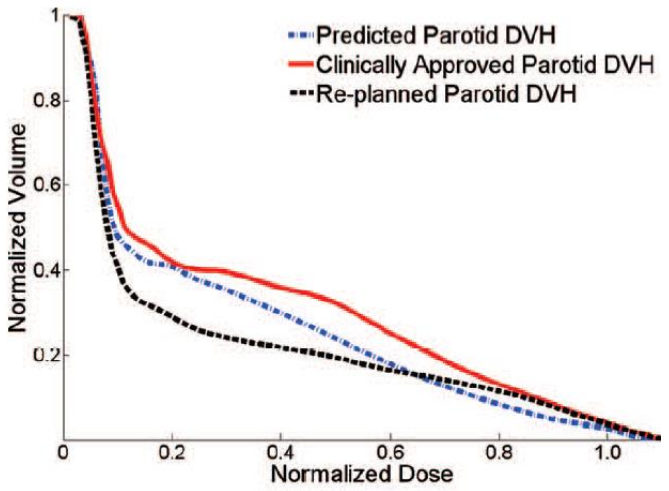


Moore et al, IJROBP 81 (2): 545-551 (2011)

Evaluating & Quantifying Plan Quality

- Metrics can be developed using previous plans to alert user that their current plan is suboptimal





Appenzolle et al, Med Phys 39 (12): 7446-7461 (2012)

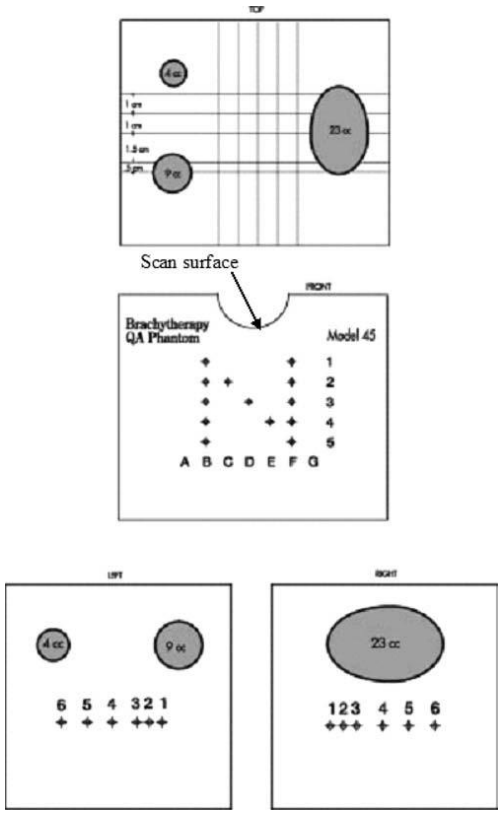
Prostate Implant Brachytherapy - Third Party Products and Services

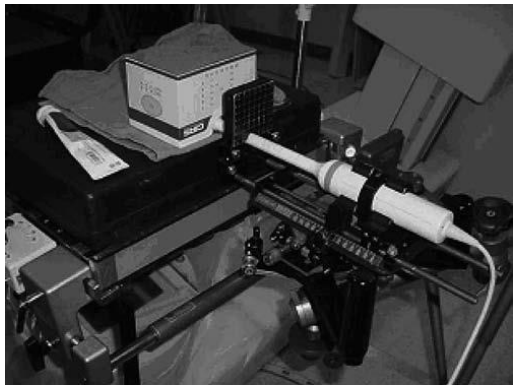
- American Cancer Society estimates approximately 180,890 new prostate cancer patients in the US in 2016
- Low dose rate prostate brachytherapy (prostate implant) is a treatment option depending upon the extent of the disease and approximately 40,000 men receive this treatment in the US annually
- Third party products (equipment, sources, etc.) and services (commissioning, QA, etc.) are available for performing prostate implants and qualified medical physicists should perform adequate QA to validate such products or services prior to clinical use

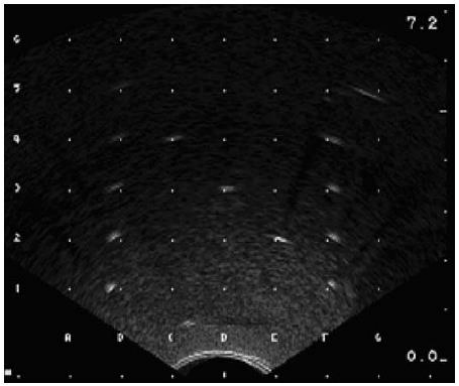
Ultrasound Commissioning and QA

- AAPM TG128 provides guidance on Trans Rectal Ultrasound QA

Test	Minimum frequency	Action level
Grayscale visibility	Annual	Change >2 steps or 10% from baseline
Depth of penetration	Annual	Change >1 cm from baseline
Axial and lateral resolution	Annual	Change >1 mm from baseline
Axial distance measurement accuracy	Annual	Error >2 mm or 2%
Lateral distance measurement accuracy	Annual	Error >3 mm or 3%
Area measurement accuracy	Annual	Error >5%
Volume measurement accuracy	Annual	Error >5%
Needle template alignment	Annual	Error >3 mm
Treatment planning computer volume accuracy	Acceptance testing	Error >5%





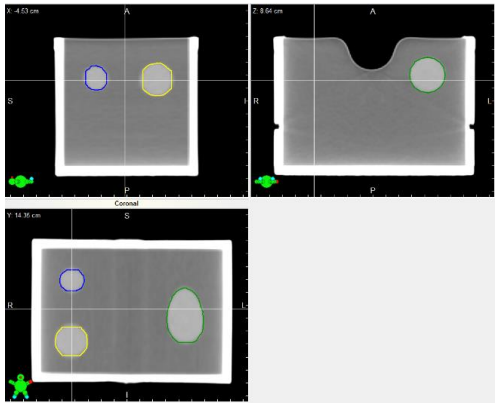


Pfeiffer et al., QA tests for prostate brachytherapy US systems. Med Phys 35,12, 5471-89 2008

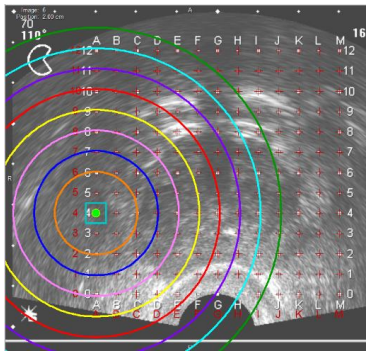
Prostate Implant TPS QA

- AAPM TG43 and TG43 updates provide dose calculation recommendations
- AAPM TG53 provides TPS QA guidelines

Contour Verification



Isodose Verification



Dose Verification

Dose point calculation for I-125 Model 6711 seed using Point Source Model and Line Source Model

Dose = Air Kerma * DoseRateConstant * GeometryFunction * RadialDoseFunction * AnisotropicFunction * Time

Dose was computed based on TG43 formalism.

seed activity	78.7	mCi
Source Length	0.3	cm
seed activity (Air Kerma)	100.00	U
Decay Constant	0.000486	/hr
DoseRateConstant	0.965	cGy/(hr*U)
Mean Life	2057.6	hr
Treatment Time	2057.7	hr

distance (cm)	Radial Dose Function (Point)†	Radial Dose Function (Line)†	Anisotropic Factor † (Theta = 90)	Anisotropic Function † (Theta = 90)	Line Geometry Function	Dose (Gy) Aniso Factor (Point Model)	Dose (Gy) Aniso Factor (Line Model)	Dose (Gy) Aniso Function (Line Model)	Dose Delivered (Gy) During the Treatment Aniso Factor (Point Model)	Dose Delivered (Gy) During the Treatment Aniso Factor (Line Model)	Dose Delivered (Gy) During the Treatment Aniso Function (Line Model)
0.50	1.0480	1.0710	0.9730	1.0000	3.8861	8659.88	8848.33	8264.06	8638.53	8988.35	8394.57
1.00	1.0000	1.0000	0.9440	1.0000	0.9926	1874.40	1868.53	1985.60	1883.59	1863.65	1980.56
1.50	0.9120	0.9080	0.9435	1.0000	0.4430	759.36	753.52	801.30	763.08	757.21	802.56
2.00	0.8190	0.8140	0.9410	1.0000	0.2495	382.56	378.52	404.07	384.44	381.38	405.29
2.50	0.7275	0.7230	0.9415	1.0000	0.1598	217.60	216.00	229.69	218.67	217.06	230.54
3.00	0.6360	0.6320	0.9420	1.0000	0.1110	132.18	131.24	139.43	132.83	131.88	140.09
3.50	0.5575	0.5540	0.9430	1.0000	0.0816	86.74	86.15	91.42	87.17	86.58	91.81
4.00	0.4890	0.4960	0.9440	1.0000	0.0625	58.46	58.08	61.55	58.74	58.36	61.83
4.50	0.4330	0.4300	0.9440	1.0000	0.0494	40.08	39.79	42.16	40.28	39.98	42.35
5.00	0.3870	0.3840	0.9440	1.0000	0.0400	27.62	27.28	28.91	27.65	27.42	29.04
5.50	0.3495	0.3470	0.9440	1.0000	0.0330	19.80	19.64	20.81	19.89	19.73	20.90
6.00	0.2720	0.2700	0.9440	1.0000	0.0278	14.16	14.06	14.89	14.23	14.12	14.96
6.50	0.2360	0.2345	0.9440	1.0000	0.0237	10.47	10.40	11.02	10.52	10.45	11.07
7.00	0.2000	0.1990	0.9440	1.0000	0.0204	7.65	7.61	8.06	7.69	7.65	8.10

† The values are hard coded to reflect the most accurate computation. Obtained from VariSeed Commissioning Source Specification

Use this to compute dose (Gy) for any arbitrary distance (B37), seed activity(D10), and treatment time (D14).

Distance (cm)	Radial Dose Function (Point)	Radial Dose Function (Line)	Anisotropic Factor	Anisotropic Function	Line Geometry Function	Dose (Gy) Aniso Factor (Point Model)	Dose (Gy) Aniso Factor (Line Model)	Dose (Gy) Aniso Function (Line Model)
4	0.4948	0.4915	0.9427	1	0.0625	58.17	57.76	61.27

***Because some of the values were interpolated, there is finite error associated with the computation.

distance (cm)	Reference Dose (Gy) Aniso Factor (Point	% Difference*	Reference Dose (Gy) Aniso Factor (Line Model)	% Difference*	Reference Dose (Gy) Aniso Function (Line Model)	% Difference*
0.50	8680.19	0.23%	8682.18	-0.51%	8306.46	-0.51%
1.00	1870.08	0.23%	1870.08	-0.51%	1981.01	0.23%
1.50	756.8	0.34%	756.58	-0.46%	802.74	-0.18%
2.00	381.68	0.23%	381.47	-0.51%	405.38	-0.32%
2.50	217.1	0.23%	217.11	-0.51%	230.6	-0.39%
3.00	131.87	0.23%	131.91	-0.51%	140.03	-0.43%
3.50	86.5	0.28%	86.55	-0.46%	91.83	-0.45%
4.00	58.26	0.34%	58.32	-0.41%	61.84	-0.46%
4.50	39.97	0.27%	39.97	-0.46%	42.36	-0.46%
5.00	27.45	0.24%	27.42	-0.52%	29.05	-0.48%
5.50	19.75	0.24%	19.74	-0.52%	20.91	-0.45%
6.00	14.13	0.23%	14.13	-0.53%	14.97	-0.52%
6.50	10.45	0.19%	10.46	-0.56%	11.08	-0.54%
7.00	7.63	0.27%	7.65	-0.51%	8.1	-0.45%

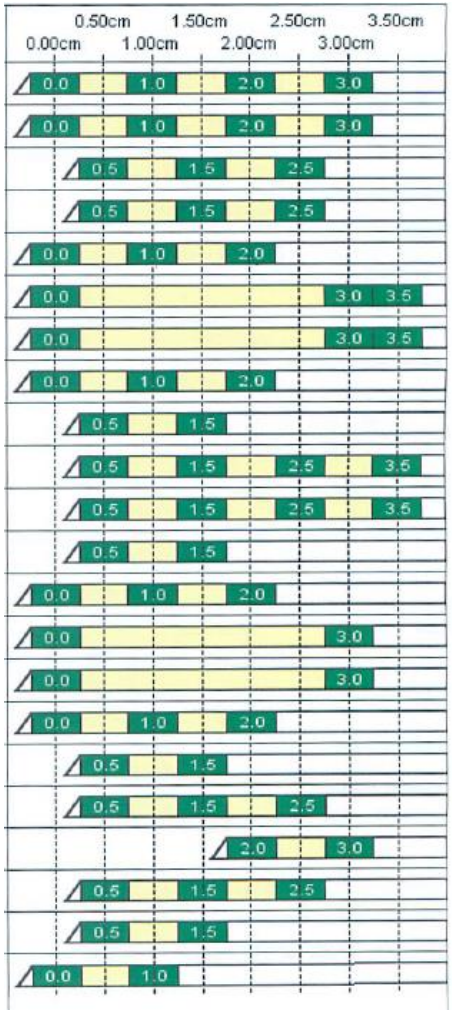
The reference doses were obtained from Varian VariSeed 8.0 Source Specification document

* % Difference will only be computed if the seed activity is set to 100 U.

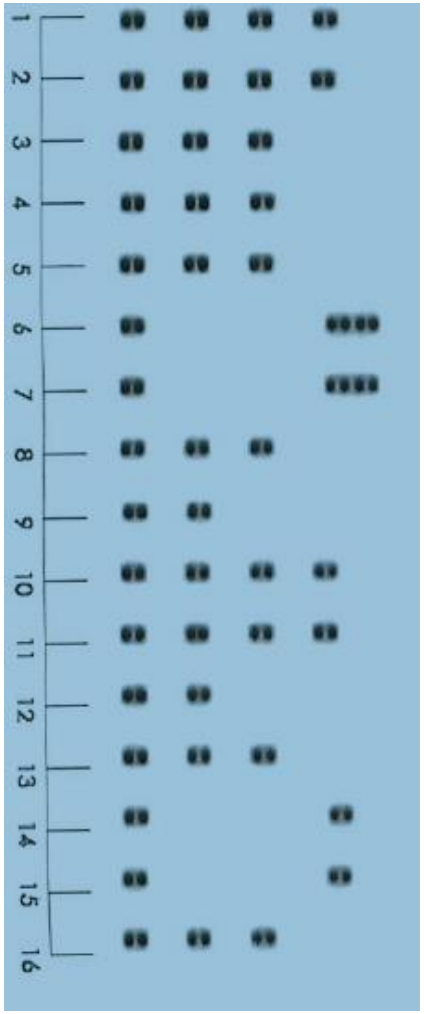
DosePointCalc / TabRadialDoseFunPoint / TablRadialDoseFunLine / Aniso Factor / Sheet3

Ready

Source/Seed Location QA Film



Treatment Plan
Needle Loading Pattern



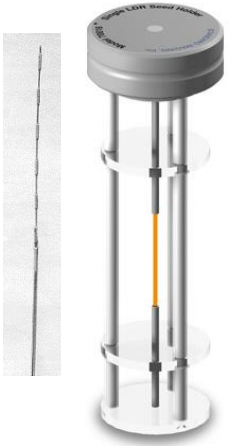
Loaded Needles

Source Assay

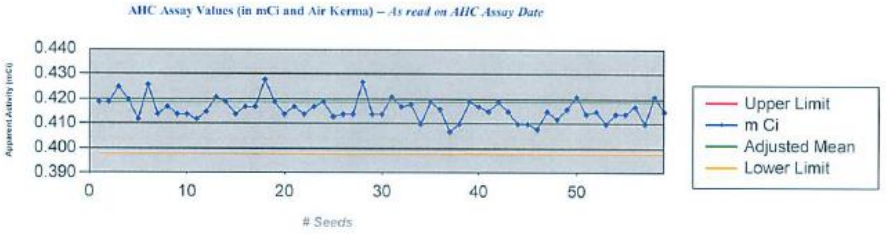
- Variety of options are available for sources and applicators
- The physicist must be aware of the different assay requirements for sources that are loose, stranded, or ones that are preloaded into needles
- Third party vendors provide assay services, although mistakes can still occur, thus the qualified medical physicist should independently verify the assay
- AAPM TG56 recommends a random sample of 10% of the sources in a shipment be checked

Source Assay

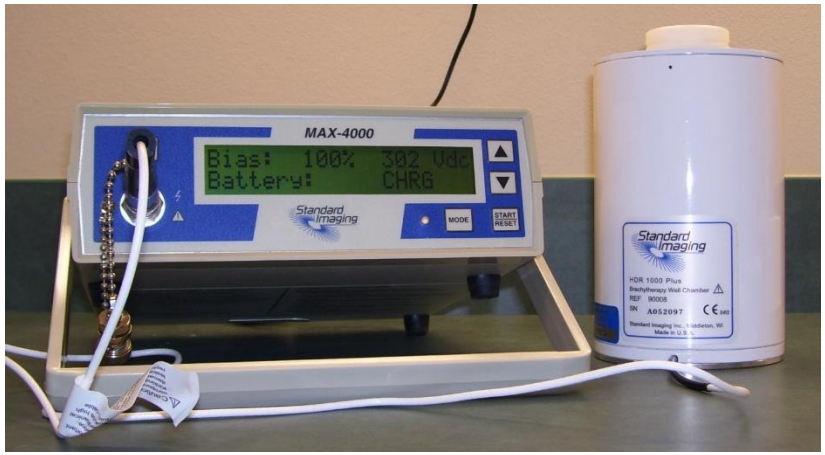
Needles, strand and source holder



Vendor 100% source assay



Calibrated Well Chamber & Electrometer



Independent institution assay

Isotope:	I-125 IsoAid				Half Time :	59.4 days
Chamber Calibration Factor:	0.1785	mCi/pA	Chamber:	Standard Imaging, A052097		
Electrometer Calibration Factor:	0.999	pA/Reading	Expiration Date:	2/27/2017		
Temperature:	21.3	degrees C	Electrometer:	Standard Imaging, F143149		
Pressure:	761.2	mmHg	Expiration Date:	2/27/2017		
MDACC Assay Date:	3/31/2015					
Seed Manufacturer:	IsoAid					
Manufacturer Calibration Date:	4/1/2015					
Manufacturer Certified Activity: (on Manufacturer Calibration Date)	0.388	mCi				
Days since Manufacturer Calibration:	-1					
Number of QA Seeds:	5					
Duration of Charge Collection:	15	seconds/reading				
Background Reading:	0.06	pC				

			MDACC Activity		
Seed #	Reading(pC)	pA	on Date of MDACC Assay	on Date of Manufacturer Calib	MDACC/ Manufacturer
1	33.58	2.235	0.397	0.392	1.011
2	32.47	2.161	0.384	0.379	0.978
3	32.99	2.195	0.390	0.385	0.993
4	33.29	2.215	0.393	0.389	1.002
5	33.00	2.196	0.390	0.386	0.994
Averages	33.07	2.200	0.391	0.386	0.996

Enter readings here.

Seed #	Reading1	Reading2	Reading3
1	33.64	33.51	33.60
2	32.51	32.52	32.39
3	32.99	32.93	33.04
4	33.35	33.28	33.24
5	33.04	32.94	33.02

Quantity of brachytherapy sources to be assayed by the end-user physicist

Source Form	Number to be Assayed
All loose sources, non-sterile	≥10% of total or 10 seeds, whichever is larger
Non-sterile cartridges	≥10% of total via whole cartridge assay or via single sources
Mixture of non-sterile loose sources and sterile assemblies	Loose sources amounting to ≥10% of the total order or ten seeds, whichever is larger
Sterile source assemblies	≥10% of assemblies via sterile well chamber inserts or quantitative image analysis Alternatively, order and assay non-sterile loose seeds equal to 5% of the total or five seeds, whichever is fewer
Strands	≥10% of total of two strands, whichever is larger, using single-seed calibration coefficient Alternatively, order and assay non-stranded loose seeds equal to 5% of the total or five seeds, whichever is fewer

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Action to be taken based on sample size and relative difference ΔS_K

Sample size for assay of sources by end-user medical physicist	Relative difference vendor and physicist assay (ΔS_K)	Action by end-user medical physicist
Individual source as part of an order of ≥ 10 sources	$\Delta S_K \leq 6\%$ $\Delta S_K > 6\%$	Nothing further Consult with radiation oncologist regarding use of the outlier source
≥10% but <100% of order, or batch measurements of individual sterile strands, cartridges or preloaded needles	$\Delta S_K \leq 3\%$ $5\% \geq \Delta S_K > 3\%$ $\Delta S_K > 5\%$	Nothing further Investigate source of discrepancy or increase no. Consult with vendor to resolve difference & Radonc
100% of order, or batch measurement of each sterile strand, cartridge or preloaded needle	$\Delta S_K \leq 3\%$ $5\% \geq \Delta S_K > 3\%$ $\Delta S_K > 5\%$	Nothing further Investigate source of discrepancy or increase no. Consult with vendor to resolve difference & Radonc

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Conclusions

- There is an increased use of third party radiation therapy products and services
- These products and services play an important role by filling a need due to lack of well qualified physicists in certain regions
- It is alright to use third-party products and services, however, these products and services should be thoroughly validated prior to clinical use