IMRT/VMAT: AAPM Recommendations for Commissioning and Delivery Verification

Emilie Soisson, Ph.D.
ICTP 2019

Learning Objectives

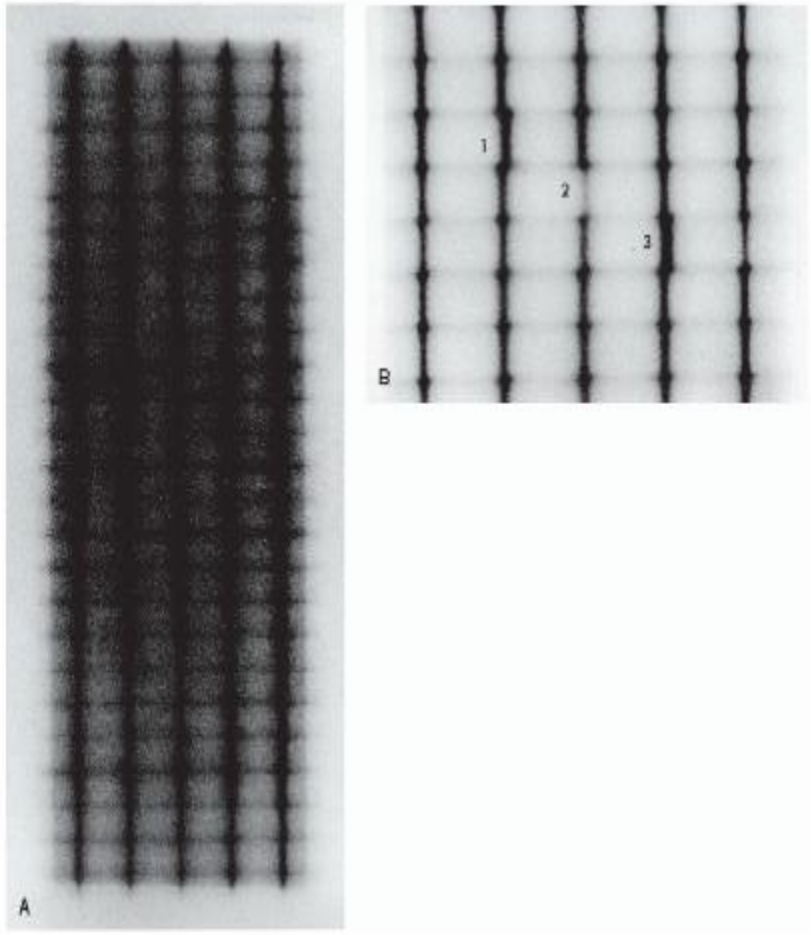
- To understand IMRT/VMAT commissioning and QA
- To be able to describe available measurement tools and analysis technique
- To be able to describe the limitations of each technique and future directions

Commissioning

- IMRT and VMAT can be available usually with minor hardware and software upgrades
- Validation can be challenging
- Commissioning is require for both planning and delivery to make sure planned doses can be delivered accurately

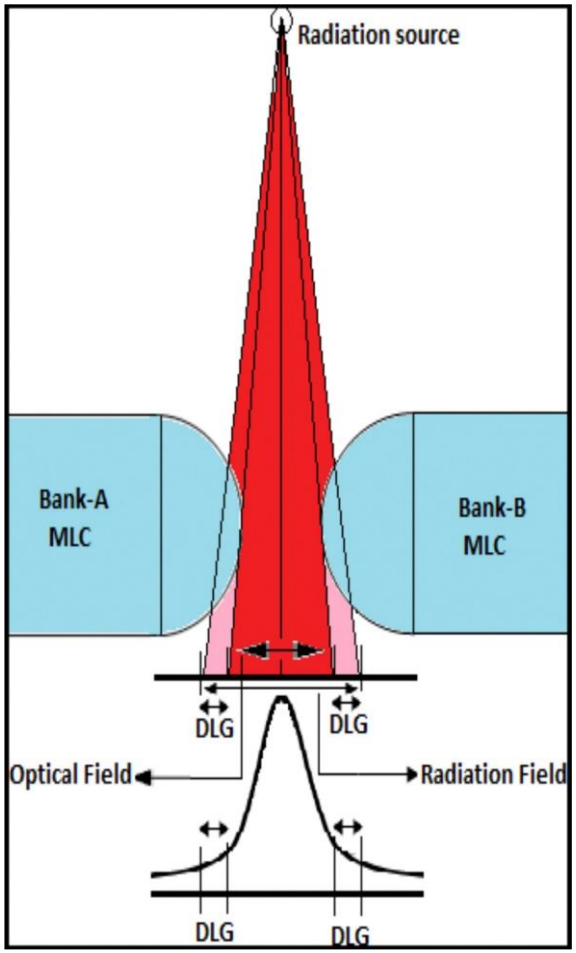
IMRT/VMAT – MLC tests

- Additional MLC tests may be required
  - Dosimetry
  - – Leaf gap
  - – Transmission
  - Mechanical
  - – Speed
  - – Positioning



Chui CS, Spirou S, LoSasso T. Testing of dynamic multileaf collimation. Med Phys. 1996;23:635-641

MLC Characteristics



From Shende et al. Reports of Practical Oncology & Radiotherapy Volume 22, Issue 6, November–December 2017, Pages 485-494

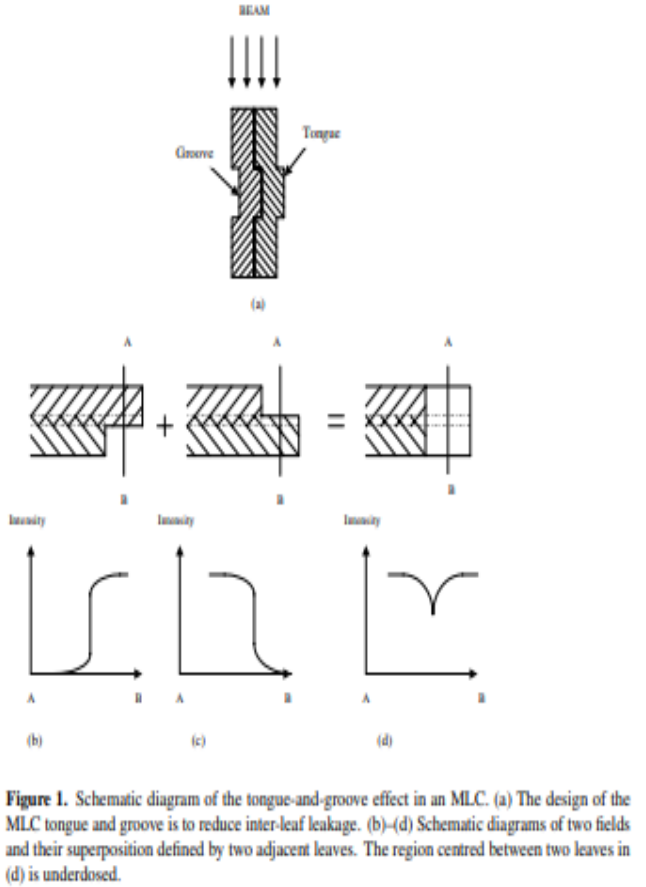
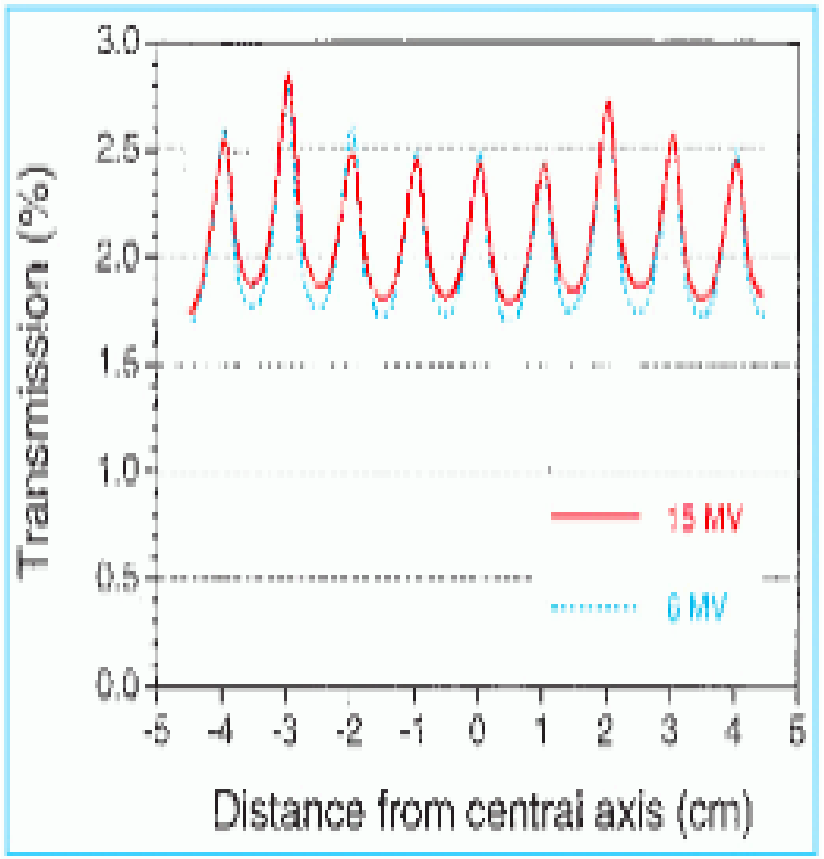
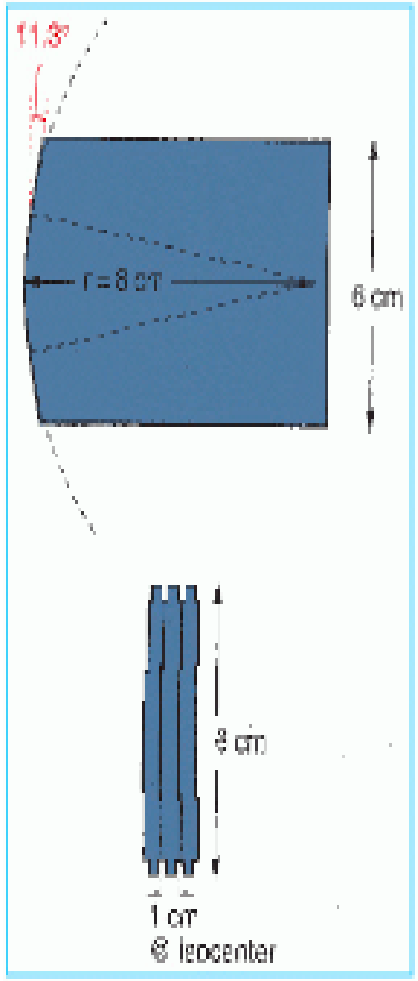


Figure 1. Schematic diagram of the tongue-and-groove effect in an MLC. (a) The design of the MLC tongue and groove is to reduce inter-leaf leakage. (b)-(d) Schematic diagrams of two fields and their superposition defined by two adjacent leaves. The region centred between two leaves in (d) is underdosed.

From Deng et al. The MLC tongue-and-groove effect on IMRT dose distributions. Phys. Med. Biol. 46 (2001) 1039–1060

Inter- and Intra-leaf Leakage





LoSasso T, Chui CS, Ling CC. Physical and dosimetric aspects of a mu collimation system used in the dynamic mode for implementing intensity-modulated radiotherapy. Med Phys. 1998;25:1919-1927

Int. J. Radiation Oncology Biol. Phys., Vol. 72, No. 2, pp. 575–581, 2008

0360-3016/08/$–see front matter

ELSEVIER

doi:10.1016/j.ijrobp.2008.05.060

PHYSICS CONTRIBUTION

COMMISSIONING AND QUALITY ASSURANCE OF RAPIDARC RADIOTHERAPY DELIVERY SYSTEM

C. CLIFTON LING, PH.D.,*† PENGPENG ZHANG, PH.D.,† YVES ARCHAMBAULT, M.SC.,* JIRI BOCANEK, M.SC.,* GRACE TANG, M.PHIL.,‡ AND THOMAS LOSASSO, PH.D.†

*Varian Medical Systems, Palo Alto, CA; †Memorial Sloan-Kettering Cancer Center, New York, NY; and ‡University of Maryland, Baltimore, MD

Purpose: The Varian RapidArc is a system for intensity-modulated radiotherapy (IMRT) treatment planning and delivery. RapidArc incorporates capabilities such as variable dose-rate, variable gantry speed, and accurate and fast dynamic multileaf collimators (DMLC), to optimize dose conformality, delivery efficiency, accuracy and reliability. We developed RapidArc system commissioning and quality assurance (QA) procedures.

Methods and Materials: Tests have been designed that evaluate RapidArc performance in a stepwise manner. First, the accuracy of DMLC position during gantry rotation is examined. Second, the ability to vary and control the dose-rate and gantry speed is evaluated. Third, the combined use of variable DMLC speed and dose-rate is studied.

Results: Adapting the picket fence test for RapidArc, we compared the patterns obtained with stationary gantry and in RapidArc mode, and showed that the effect of gantry rotation on leaf accuracy was minimal (≤0.2 mm). We then combine different dose-rates (111–600 MU/min), gantry speeds (5.5–4.3°/s), and gantry range ($\Delta\theta = 90$–$12.9°$) to give the same dose to seven parts of a film. When normalized to a corresponding open field (to account for flatness and asymmetry), the dose of the seven portions show good agreement, with a mean deviation of 0.7%. In assessing DMLC speed (0.46, 0.92, 1.84, and 2.76 cm/s) during RapidArc, the analysis of designed radiation pattern indicates good agreement, with a mean deviation of 0.4%.

Conclusions: The results of these tests provide strong evidence that DMLC movement, variable dose-rates and gantry speeds can be precisely controlled during RapidArc. © 2008 Elsevier Inc.

RapidArc, Commissioning, QA.

Accuracy of MLC During RapidArc

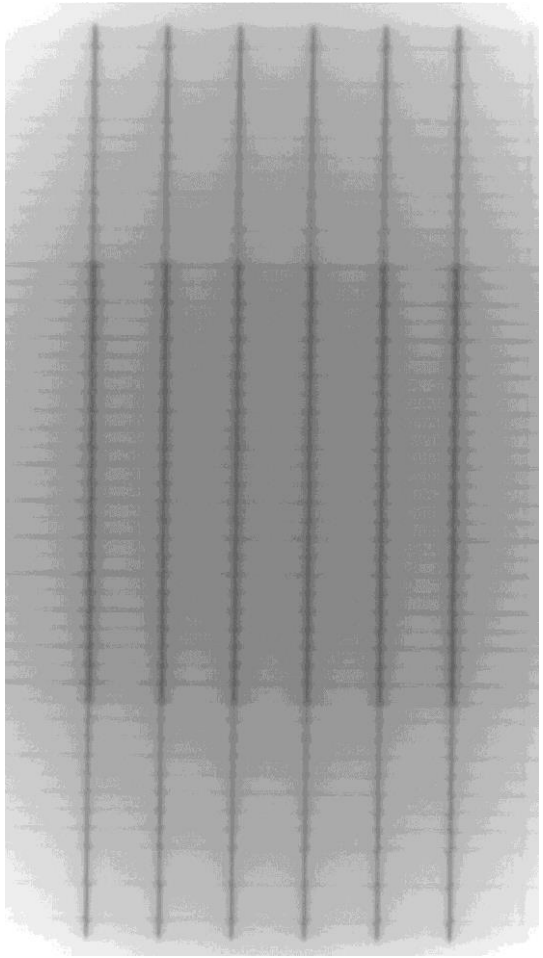
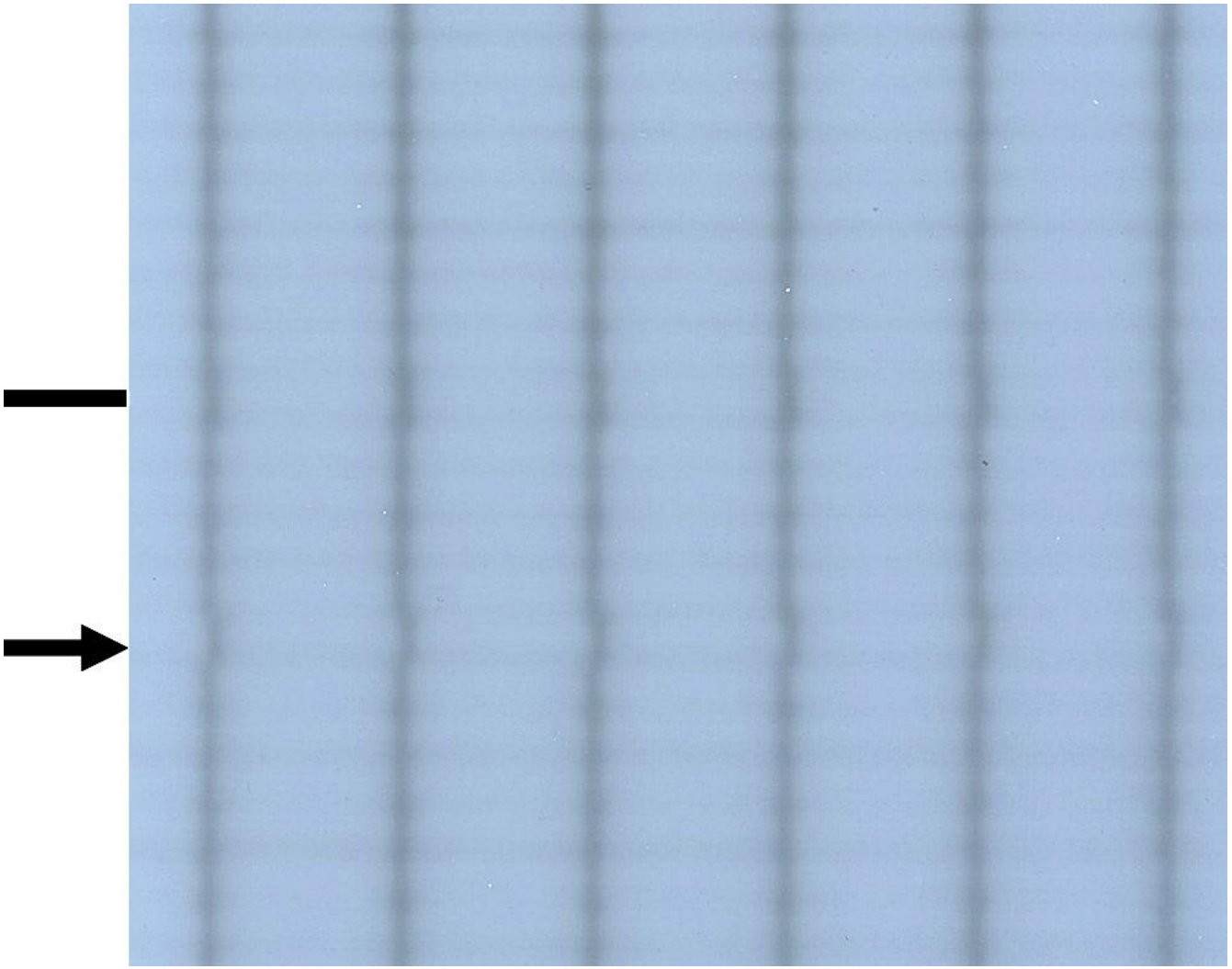


Image of a film that was exposed twice to the 1-mm-wide picket fence pattern, once at stationary gantry angle and a second time in RapidArc mode.

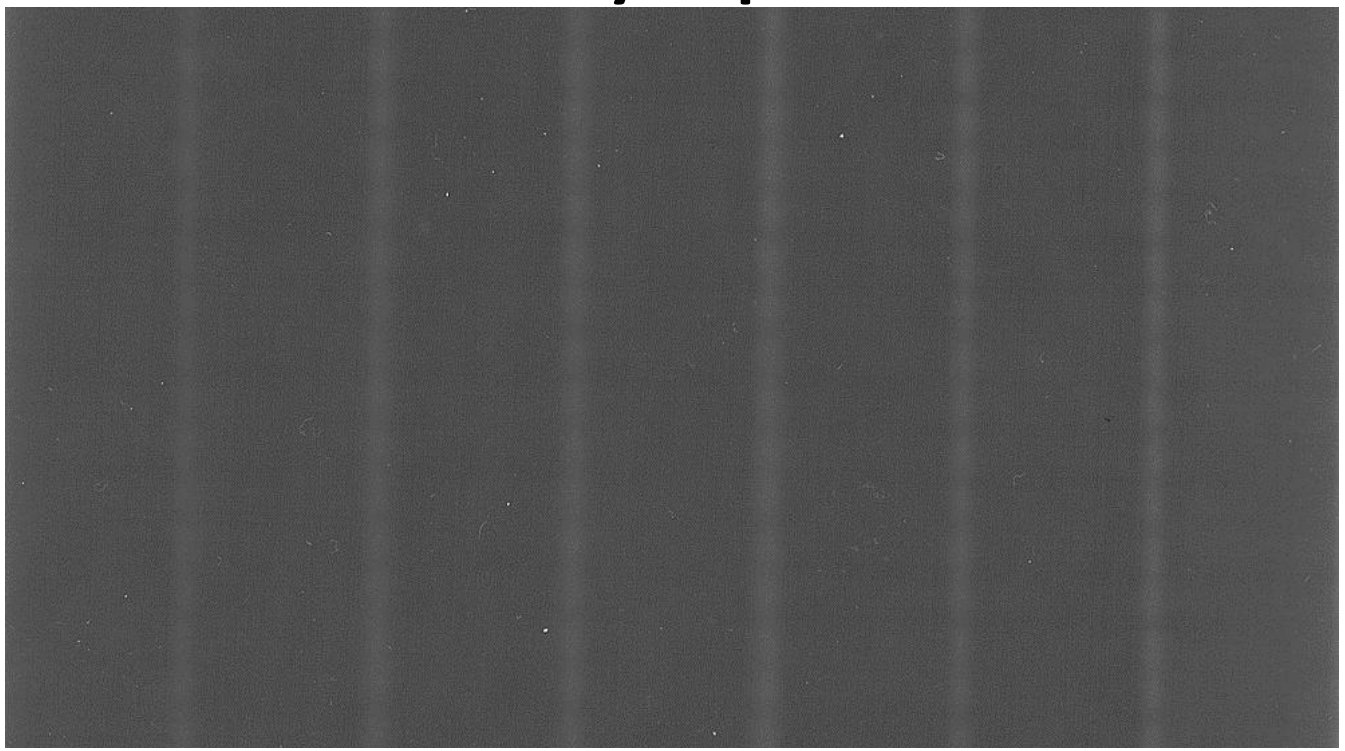
Ling et al. International Journal of Radiation Oncology • Biology • Physics
Volume 72, Issue 2, Pages 575-581 (October 2008)

Intentional Leaf Positioning Errors



A film exposed to the 1-mm-wide picket fence pattern with “intentional” errors in fence width and position.

Ability to vary Dose Rate and Gantry Speed

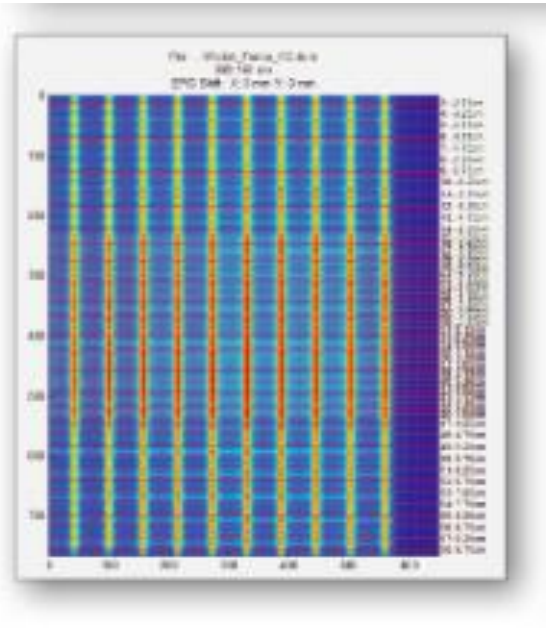


Film exposed to a RapidArc QA plan, combining different dose-rates, gantry ranges, and gantry speeds, to give the same monitor unit (MU) to the different parts of the field.

MLC Tests for VMAT

RapidArc® MLC

- **Test 0.1:** dMLC Dosimetry
- **Test 0.2:** Picket Fence Test vs. Gantry Angle
- **Test 1.1:** Picket Fence Test during RapidArc®
- **Test 1.2:** Picket Fence Test during RapidArc® with Intentional Errors
- **Test 2:** Accurate Control of Dose Rate and Gantry Speed during RapidArc® Delivery
- **Test 3:** Accurate Control of Leaf Speed during RapidArc® Delivery



https://radimage.com/solutions/mlc-qa/

Received: 30 January 2017 | Revised: 28 February 2017 | Accepted: 6 March 2017
DOI: 10.1002/acm2.12080

AAPM REPORTS & DOCUMENTS

WILEY

AAPM Medical Physics Practice Guideline 8.a.: Linear accelerator performance tests

Koren Smith[1] | Peter Balter[2] | John Duhon[3] | Gerald A. White Jr.[4] | David L. Vassy Jr.[5] | Robin A. Miller[6] | Christopher F. Serago[7] | Lynne A. Fairobent[8]

Recommended Monthly

D5 Dynamic delivery control

Volumetric modulated arc therapy (VMAT) and sliding window techniques are types of dynamic deliveries routinely used that require the synchronization of the dose rate with other dynamic components of the machine. To produce a dynamic delivery, some combination of multileaf collimator (MLC) position, MLC leaf speed, dose rate, and gantry speed and position are varied throughout the treatment. Patient-specific QA may not test the full range of these parameters, therefore, a **monthly** test of each of the dynamic control components used clinically is recommended. Tests have been designed to ensure the machine control of the individual dynamic components or to test them in combination by varying one dynamic control against another. Varian Medical Systems provides a series of tests for dynamic delivery along with the Digital Imaging and Communications in Medicine (DICOM) plans needed to execute them and spreadsheets to help with the analysis. In these tests, the gantry speed is varied against the dose rate control in one test and the MLC speed is varied against the dose rate control in another. Elekta provides similar tests at the time of acceptance. Or the user may design their own fields to test the different elements. With this

IMRT/VMAT Commissioning - TPS

- AAPM MPPG 5a recommends the following tests
- VMAT, Segmental IMRT, and Dynamic IMRT need to be validated separately

	Test	Description
1	Verify small field PDD	<2x2cm2, MLC shaped
2	Output for small MLC defined field	Small MLC defined segments
3	AAPM TG-119 tests	Plan, measure and compare benchmark cases
4	Clinical tests	Plan, measure and compare representative clinical cases
5	External Review	Sim, plan, and treat anthropomorphic phantom

From AAPM MPPG 5a. Journal of Applied Clinical Medical Physics, Vol. 16, No. 5, 2015

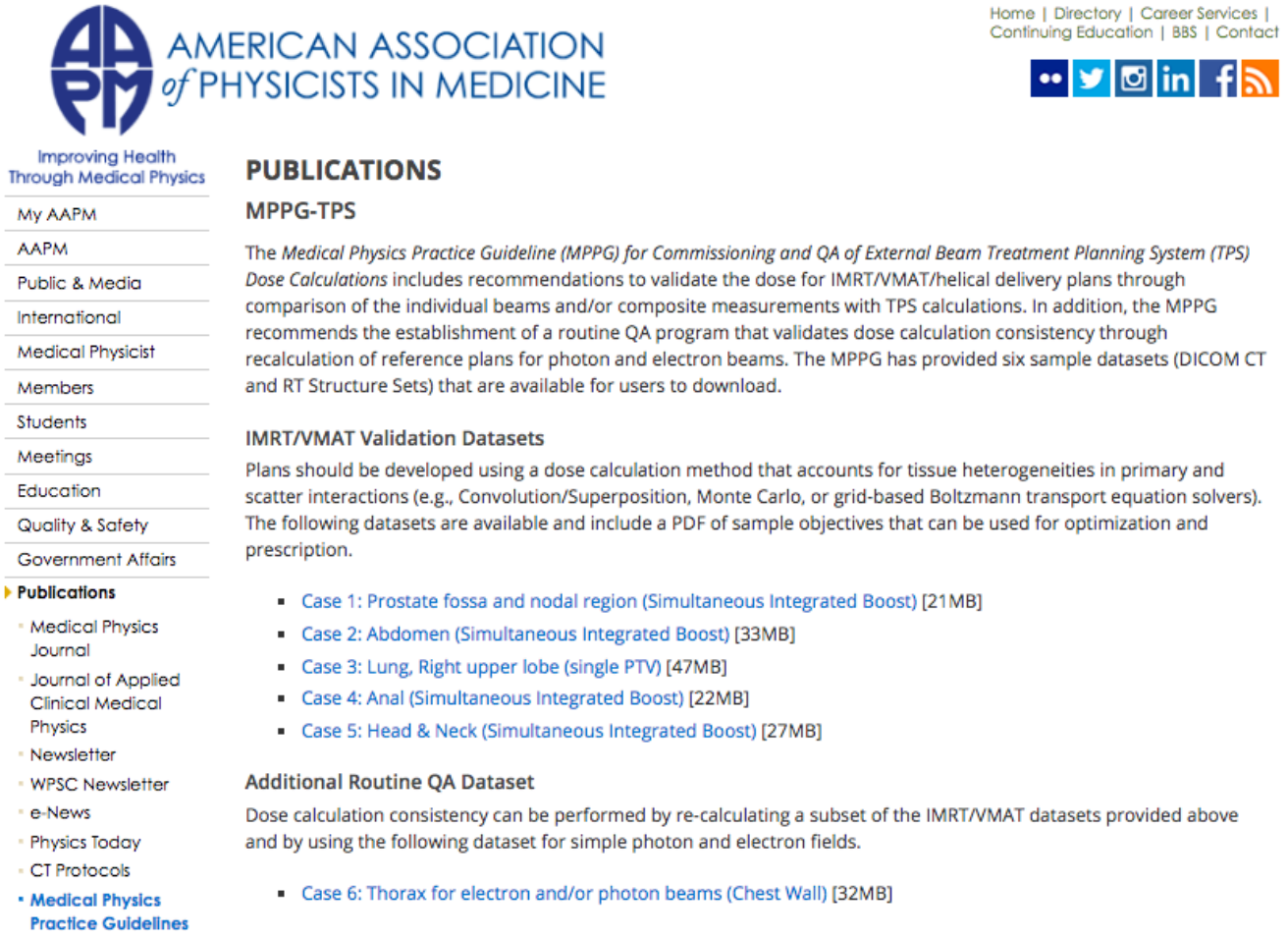
TABLE 7. VMAT/IMRT test summary.

Test	*Objective*	*Description (example)*	*Detector*	*Ref*
7.1	Verify small field PDD	≤ 2×2 cm^2 MLC shaped field, with PDD acquired at a clinically relevant SSD	Diode or plastic scintillator	Yunice et al.[16]
7.2	Verify output for small MLC-defined fields	Use small square and rectangular MLC-defined segments, measuring output at a clinically relevant depth for each[a]	Diode, plastic scintillator, minichamber or microion chamber	Cadman et al.[58]
7.3	TG-119 tests	Plan, measure, and compare planning and QA results to the TG119 report for both the Head and Neck and C-shape cases	Ion chamber, film and/or array	TG-119 (Ezzell et al.[37])
7.4	Clinical tests	Choose at least 2 relevant clinical cases; plan, measure, and perform an in-depth analysis of the results	Ion chamber, film and/or array	Nelms et al.[42]
7.5	External review	Simulate, plan, and treat an anthropomorphic phantom with embedded dosimeters.	Various options exist[b]	Kry et al.[39]

[a] A bar pattern scanned with a diode can be used to obtain additional absolute dose profile comparison in the direction perpendicular to MLC movement

[b] If IROC Houston service is used, they typically employ TLDs and radiochromic film. Certain commercial phantoms can accommodate ion chambers for point dose measurements

MPPG 5A Additional Resources



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  - Newsletter
  - WPSC Newsletter
  - e-News
  - Physics Today
  - CT Protocols
  - **Medical Physics Practice Guidelines**

PUBLICATIONS

MPPG-TPS

The *Medical Physics Practice Guideline (MPPG) for Commissioning and QA of External Beam Treatment Planning System (TPS) Dose Calculations* includes recommendations to validate the dose for IMRT/VMAT/helical delivery plans through comparison of the individual beams and/or composite measurements with TPS calculations. In addition, the MPPG recommends the establishment of a routine QA program that validates dose calculation consistency through recalculation of reference plans for photon and electron beams. The MPPG has provided six sample datasets (DICOM CT and RT Structure Sets) that are available for users to download.

IMRT/VMAT Validation Datasets

Plans should be developed using a dose calculation method that accounts for tissue heterogeneities in primary and scatter interactions (e.g., Convolution/Superposition, Monte Carlo, or grid-based Boltzmann transport equation solvers). The following datasets are available and include a PDF of sample objectives that can be used for optimization and prescription.

- Case 1: Prostate fossa and nodal region (Simultaneous Integrated Boost) [21MB]
- Case 2: Abdomen (Simultaneous Integrated Boost) [33MB]
- Case 3: Lung, Right upper lobe (single PTV) [47MB]
- Case 4: Anal (Simultaneous Integrated Boost) [22MB]
- Case 5: Head & Neck (Simultaneous Integrated Boost) [27MB]

Additional Routine QA Dataset

Dose calculation consistency can be performed by re-calculating a subset of the IMRT/VMAT datasets provided above and by using the following dataset for simple photon and electron fields.

- Case 6: Thorax for electron and/or photon beams (Chest Wall) [32MB]

Other IMRT/VMAT Commissioning

- Ezzel GA, Galvin JM, Low D et al. Guidance document on delivery, treatment planning, and clinical implementation of IMRT: report of the IMRT subcommittee of the AAPM radiation therapy committee. Med Phys. 2003; 30:2089-2115.
- Ling et al. Commissioning and quality assurance of rapidarc delivery system. IJROBP.2008 Oct 1;72(2):575-81 (Varian)
- Beford et al. Commissioning of Voumetric Modulated Arc Therapy (VMAT). IJROBP. 2009;73:537-545. (Elekta)
- ESTRO Booklet 9
- AAPM MPPG 5A
- AAPM TG119, 120, 218
- Read the manual!

AAPM Recommendations: Report of Task Group 120

Dosimetry tools and techniques for IMRT

Daniel A. Low[a)]
Washington University, St. Louis, Missouri 63110

Jean M. Moran
University of Michigan, Ann Arbor, Michigan 48109

James F. Dempsey
Viewray Incorporated, Cleveland, Ohio 44106

Lei Dong
M. D. Anderson Cancer Center, Houston, Texas 77013

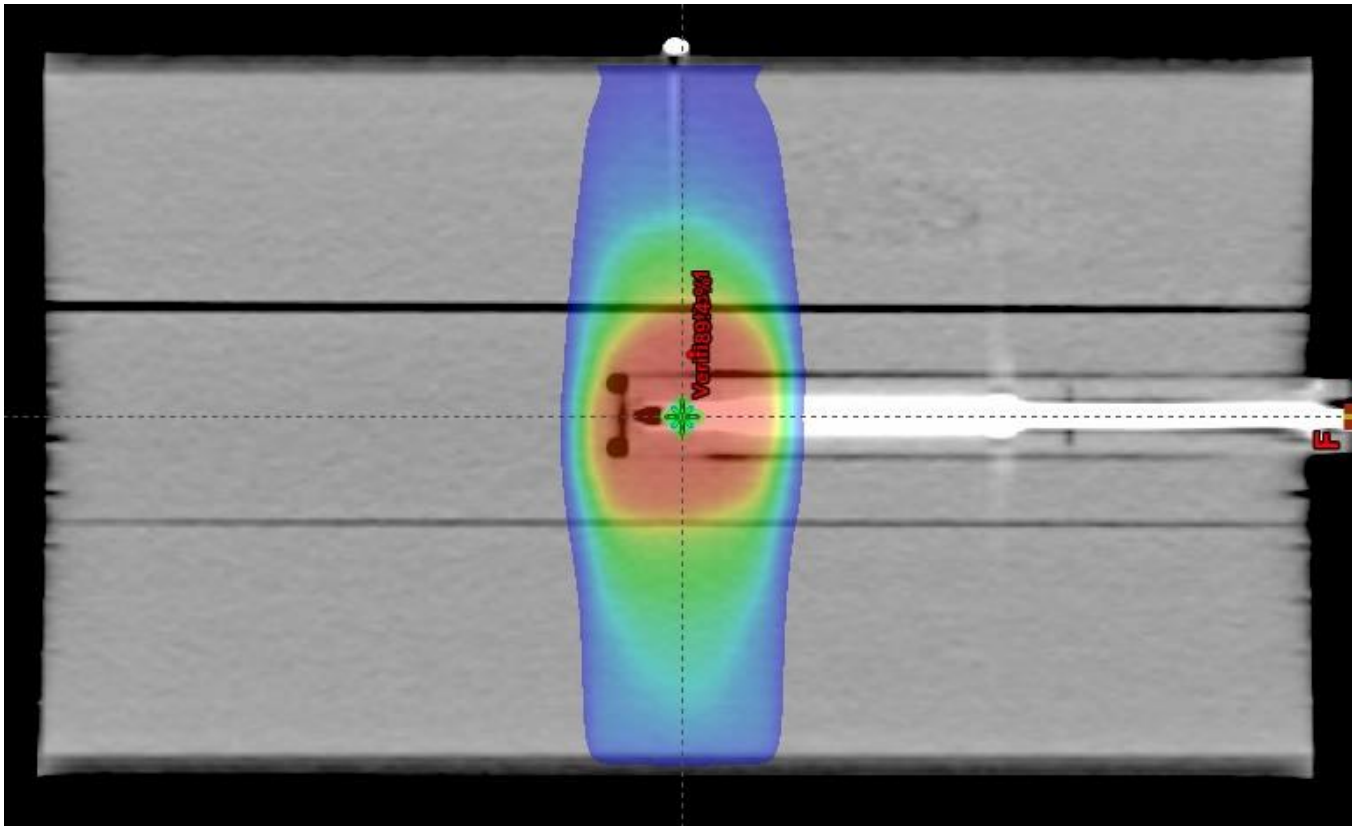
Mark Oldham
Duke University Medical Center, Durham, North Carolina 27710

(Received 25 January 2010; revised 4 October 2010; accepted for publication 4 October 2010; published 16 February 2011)

"This report provides a comprehensive overview of how dosimeters, phantoms, and dose distribution analysis techniques should be used to support the commissioning and quality assurance requirements of an IMRT Program."

Med. Phys. 38(3). March 2011.

Phantoms



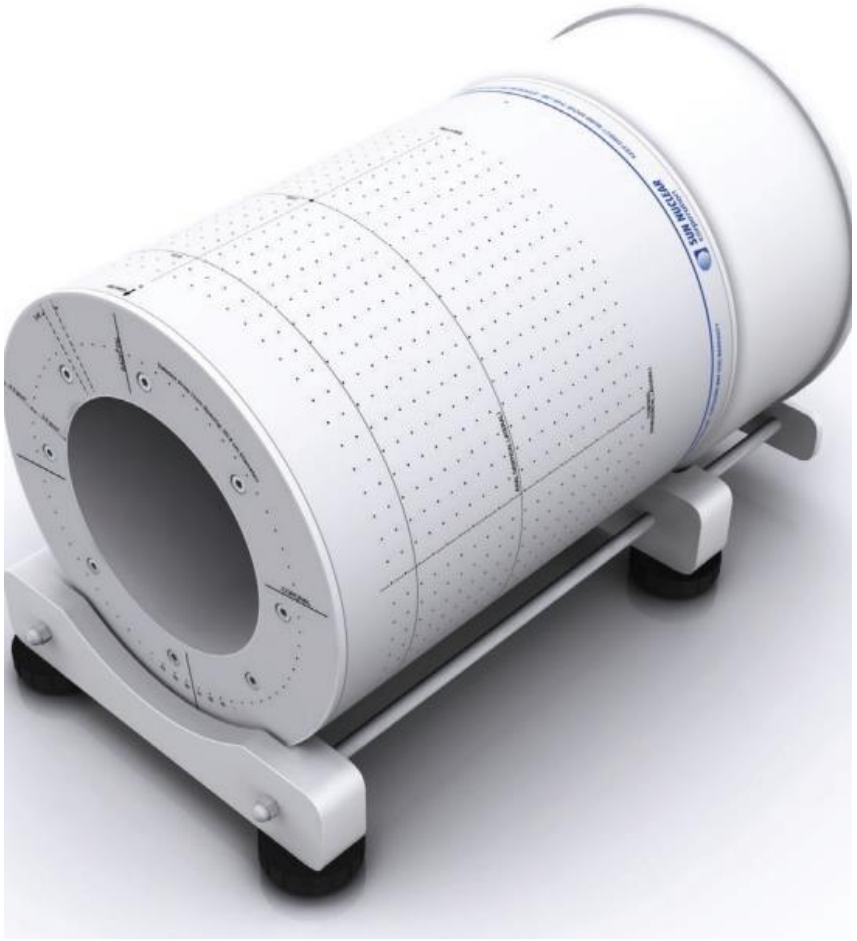
AAPM Recommendations: Point Dose

- Absolute dose
  - Calibrated cylindrical ion chamber
  - Size should be small enough to limit dose heterogeneity across the volume to <10%
  - Avoid high z central electrode
  - Leakage <5% of reading (correction >2%)
- Measurement location
  - Homogeneous (<10%)
  - <10% dose difference 2mm from detector
- Reference dose
  - Calculated average over collecting volume
  - Avoid point dose

AAPM Recommendations: 2D Detectors

- Detectors
  - Film
  - Diode Arrays
  - Ion chamber arrays
  - EPID
- Recommendations
  - Use for relative dosimetry
  - Film calibration protocol
  - Commissioning with film before moving to 2D arrays for routine QA

Diode Arrays



TG 120: Sample Recommendations Diode Arrays

II.B.2.c. Recommendations for use

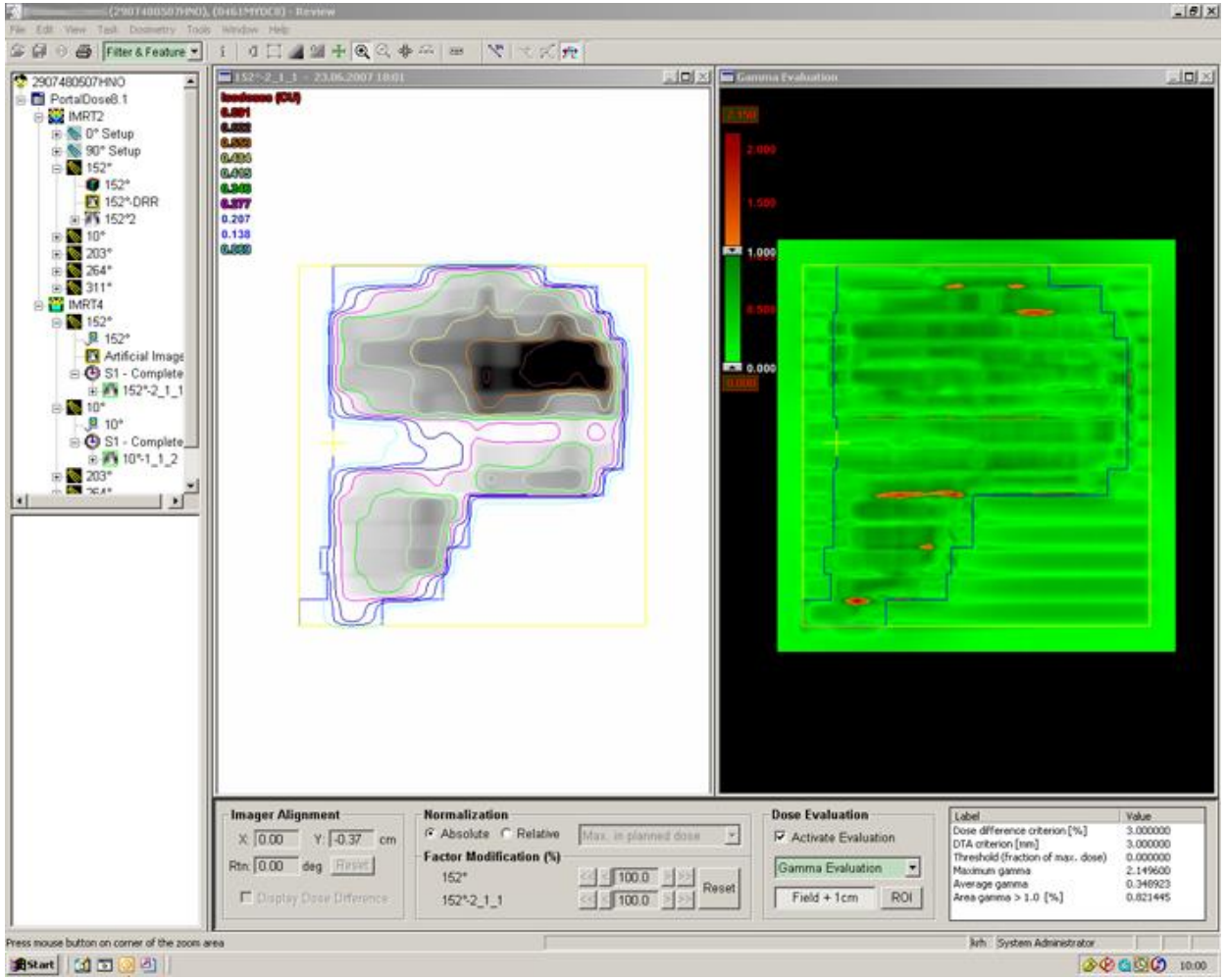
(1) Useful for efficient routine QA of a precommissioned IMRT technique. Initial commissioning should be performed with a system with higher spatial resolution (e.g., film).

(2) For calibration and all measurements with the device, the linear accelerator dose repetition rate should be the same as for the clinical treatment.

(3) The device calibration should be checked monthly, or as specified by the manufacturer or published literature.

(4) Careful consideration should be given to the development of pass/fail acceptance criteria for the evaluation of the results from an array detector. For example, AAPM Task Group 119 (Ref. 17) demonstrated pass rates of $> 90\%$ of the evaluated points when using 3 mm/3% distance-to-agreement (DTA) and dose-difference criteria, respectively, when reporting institution's planar diode detector measurement QA results. Each physicist should determine acceptance criteria that are appropriate for the treatment site, the treatment objectives, and the clinic's policies.

EPID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2907480507HNO
PortalDose8.1
IMRT2
0° Setup
90° Setup
152°
152°.DRR
152°2
10°
203°
264°
311°
IMRT4
152°
Artificial Image
S1 - Complete
152°-2_1_1
10°
S1 - Complete
10°-1_1_2
203°
Gamma Evaluation
2.000
1.500
1.000
0.500
0.000
Imager Alignment
X: 0.00
Y: -0.37
cm
Rtn: 0.00
deg
Reset
Display Dose Difference
Normalization
Absolute
Relative
Max. in planned dose
Factor Modification (%)
152°
152°-2_1_1
100.0
100.0
Reset
Dose Evaluation
Activate Evaluation
Gamma Evaluation
Field + 1cm
ROI
Label
Value
Dose difference criterion [%] 3.000000
DTA criterion [mm] 3.000000
Threshold (fraction of max. dose) 0.000000
Maximum gamma 2.149600
Average gamma 0.348923
Area gamma > 1.0 [%] 0.821445
Press mouse button on corner of the zoom area
System Administrator
Start
10:00

TG 120: Sample Recommendations EPID

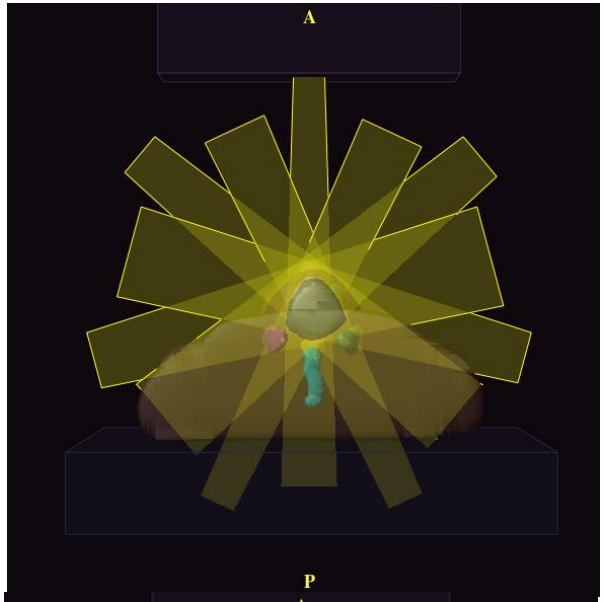
V.A.2. Recommendations for use

Once an IMRT program has been started with ion chamber and film measurements, it may be appropriate to use an EPID for individual IMRT field verification measurements if a reliable method of operation has been developed. The EPID response must be characterized for a range of situations (e.g., dose, dose rate, field size, and leaf speed). Once the system is characterized, a number of corrections must be made to the system depending on the type of system and the composition of the detector. The presence of a fluorescent screen leads to an over-response of the detectors to low doses. To calculate a portal dose prediction or portal dose image for AMFPI systems, pencil beam,[185] convolution,[183] or Monte Carlo[194] techniques have been used to approximate or model the interactions in the EPID including the effect of the fluorescent layer.

Some centers are utilizing commercial systems for IMRT dosimetry. When establishing a QA program with an EPID, the sensitivity of the system and the appropriate action levels and criteria for evaluation must be set.[195] Further development of EPIDs for individual IMRT field verification and for patient transit dosimetry is expected to continue.[191–193,196–200] Exciting developments include reconstruction of three-dimensional dose distributions.[201]

Basic Pre-Treatment IMRT PSQA Rationale

- MU calculations and delivery are complex so a simple backup MU check may not be possible/adequate
- The patient's plan can be measured by copying the plan to a phantom and performing a calculation of the patient's fields on a phantom
- Point dose measurements in addition to a comparison of the planar dose distribution should be performed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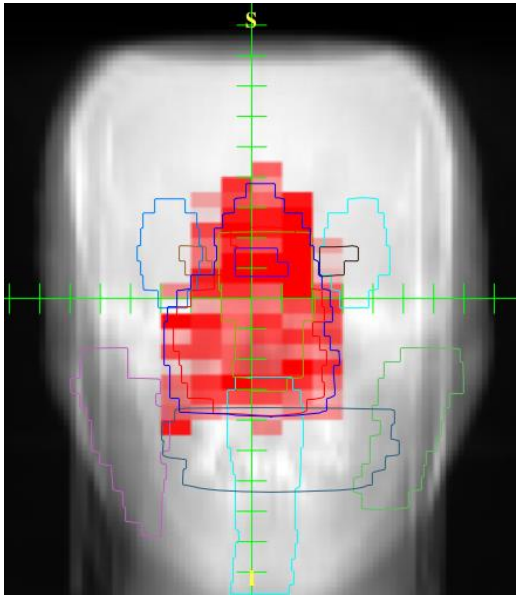
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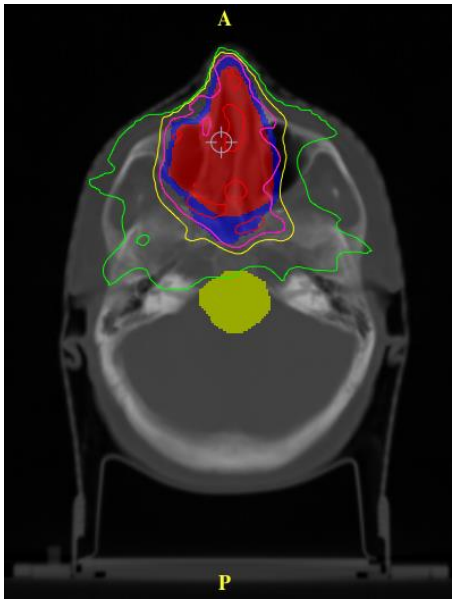
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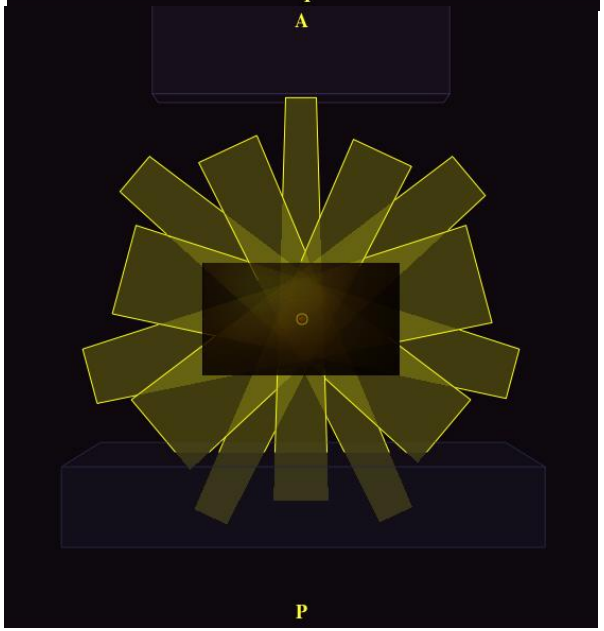
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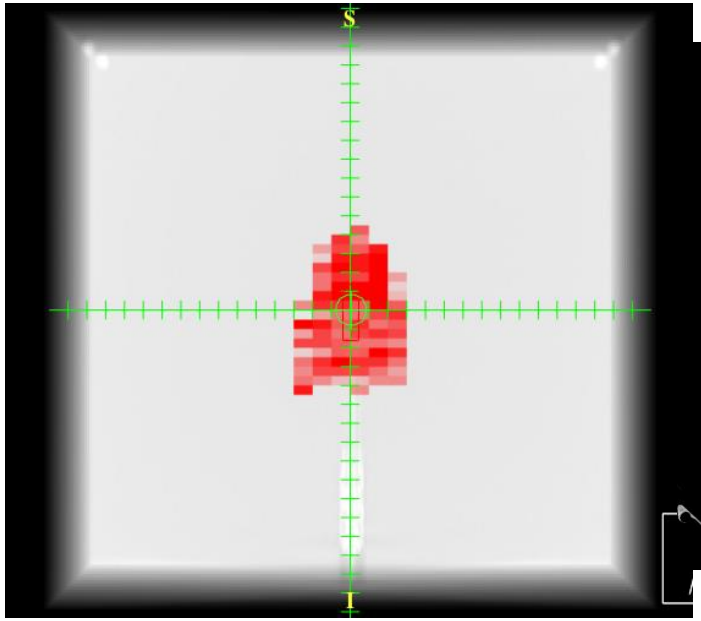
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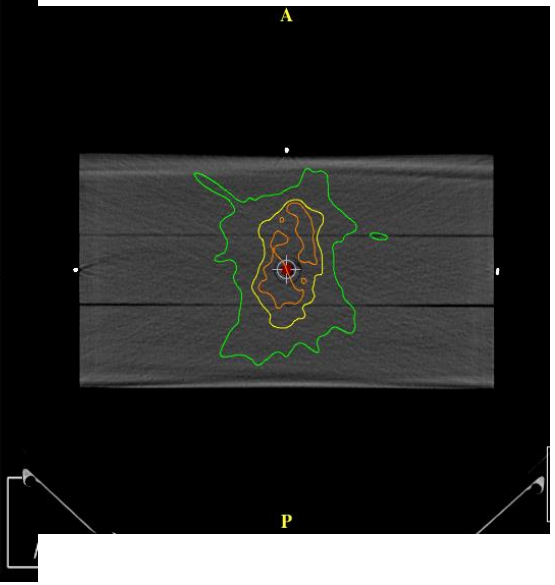
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Comparison of four commercial devices for RapidArc and sliding window IMRT QA

Varatharaj Chandraraj[1,2], Sotirios Stathakis[1,a], Ravikumar Manickam[2], Carlos Esquivel[1], Sanjay S. Supe[2], Nikos Papanikolaou[1]

Department of Radiation Oncology, [1] CTRC, The University of Texas Health Science Center at San Antonio, TX 78229, USA, Department of Radiation Physics, [2] Kidwai Memorial Institute of Oncology, Bangalore –560029, India.
stathakis@uthscsa.edu.

Received 20052010: Accepted 13 December 2010

For intensity-modulated radiation therapy, evaluation of the measured dose against the treatment planning calculated dose is essential in the context of patient-specific quality assurance. The complexity of volumetric arc radiotherapy delivery attributed to its dynamic and synchronization nature require new methods and potentially new tools for the quality assurance of such techniques. In the present study, we evaluated and compared the dosimetric performance of EDR2 film and three other commercially available quality assurance devices: IBA I'MatriXX array, PTW Seven29 array and the Delta[4] array. The evaluation of these dosimetric systems was performed for RapidArc and IMRT deliveries using a Varian NovalisTX linear accelerator. The plans were generated using the Varian Eclipse treatment planning system. Our results showed that all four QA techniques yield equivalent results. All patient QAs passed our institutional clinical criteria of gamma index based on a 3% dose difference and 3 mm distance to agreement. In addition, the Bland-Altman analysis was performed which showed that all the calculated gamma values of all three QA devices were within 5% from those of the film. The results showed that the four QA systems used in this patient-specific IMRT QA analysis are equivalent. We concluded that the dosimetric systems under investigation can be used interchangeably for routine patient specific QA.

PACS numbers: 87.55.Qr, 87.56.Fc

Key words: IMRT, quality assurance, photons, film dosimetry, RapidArc

JACMP. 12 (2) 2011.

How Often?

- Prior to delivery of every plan?
- When simple backup MU calculation is not possible or does not pass?
- Until you have data on X number of cases?

CPQR
Canadian Partnership for Quality Radiotherapy
PCQR
Partenariat canadien pour la qualité en radiothérapie

Canadian Partnership for Quality Radiotherapy

Technical Quality Control Guidelines for Patient-Specific Dosimetric Measurements for Intensity Modulated Radiation Therapies

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A guidance document on behalf of:

Canadian Association of Radiation Oncology

Canadian Organization of Medical Physicists

Canadian Association of Medical Radiation Technologists

Canadian Partnership Against Cancer

July 4, 2016

PDM.2016.07.01

www.cpqr.ca

CPQR Recommedations

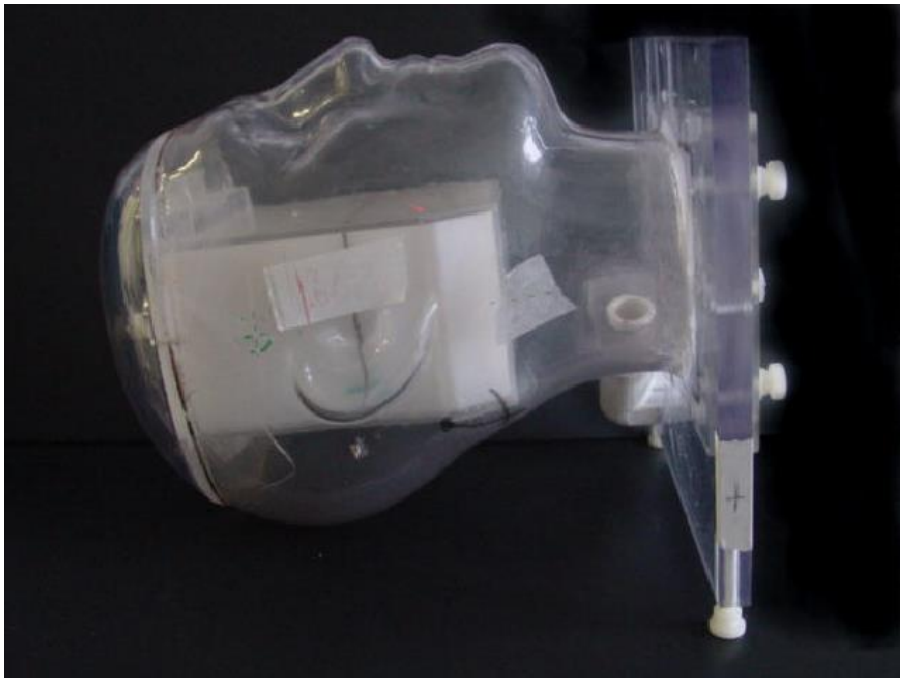
Test Tables

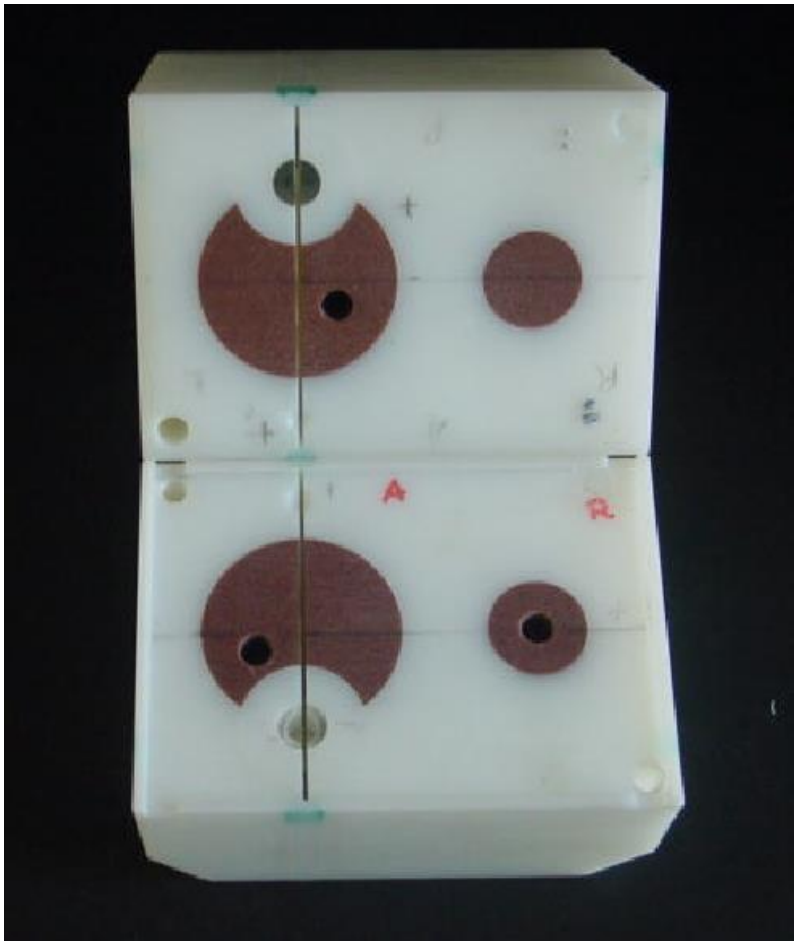
Table 1: IMRT quality control tests

Designator	Test	Performance	
		Tolerance	Action
IMRT1	Patient-specific IMRT quality control test	Complete	
IMRT2	IMRT quality control test case	Complete	
IMRT3	IMRT quality control constancy test	Complete	
IMRT4	Patient-specific IMRT quality control procedure review of protocol	Complete	
IMRT5	Independent audit or review	Complete	

- IMRT1: PSQA
  - Or can be dropped with “rigorous” statistical analysis
- IMRT 2: Set of commissioning plans that mimic clinical cases
- IMRT 3: Case chosen for repeat delivery on quarterly basis
- IMRT 4: Annual review of IMRT protocol (passing criteria, methods, frequency, etc.)
- IMRT 5: External audit

IROC Audit





TomoTherapy Planning Station -- 0210130

No Photo

Patient: QA_RPCHEAD2, QA_RPCHEAD2
DOB: Sex: M
ID: QA_RPCHEAD2
Plan date: Sep 18, 2007 2:07:26 PM
Oncologist:
Disease: 17521

Plan: Plan_02
Plan status: Approved
DQA plan:
Patient position: HFS

What's Next
Define Rx Constraints
- Define constraints for tumors.
- Define constraints for sensitive structures.
- Set isodose display options.

When you are satisfied, click Start to begin optimization.

User Name: Super physics
About TomoTherapy . . .

ROIs | Optimization | Fractionation | Delivery QA Setup | Delivery QA Analysis

Prescription
% Vol / Stats
For PTV_66 96.0 % will receive ..... 6.6 Gy
Field Width: 2.5 cm - Jaws(1.0,-1.0) Pitch: 0.300 Calc Grid: Normal Batch Beamlets

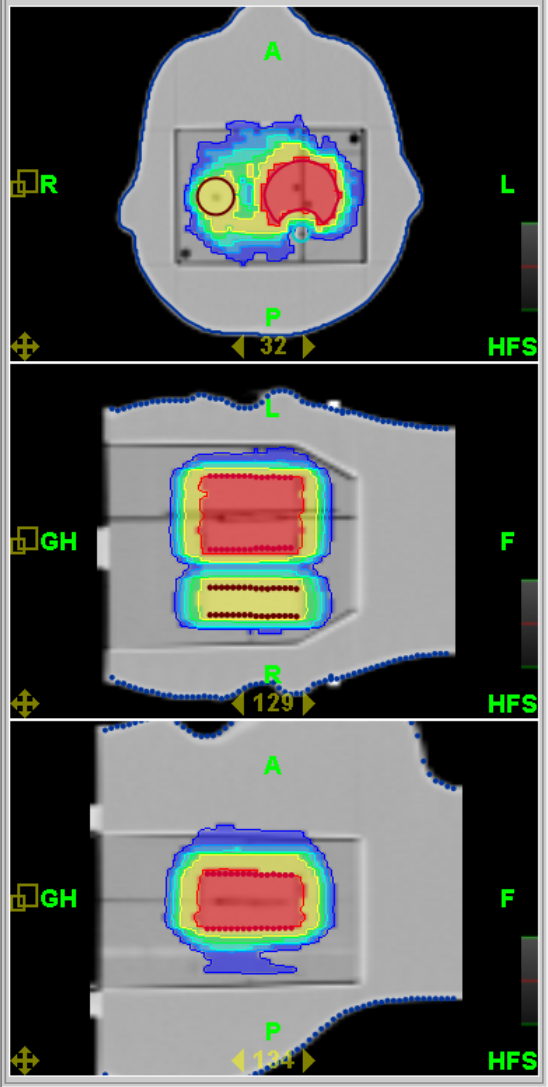
Tumor Constraints

Name	Display	Color	Blocked	Use?	Importa...	Max Dose [...	Max Dose ...	DVH Vol [...	DVH Dose [...	Min Dose [...	Min Dose P...
PTV_66	✓		None	✓	100	6.6	100	96.0	6.6	6.6	100
PTV_54	✓		None	✓	100	5.4	100	96.0	5.4	5.4	100

Sensitive Structure Constraints

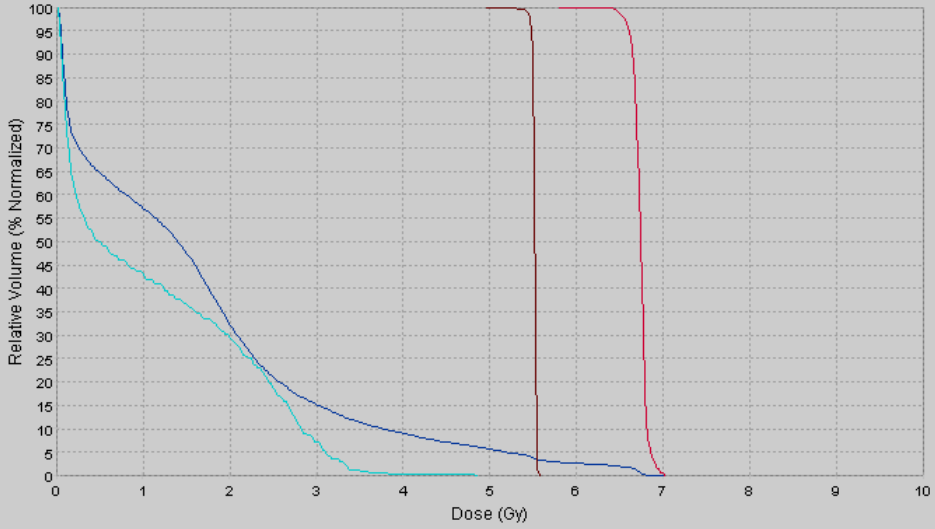
Name	Display	Color	Blocked	Use?	Importance	Max Dose [...	Max Dose ...	DVH Vol [%]	DVH Dose [...	DVH Pt. Pen.
External	✓		None	✓	1	1.0	1	1.0	1.0	1
66_Iant_TLD	☐		None	☐						
66_Sant_TLI	☐		None	☐						
66_Spost_TI	☐		None	☐						

Dose Display
Isodose
6.6
5.4
5
4.5
4
3.5

Patient Images


Density Image Viewer
Density Image

Optimize
Mode: Beamlet
Modulation Factor: 2.000
Initiate Full Dose after 20 iterations.
Start
Pause
Resume
Get Full Dose
Cancel

Dose-Volume Histogram - Cumulative Mode Relative


Vol Min < 0.0 > Vol Max < Gy Min < 0.0 > Gy Max < 10.0 >

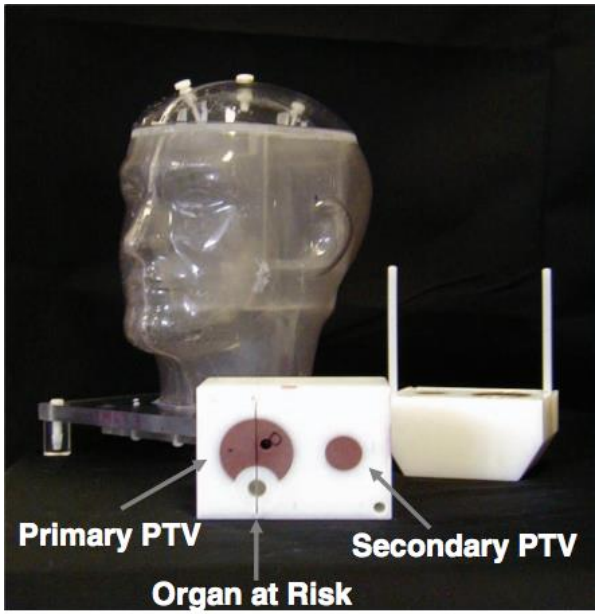
Tuesday, January 27, 2009 17:23:57

Start | TomoTherapy Plannin... | CRS Admin Console (tom... | Calculator | 5:23 PM

Credentialing results from IMRT irradiations of an anthropomorphic head and neck phantom

Andrea Molineu,[a)] Nadia Hernandez, Trang Nguyen, Geoffrey Ibbott, and David Followill
Department of Radiation Physics, The University of Texas MD Anderson Cancer Center, Houston, Texas 77030

(Received 10 April 2012; revised 15 November 2012; accepted for publication 7 December 2012; published 8 January 2013)



Results: The phantom was irradiated 1139 times by 763 institutions from 2001 through 2011. 929 (81.6%) of the irradiations passed the criteria. 156 (13.7%) irradiations failed only the TLD criteria, 21 (1.8%) failed only the film criteria, and 33 (2.9%) failed both sets of criteria. Only 69% of the irradiations passed a narrowed TLD criterion of ±5%. Varian-Elipse and TomoTherapy-HiArt combinations had the highest pass rates, ranging from 90% to 93%. Varian-Pinnacle^3, Varian-XiO, Siemens-Pinnacle^3, and Elekta-Pinnacle^3 combinations had pass rates that ranged from 66% to 81%.

Med. Phys. 40(2) 2013.

Criteria +/- 7%DD, 4mm DTA

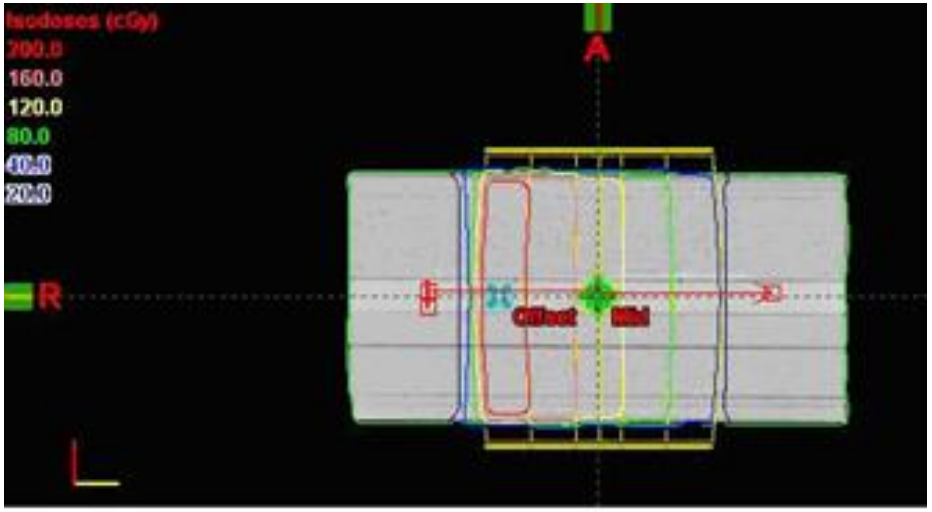
Reasons for Failing Results

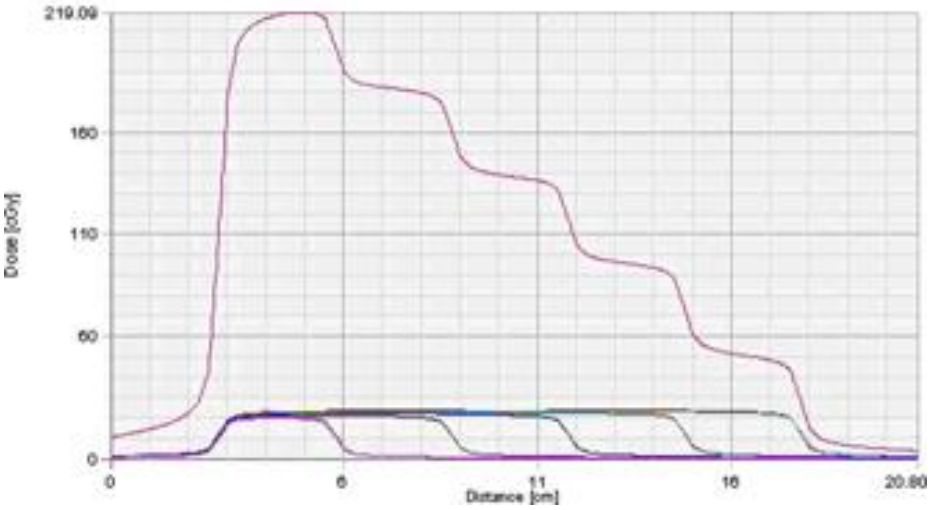
- Incorrect data entered into the TPS
- Inexact beam modeling
- Software and hardware failures

AAPM TG 119: Commissioning Tests for IMRT

- Reaction to RPC results showing failing IMRT QA results at many institutions
- Created a set of standard plans and analysis techniques to commission IMRT
- Compared results between institutions

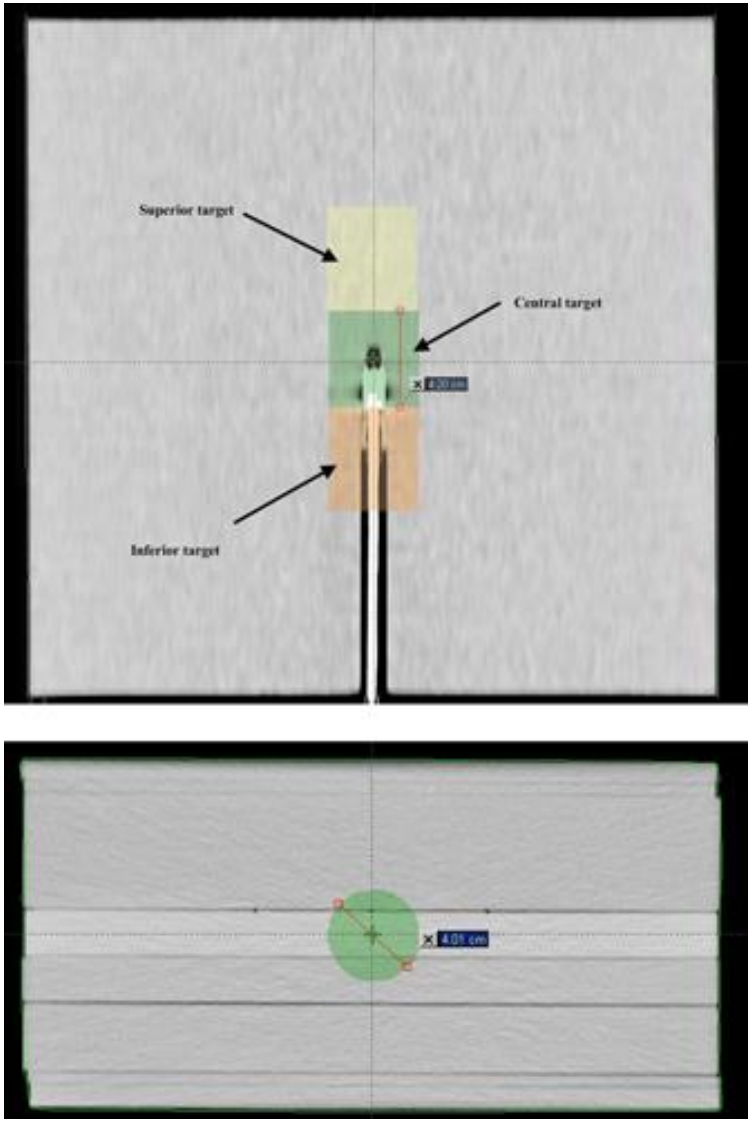
IMRT commissioning: Multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119





Medical Physics
Volume 36, Issue 11, pages 5359-5373, 30 NOV 2016 DOI: 10.1118/1.3238104
http://onlinelibrary.wiley.com/doi/10.1118/1.3238104/full#f1

IMRT commissioning: Multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119



Medical Physics
Volume 36, Issue 11, pages 5359-5373, 30 NOV 2016 DOI: 10.1118/1.3238104
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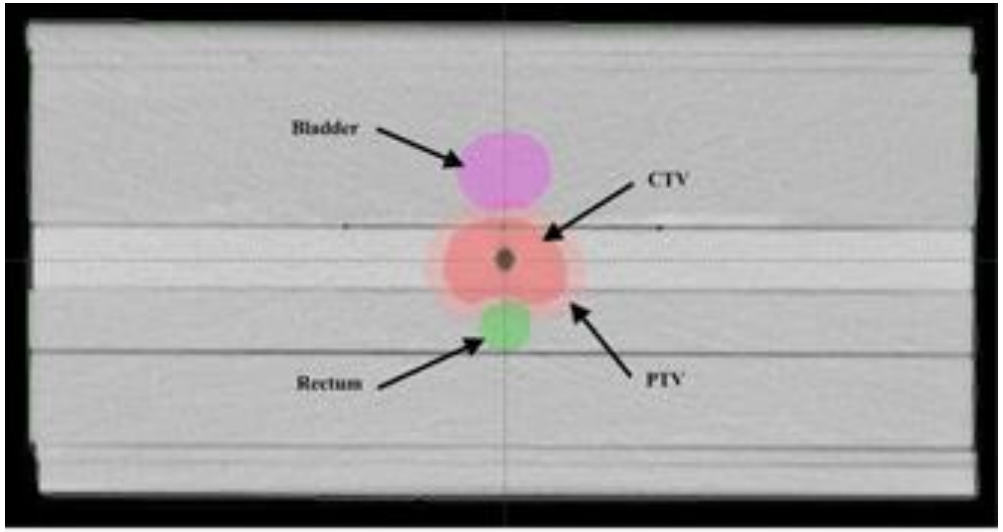
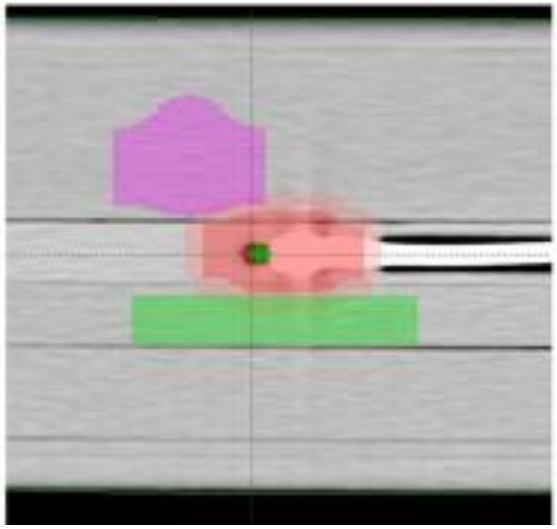
IMRT commissioning: Multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119





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Volume 36, Issue 11, pages 5359-5373, 30 NOV 2016 DOI: 10.1118/1.3238104
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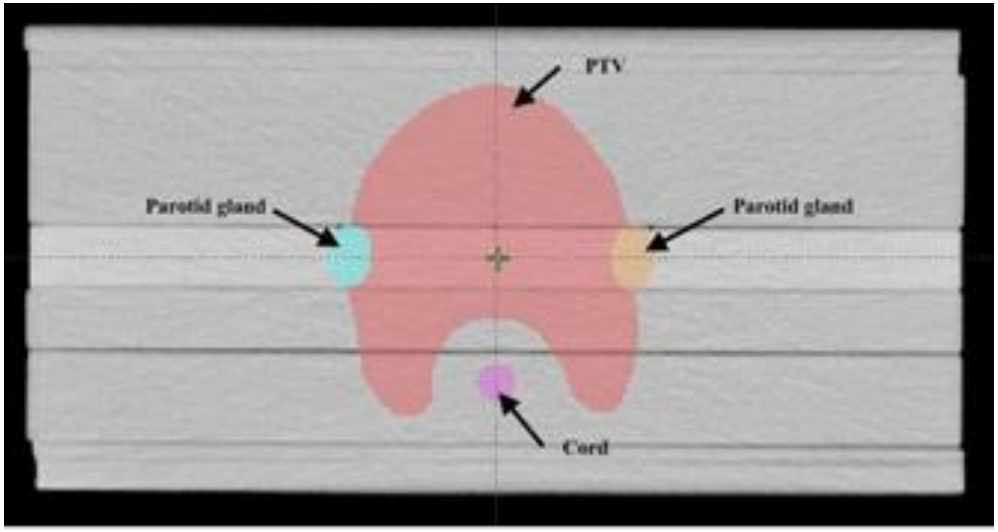
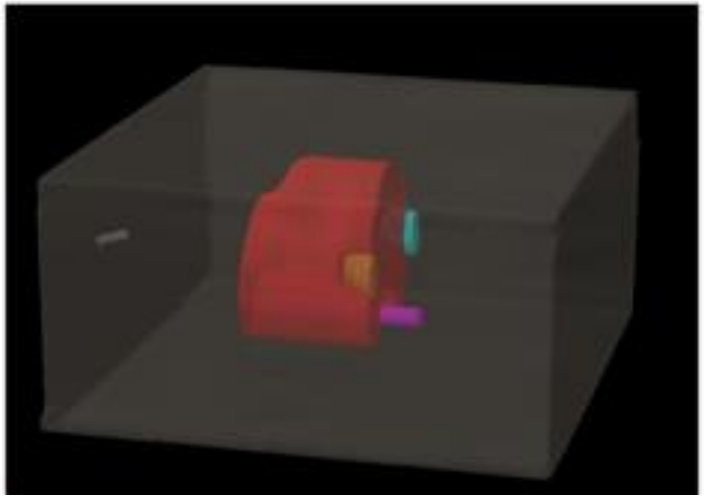
IMRT commissioning: Multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119





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Volume 36, Issue 11, pages 5359-5373, 30 NOV 2016 DOI: 10.1118/1.3238104
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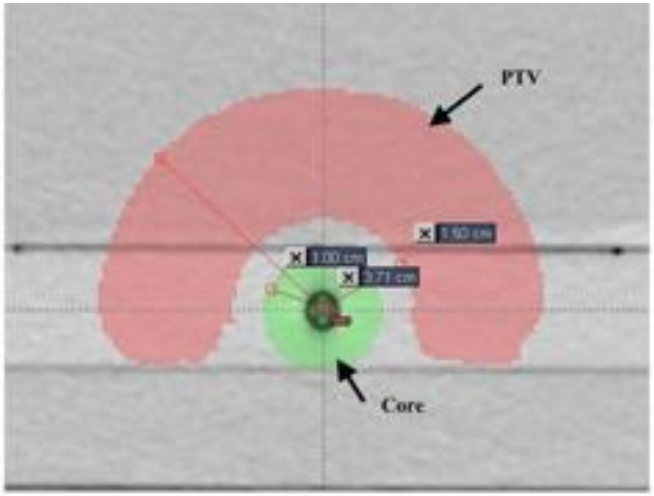
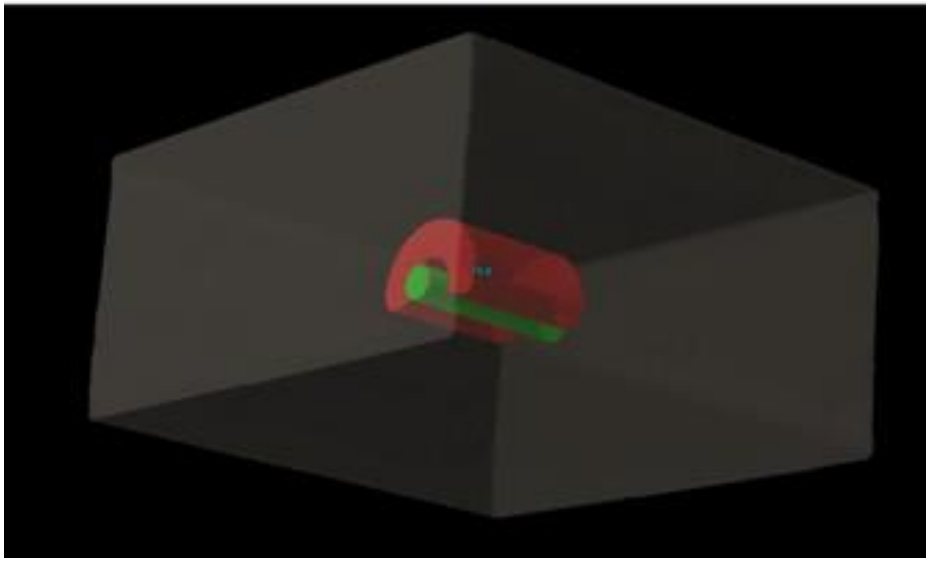
IMRT commissioning: Multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119





Medical Physics
Volume 36, Issue 11, pages 5359-5373, 30 NOV 2016 DOI: 10.1118/1.3238104
http://onlinelibrary.wiley.com/doi/10.1118/1.3238104/full#f5

TG 119 Continued

- Treatment plans were created and analyzed in several institutions
- Recommendations for action and tolerance provided
- Data sets are available for download on the AAPM web site to allow individual sites
  - Allow for comparison to these sites using the same data sets
- Suggested that these standard plans be used in commissioning to improve results
- Provide baseline tests for machine changes

PUBLICATIONS

Test Suite by Task Group 119

The material was prepared by TG119 to assist with IMRT commissioning process. It is a test suite of mock clinical cases for IMRT planning and QA measurements.

AAPM grants permission to equipment manufacturers to use the dataset, with the use of the following disclaimer:

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- The instructions for planning, measurement, and analysis are included in the following PDF.
- Download the excel data report form.
- The CT and structure package in DICOM format is in this zip file.
- IMRT commissioning: Multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119

Gamma Passing Rate

- Percentage of points analyzed that pass the DD and DTA criteria
- General looking for pass rates above 90%
- Wide variety in practice in the USA/Canada

Gamma Index

Gamma is the Euclidian distance between an evaluated distribution and each point in an evaluated distribution. Gamma is a tool to compare dose distributions. It has limitations that must be considered in IMRT QA analysis.

IC3DDose: The 6th International Conference on 3D Radiation Dosimetry IOP Publishing
Journal of Physics: Conference Series **250** (2010) 012071 doi:10.1088/1742-6596/250/1/012071

$$\Gamma(\vec{r}_e,\vec{r}_r)=\sqrt{\frac{|\vec{r}_e-\vec{r}_r|^2}{\Delta d^2}+\frac{[D_e(\vec{r}_e)-D_r(\vec{r}_r)]^2}{\Delta D^2}} \quad (1)$$

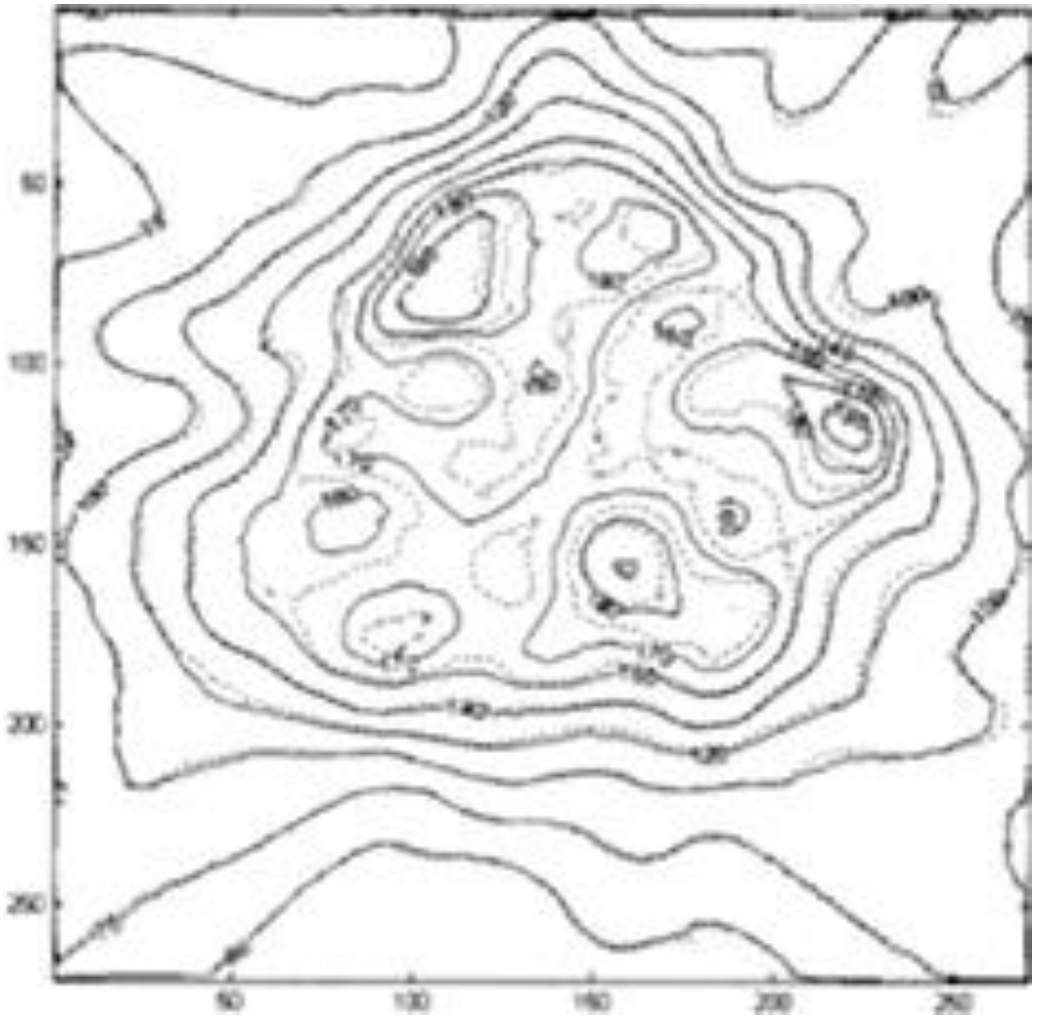
where $\vec{r}_e$ and $\vec{r}_r$ are the vector positions of the evaluated and reference points, respectively, $D_e(\vec{r}_e)$ and $D_r(\vec{r}_r)$ are the evaluated and reference doses, respectively, and Δd and ΔD are the DTA and dose difference criteria, respectively. The generalized Γ function can be computed for any pair $\vec{r}_e$ and $\vec{r}_r$, so for each reference point, there are as many values of Γ as there are evaluated points (infinite number with interpolation). The minimum value of Γ is the value of γ.

$$\gamma(\vec{r}_r)=\min\{\Gamma(\vec{r}_e,\vec{r}_r)\}\forall\{\vec{r}_e\} \quad (2)$$

Equation 2 states that γ is simply the minimum value in all of the evaluated distribution search space of Γ. While equations 1 and 2 provide the factual definition of Γ, they do not impart any intuition for what γ means and its utility.

Low, D. (2015). The importance of 3D dosimetry. In Journal of Physics: Conference Series (Vol. 573, No. 1, p. 012009). IOP Publishing.

Dosimetry tools and techniques for IMRT



Medical Physics
Volume 38, Issue 3, pages 1313-1338, 16 FEB 2011 DOI: 10.1118/1.3514120
http://onlinelibrary.wiley.com/doi/10.1118/1.3514120/full#f3

Pitfalls of the Gamma Index

Medical Physics
The International Journal of Medical Physics Research and Practice

Evaluating IMRT and VMAT dose accuracy: Practical examples of failure to detect systematic errors when applying a commonly used metric and action levels

Benjamin E. Nelms, Maria F. Chan, Geneviève Jarry, Matthieu Lemire, John Lowden, Carnell Hampton, and Vladimir Feygelman

Citation: Medical Physics **40**, 111722 (2013); doi: 10.1118/1.4826166
View online: http://dx.doi.org/10.1118/1.4826166
View Table of Contents: http://scitation.aip.org/content/aapm/journal/medphys/40/11?ver=pdfcov
Published by the American Association of Physicists in Medicine

Conclusions Nelms et al.

- Real-world cases where systematic errors were not detected with 3%/3mm
  - Error introduced to TPS, linac, delivery method, setup
- More sensitive metrics should be used to evaluate the accuracy of dose calculation algorithms, delivery systems, and QA devices.

JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS, VOLUME 16, NUMBER 6, 2015

Gamma analysis dependence on specified low-dose thresholds for VMAT QA

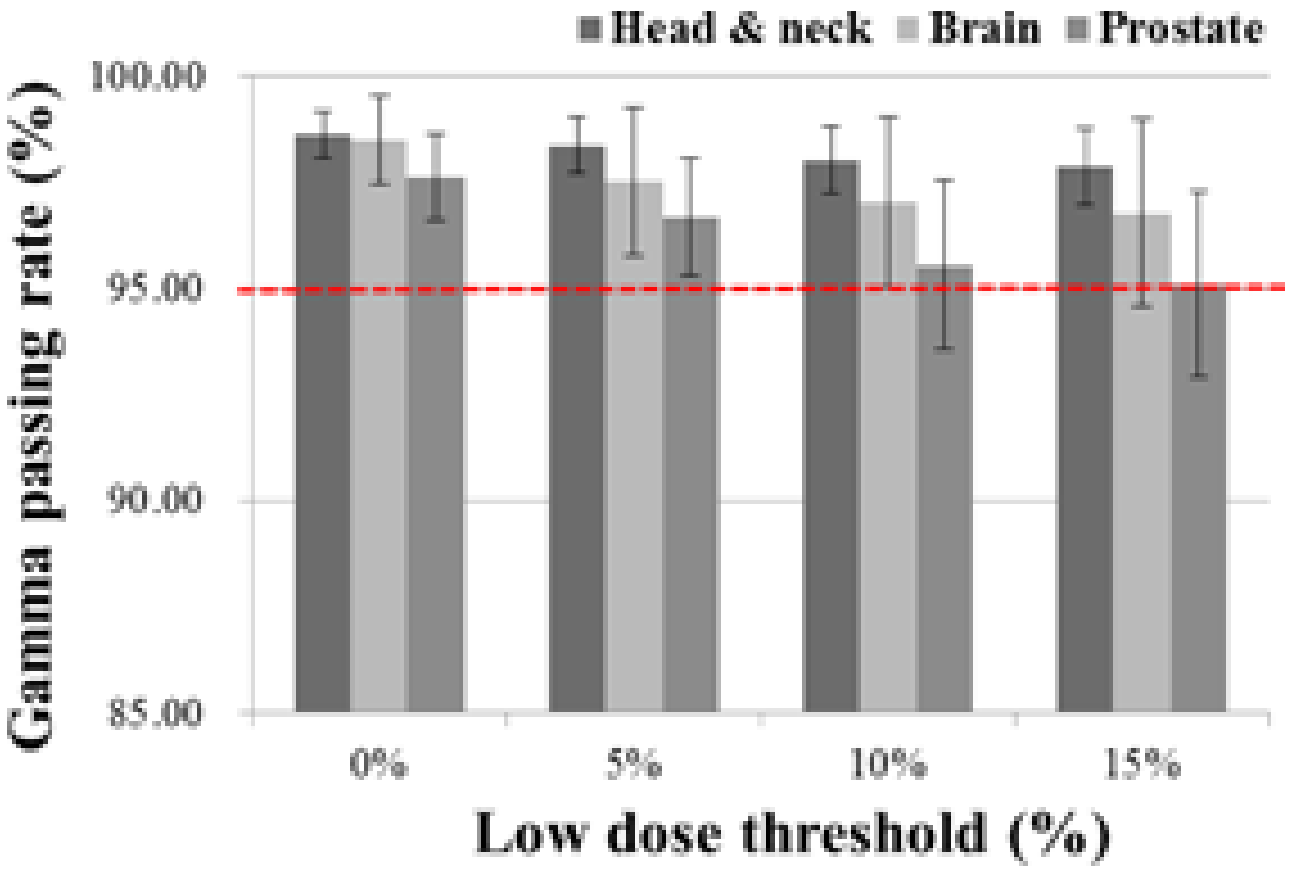
Ji-Hye Song,[1] Min-Joo Kim,[1] So-Hyun Park,[1,2] Seu-Ran Lee,[1] Min-Young Lee,[1] Dong Soo Lee,[2] Tae Suk Suh[1a]

Department of Biomedical Engineering[1] and Research Institute of Biomedical Engineering, College of Medicine, The Catholic University of Korea, Seoul 137-701, Korea; Department of Radiation Oncology,[2] Uijeongbu St. Mary's Hospital, Uijeongbu 480-717, Korea

suhsanta@catholic.ac.kr

Received 12 March, 2015; accepted 7 July, 2015

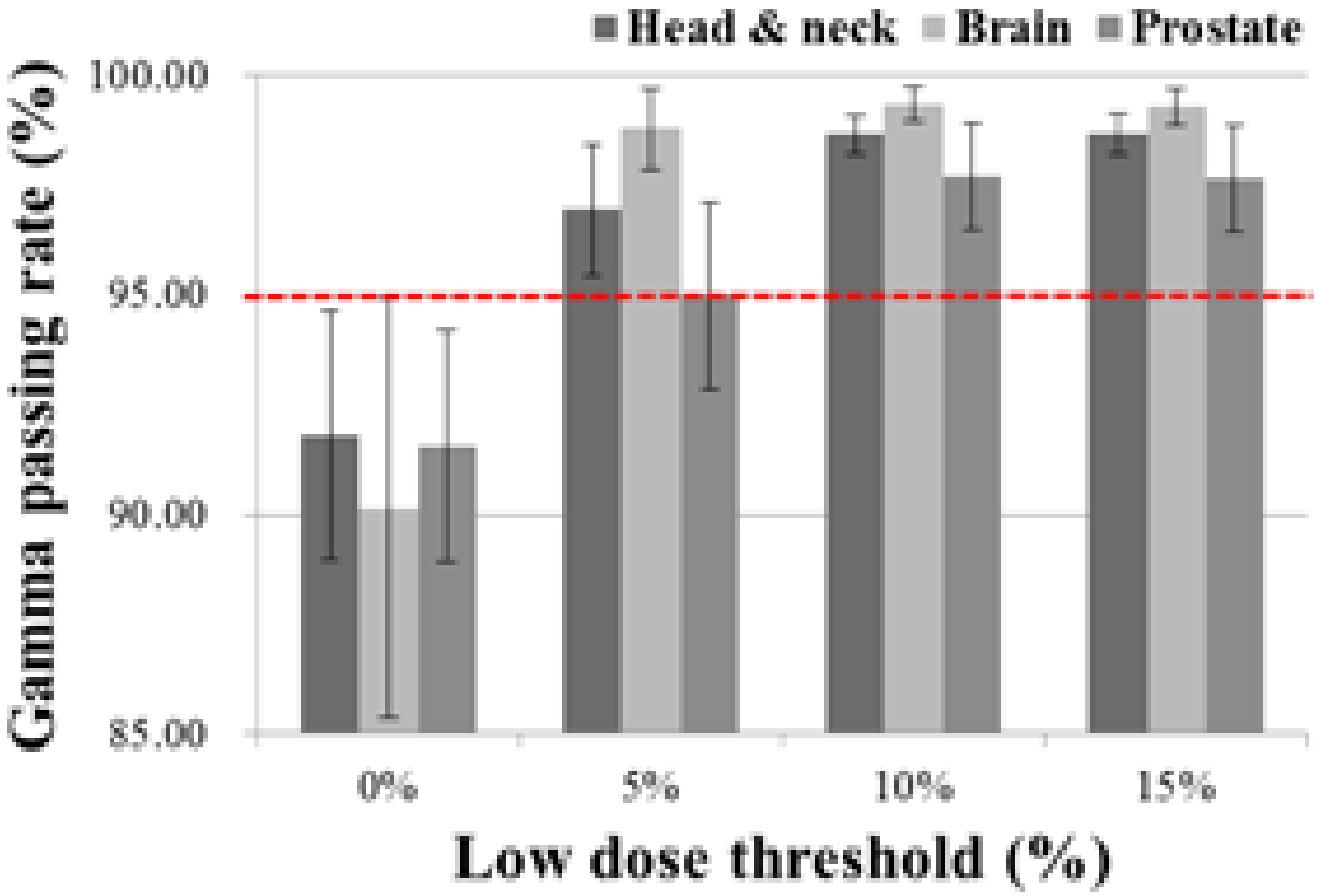
Gamma analysis dependence on specified low-dose thresholds for VMAT QA



Global Normalization

Journal of Applied Clinical Medical Physics
Volume 16, Issue 6, pages 263-272, 8 NOV 2015 DOI: 10.1120/jacmp.v16i6.5696
http://onlinelibrary.wiley.com/doi/10.1120/jacmp.v16i6.5696/full#acm20263-fig-0001

Gamma analysis dependence on specified low-dose thresholds for VMAT QA



Journal of Applied Clinical Medical Physics
Volume 16, Issue 6, pages 263-272, 8 NOV 2015 DOI: 10.1120/jacmp.v16i6.5696
http://onlinelibrary.wiley.com/doi/10.1120/jacmp.v16i6.5696/full#acm20263-fig-0002

Local normalization

Conclusion

- The low dose threshold that is chosen and the normalization technique, global or local, greatly impact Gamma passing rates

Impact of Noise on Gamma Analysis

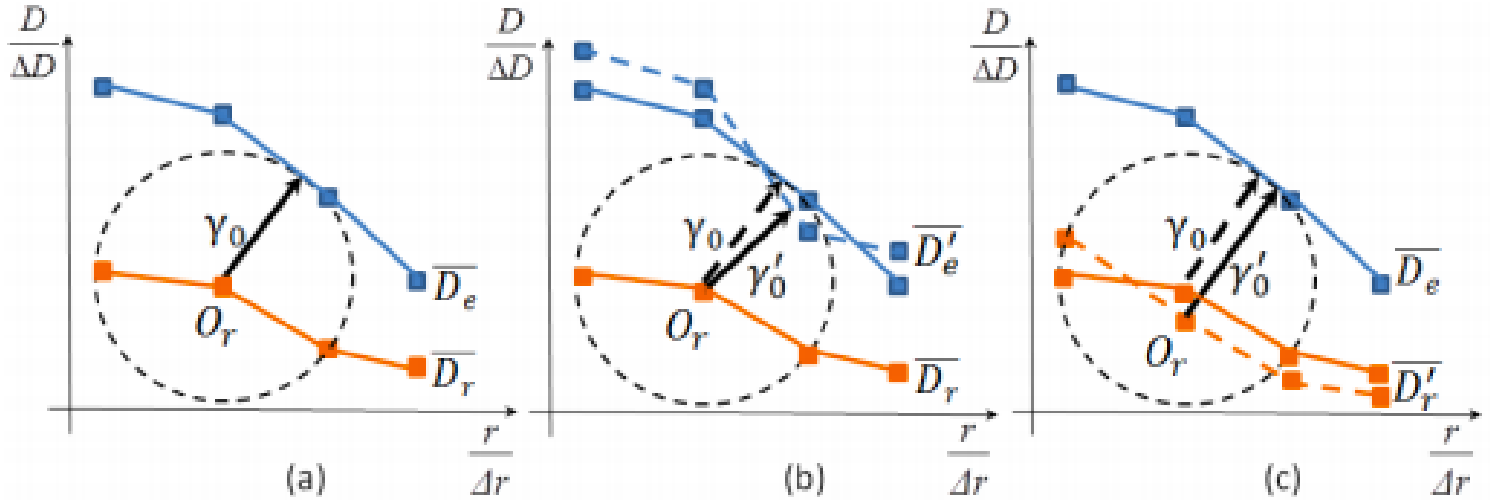


Figure 1 (a). Graphical interpretation of the γ-index in one-dimension. **(b).** An example demonstrating how the γ-index value changes due to MC statistical fluctuations in the evaluation dose. **(c).** An example demonstrating how the γ-index value changes due to MC statistical fluctuations in the reference dose.

Jiang Graves, Y., Jia, X., & Jiang, S. B. (2013). Effect of statistical fluctuation in Monte Carlo based photon beam dose calculation on gamma index evaluation. *Physics in Medicine and Biology*, *58*, 1839.

Conclusion

- Gamma can be artificially high or low depending on the noise in either your measured or calculated distribution

Resolution

IC3DDose: The 6th International Conference on 3D Radiation Dosimetry IOP Publishing
Journal of Physics: Conference Series **250** (2010) 012071 doi:10.1088/1742-6596/250/1/012071

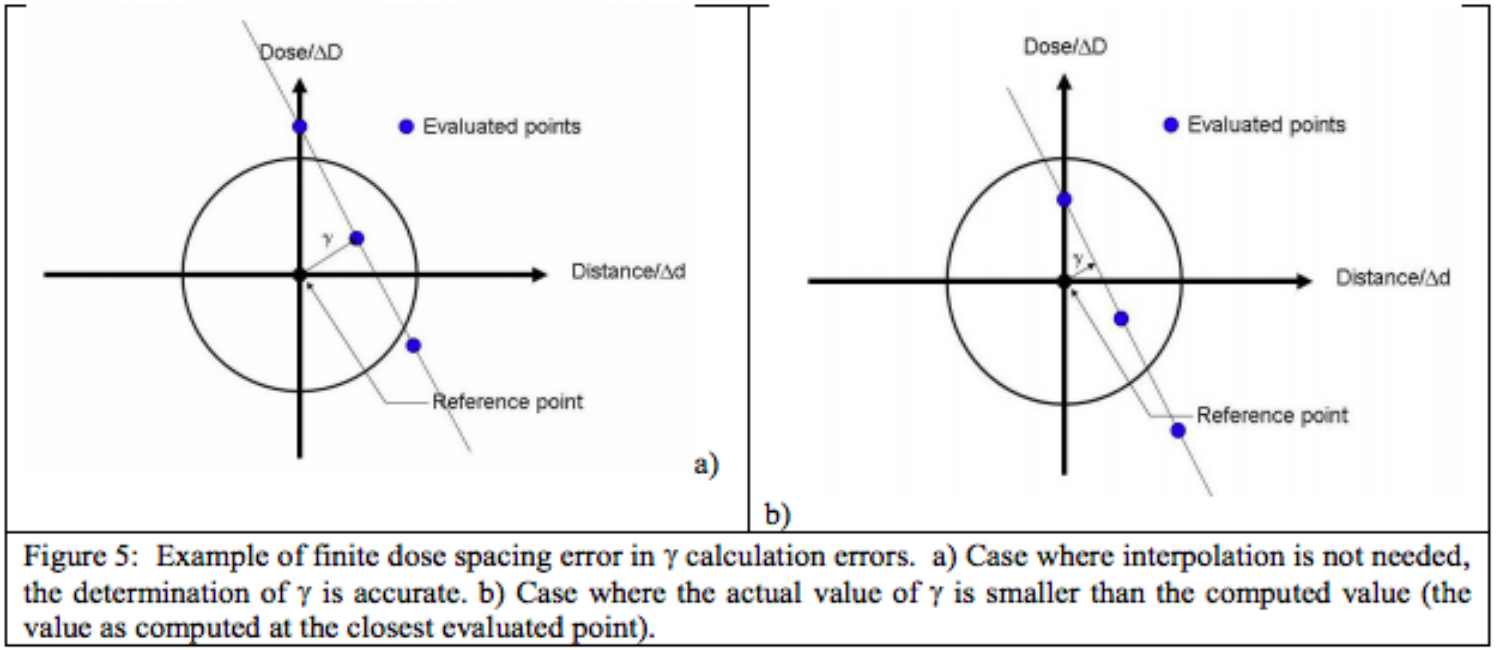


Figure 5: Example of finite dose spacing error in γ calculation errors. a) Case where interpolation is not needed, the determination of γ is accurate. b) Case where the actual value of γ is smaller than the computed value (the value as computed at the closest evaluated point).

Low, D. (2015). The importance of 3D dosimetry. In Journal of Physics: Conference Series (Vol. 573, No. 1, p. 012009). IOP Publishing.

Recommendations for Gamma

- Need interpolation between calc points to get good results
- Noisy distributions result in artificially low gamma results
- Don’t blindly use pass/fail criteria
- If points fail by a lot, look at this point
- Know where anatomically the points fail

Tolerance limits and methodologies for IMRT measurement-based verification QA: *Recommendations of AAPM Task Group No. 218*

Moyed Miften[a)]
Department of Radiation Oncology, University of Colorado School of Medicine, Aurora, CO, USA

Arthur Olch
Department of Radiation Oncology, University of Southern California and Radiation Oncology Program, Childrens Hospital of Los Angeles, Los Angeles, CA, USA

Dimitris Mihailidis
Department of Radiation Oncology, University of Pennsylvania, Perelman Center for Advanced Medicine, Philadelphia, PA, USA

Jean Moran
Department of Radiation Oncology, University of Michigan, Ann Arbor, MI, USA

Todd Pawlicki
Department of Radiation Oncology, University of California San Diego, La Jolla, CA, USA

Andrea Molineu
Radiological Physics Center, UT MD Anderson Cancer Center, Houston, TX, USA

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Department of Radiation Oncology, Washington University, St. Louis, MO, USA

Krishni Wijesooriya
Department of Radiation Oncology, University of Virginia, Charlottesville, VA, USA

Jie Shi
Sun Nuclear Corporation, Melbourne, FL, USA

Ping Xia
Department of Radiation Oncology, The Cleveland Clinic, Cleveland, OH, USA

Recommendations from AAPM TG 218 (in press)

- Measurements should be a true composite
  - Ensure detector has no angular dependence
  - No perpendicular composite, prone to masking delivery errors
- Absolute Dose vs. Relative dose
- Exclude areas with little or no clinical relevance
  - Ignore large areas of low dose that change the pass rate
- Calibration compared against a standard dose at each measurement
- Normalization
  - Global versus local normalization
  - Normalization point should be in a low gradient, high dose region ≥90% of the max dose
  - Local normalization can be used for commissioning

218 Recommendations Cont.

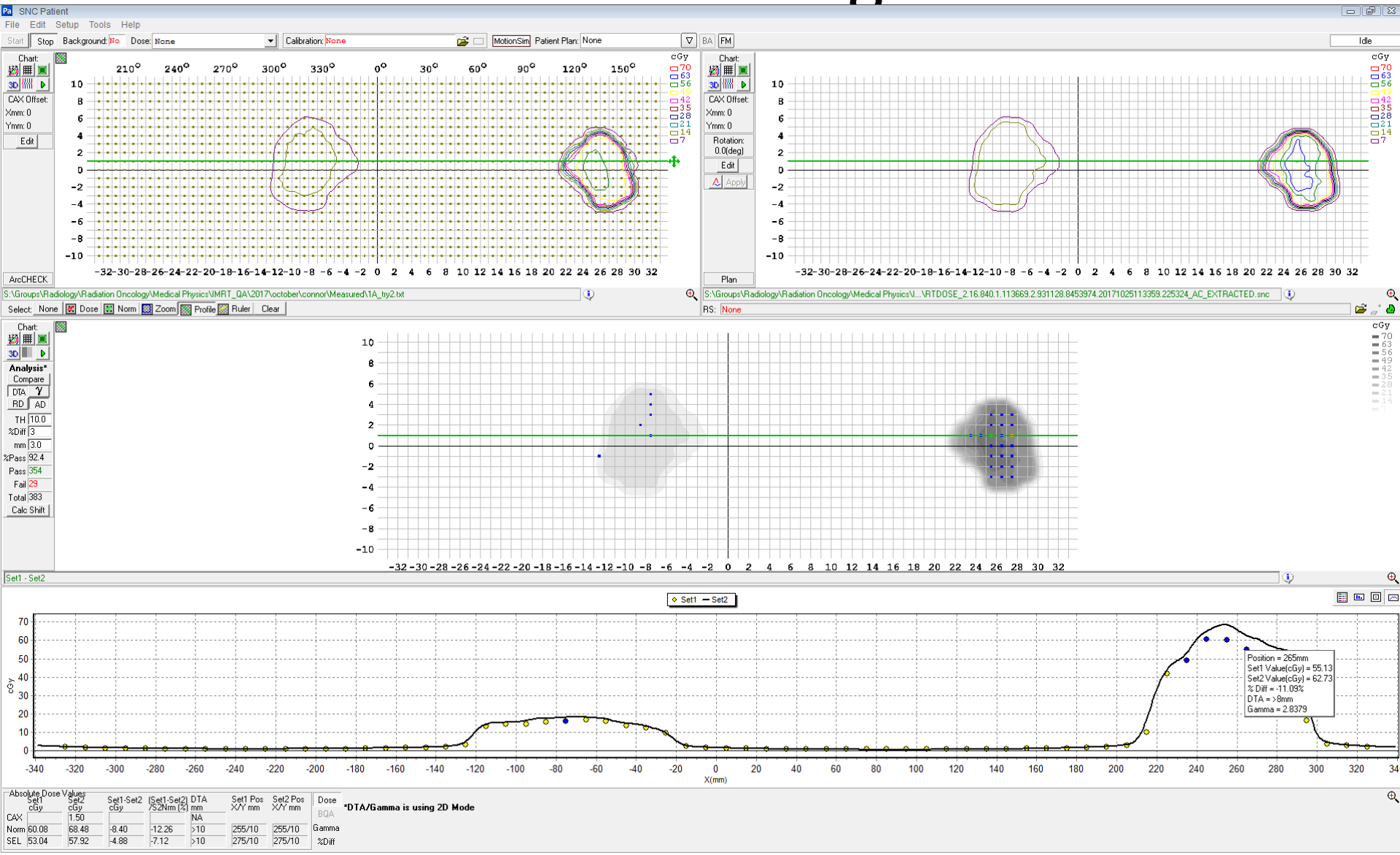
- Tolerance and action
  - Tolerance ≥95% with 3%/2mm
  - Action ≥90% with 3%/2mm
  - Ignore points <10% of rx dose
- Resolution is important for gamma analysis, need to use DTA of <3mm to detect MLC errors
  - Understand software
- Site specific tolerance and action levels are encouraged as long as it is better than these universal recommendations
  - For example if at your site you can only get 80%/3mm, then you have to do better.
- Make sure you have the appropriate equipment
- Log results to know how you are doing

What to do when plans fail

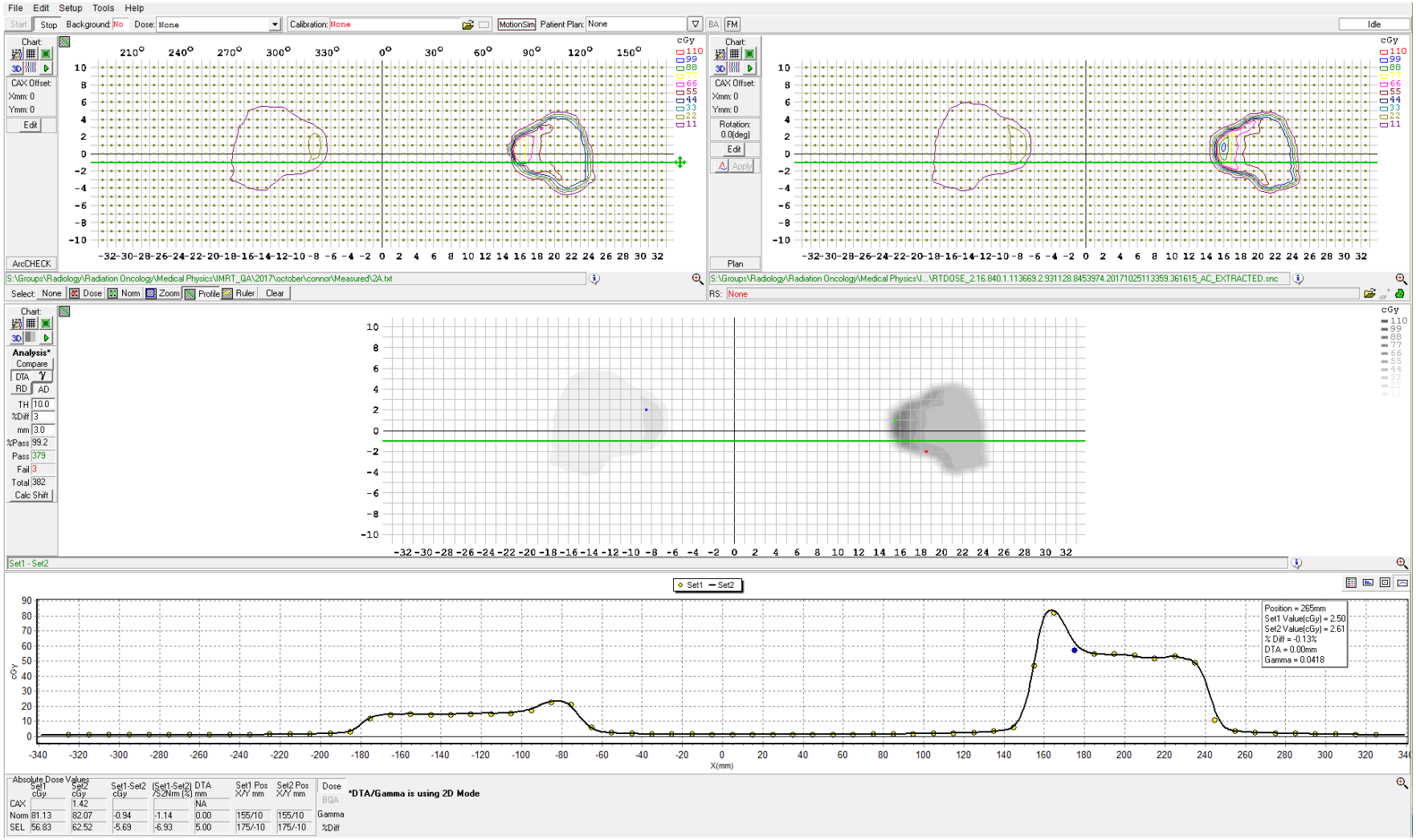
- Look at where it fails and determine if it is relevant
- Don’t just look at statistics, look at all points above gamma 1.5
- Replanning should be an option (allow ample time for QA)
- Failing Gamma rates should be investigated!

Clinical Example

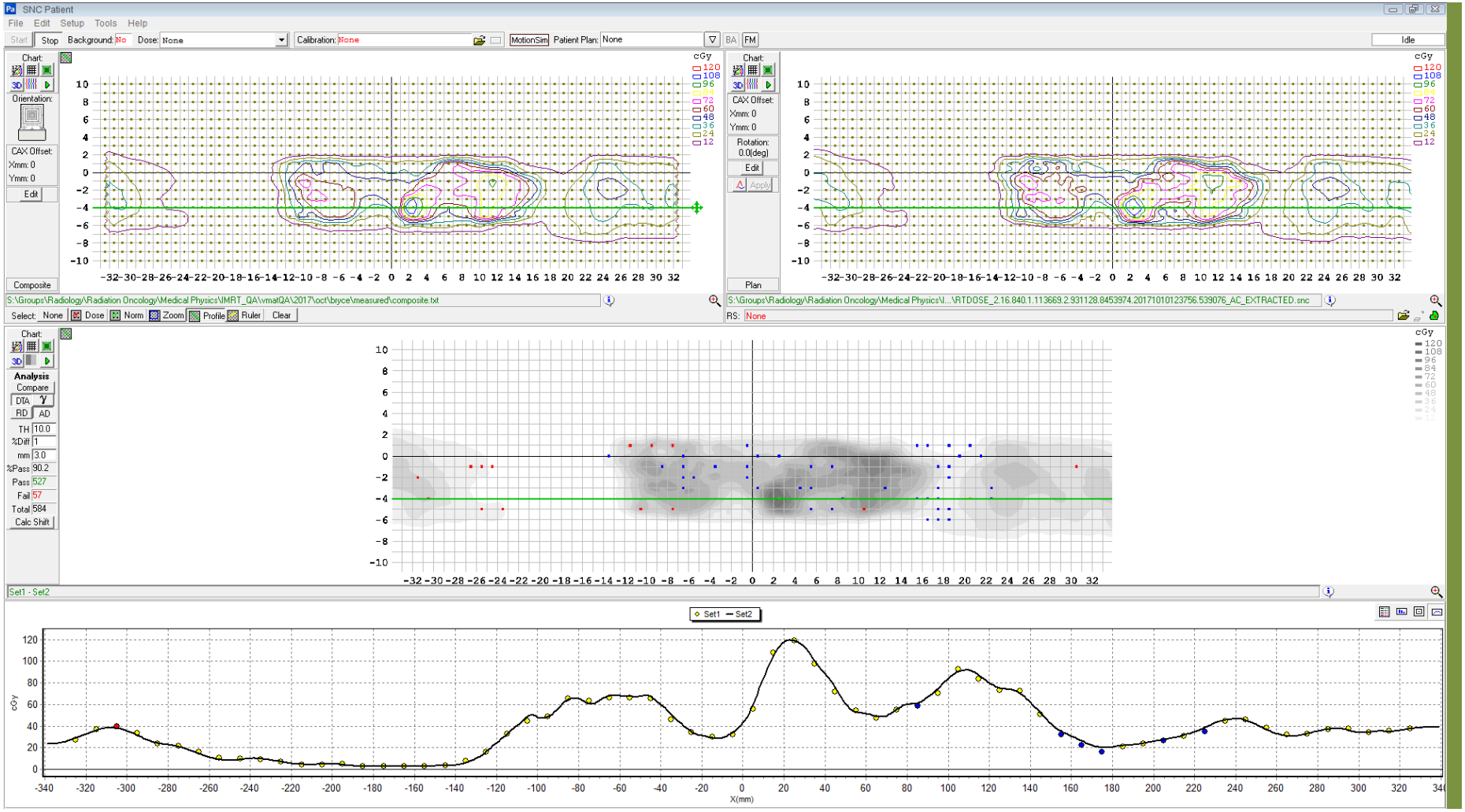
Head and Neck PSQA w/ArcCheck Beam Enters through Couch



Beam that Does Not Enter Through Couch



Composite

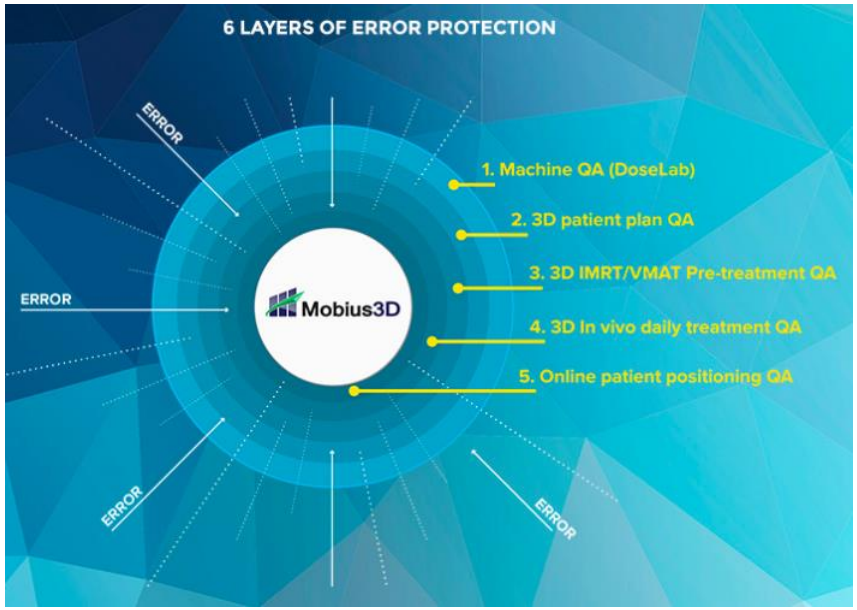

SNC Patient
File Edit Setup Tools Help
Stop
Background: No
Dose: None
Calibration: None
MotionSim
Patient Plan: None
Idle
Chart:
Orientation:
CAX Offset:
Xmm: 0
Ymm: 0
Edit
Composite
cGy
120
108
96
84
72
60
48
36
24
12
S:\Groups\Radiology\Radiation Oncology\Medical Physics\IMRT_QA\vmatQA\2017\oct\bryce\measured\composite.txt
Select: None Dose Norm Zoom Profile Ruler Clear
Rotation: 0.0(deg)
Edit
Apply
Plan
S:\Groups\Radiology\Radiation Oncology\Medical Physics\I...\RTDOSE_2.16.840.1.113669.2.931128.8453974.20171010123756.539076_AC_EXTRACTED.snc
RS: None
Analysis
Compare
DTA
RD
AD
TH 10.0
%Diff 1
mm 3.0
%Pass 90.2
Pass 527
Fail 57
Total 584
Calc Shift
Set1 - Set2
Set1
Set2
cGy
X(mm)

Other IMRT Verification Methods

- Software that analyses beam delivery files (i.e. Varian Dynalogs, Mobius)
- Import plan DVH and compare to library of standard plans or set of established dose constraints to assess plan quality
- Second TPS or Monte Carlo

Use of Treatment Log Files (3D)

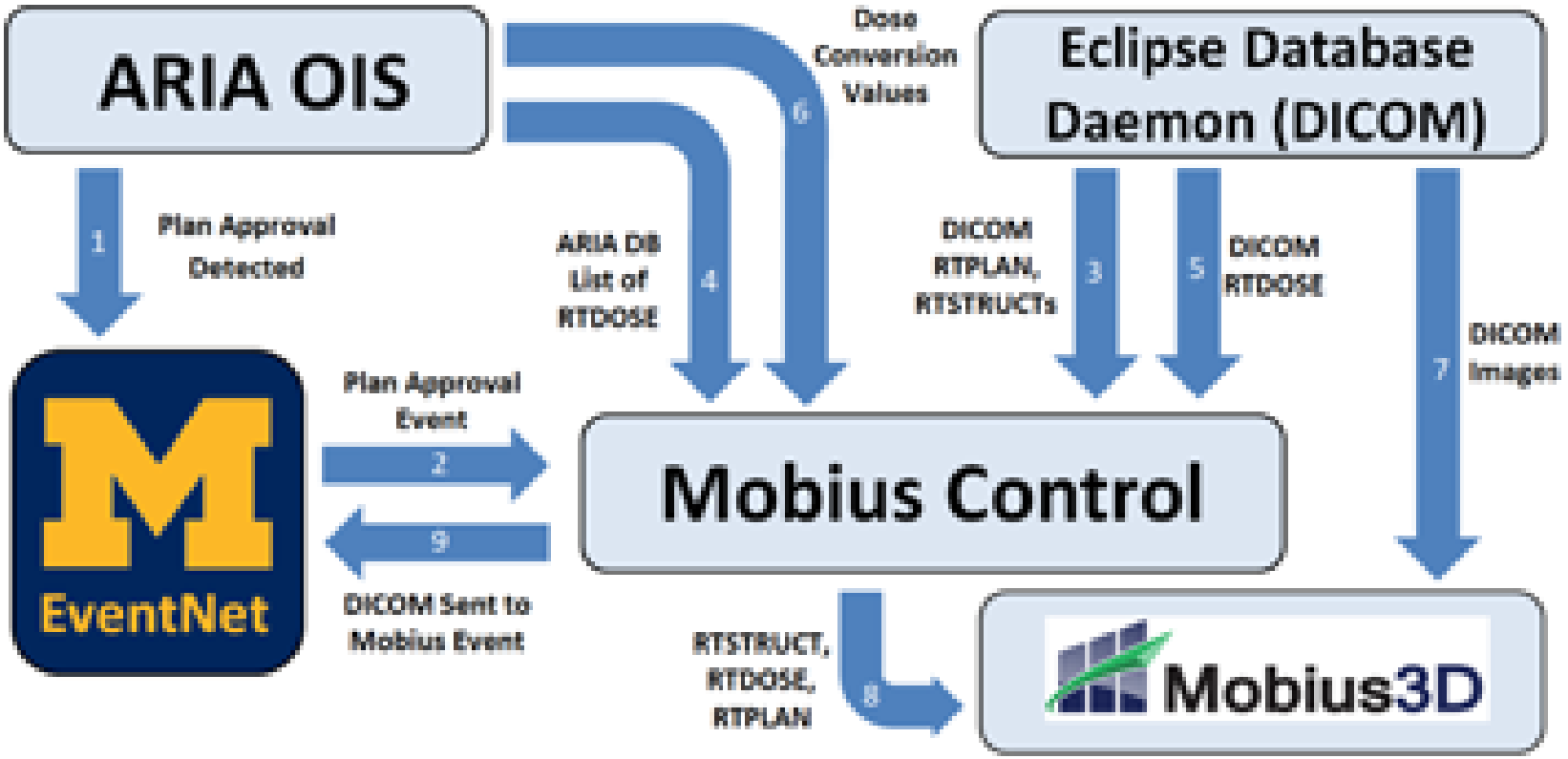
- Record treatment leaf position
- 3D delivered dose is calculated in the patient CT using collapsed cone convolution
- Allows for assessment of the impact of delivery errors on dose to the patient



MOBIUS
MEDICAL SYSTEMS

Role of Mobius in Automating QA

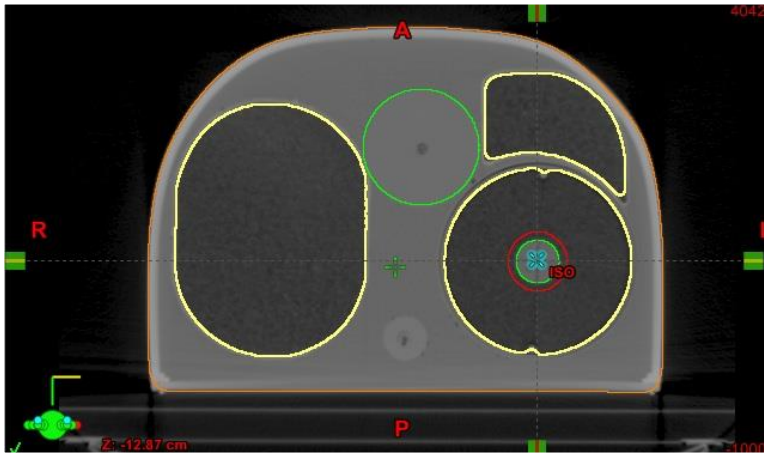
SafetyNet: streamlining and automating QA in radiotherapy

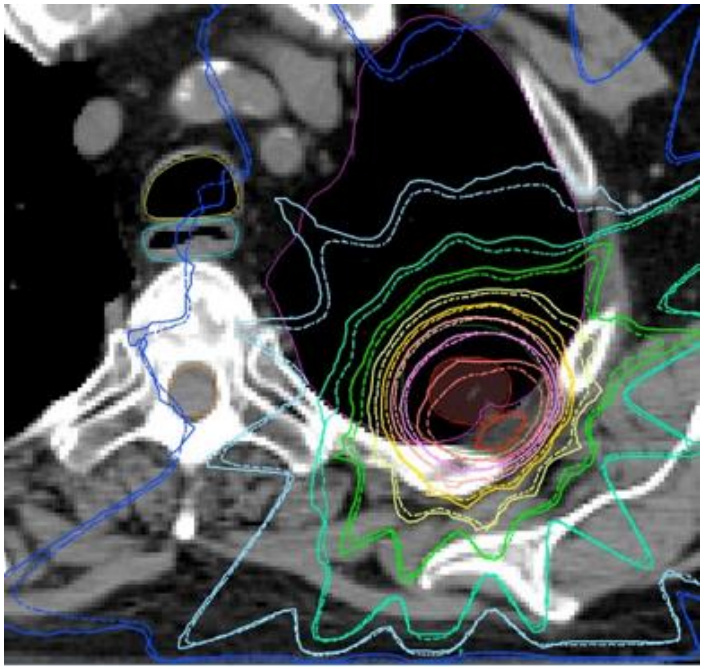


Journal of Applied Clinical Medical Physics
Volume 17, Issue 1, pages 387-395, 8 JAN 2016 DOI: 10.1120/jacmp.v17i1.5920
http://onlinelibrary.wiley.com/doi/10.1120/jacmp.v17i1.5920/full#acm20387-fig-0003

Other IMRT Verification Methods

- In general, these methods do not look at accuracy of heterogeneity corrections
- Calculate plan in a second treatment planning system





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- Varian to replace radiotherapy equipment in Copenhagen hospitals
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NEWSFEED

Jul 27, 2017

LifeLine Software acquires Radify Monte Carlo QA Technology from McGill University

AUSTIN, TEXAS, 24 July 2017 – LifeLine Software, Inc., a worldwide leader in dosimetric quality assurance tools, is pleased to announce that an agreement has been signed to acquire Radify, a Monte Carlo 3D dose volume QA software technology developed at McGill University in Quebec, Canada.

This acquisition and joint collaboration allows LifeLine Software to bring to market industry-changing 3D dose volume independent dosimetric verification products. LifeLine Software's integration of the Radify technology will immediately improve accessibility to the significant advantage of Monte Carlo accuracy in clinical settings, specifically for verifying photon, electron, and proton treatment plans.

Monte Carlo is widely recognized as the gold standard dose calculation method. The most challenging clinical cases and complex structures are analyzed with the highest accuracy and confidence. Flexible implementation options and the uncompromised accuracy of a Monte Carlo dose calculation algorithm assist radiation departments to meet their workflow requirements.

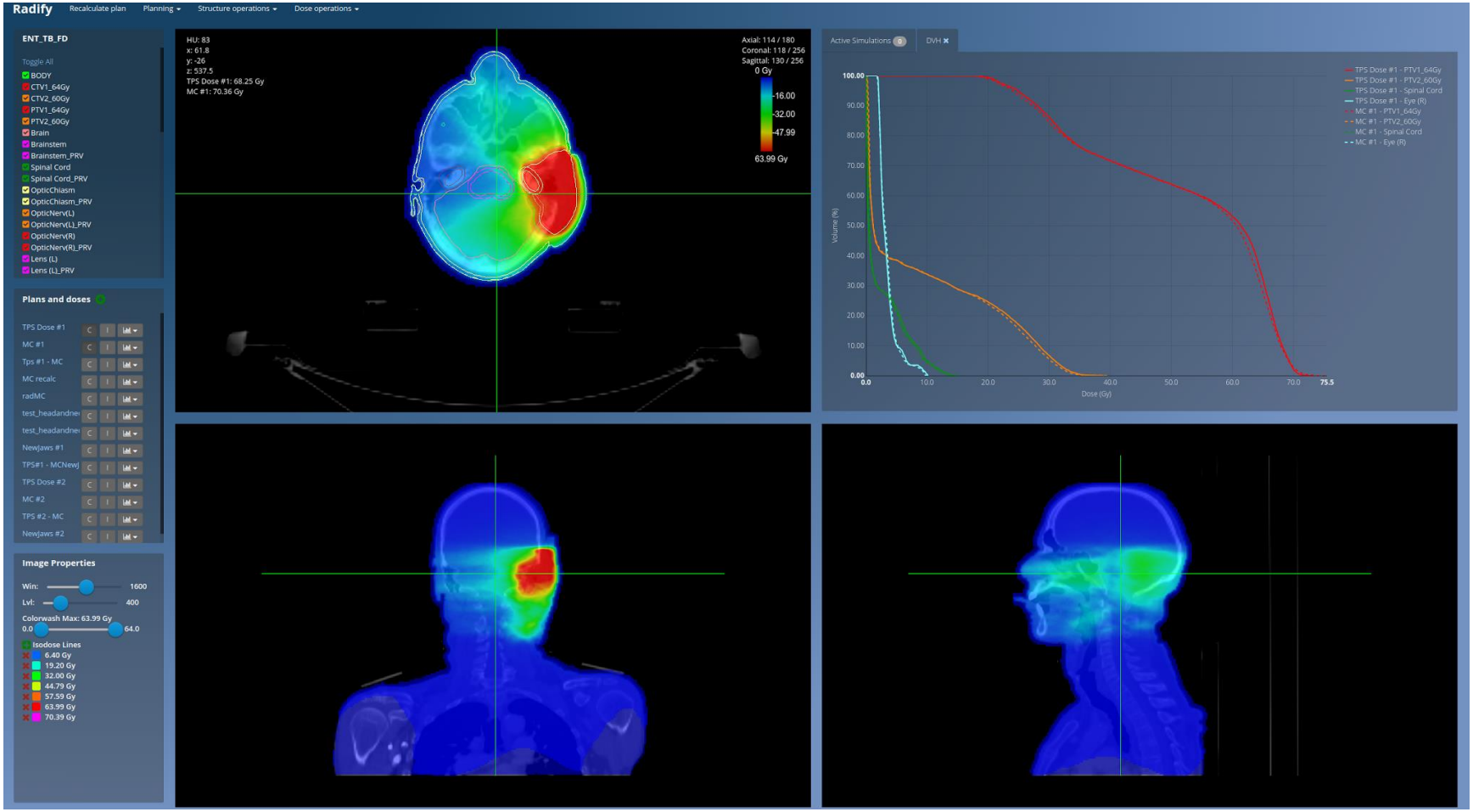
THE MPW REVIEW

Take a look at the medicalphysicsweb reviews - all previous editions are **available to view here.**

KEY SUPPLIERS

CORPORATE PARTNERS

Radify Interface



Proportion of complex plans increasing resulting in a need for more accurate MU verification. Improved accuracy may eliminate the need for measurements.

Slide courtesy of Marc-André Renaud

Dose Difference

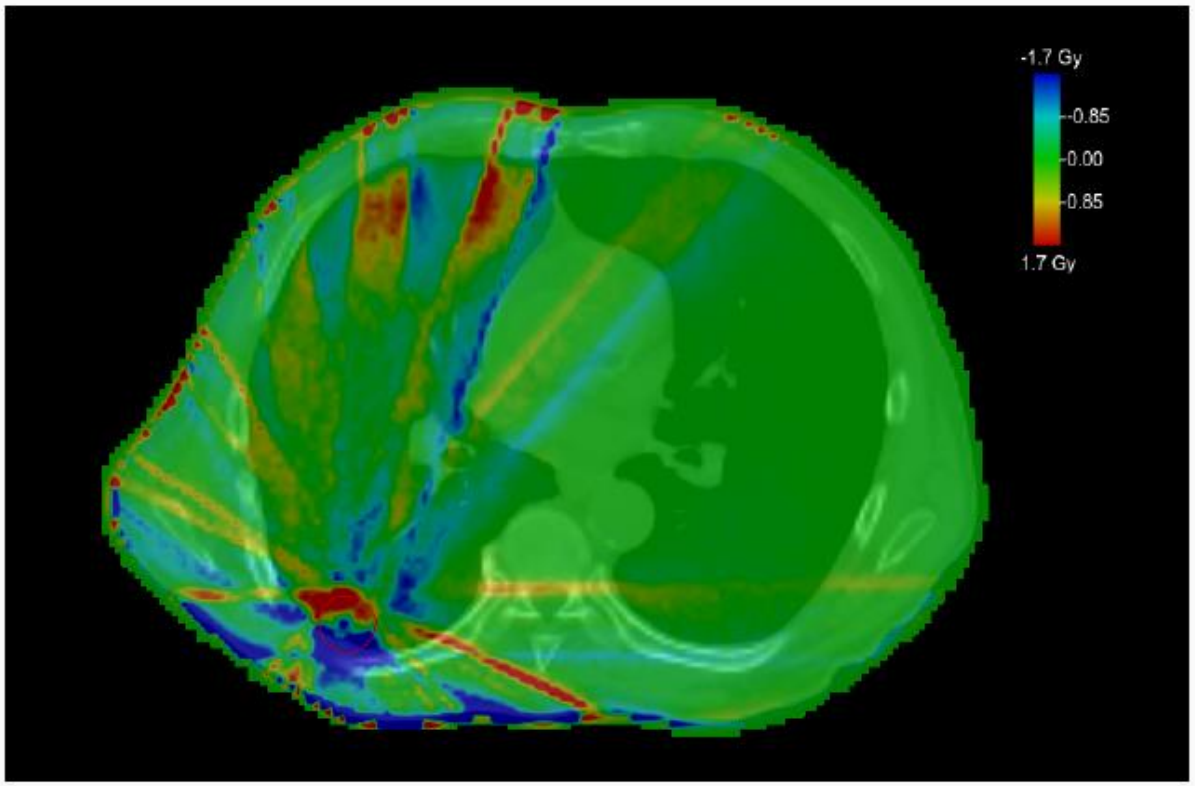


Figure 4: Dose difference: Eclipse AAA with heterogeneity corrections vs MC

Slide courtesy of Marc-André Renaud