

Quality Assurance for Image-Guided Radiation Therapy and Intensity Modulated Radiation Therapy

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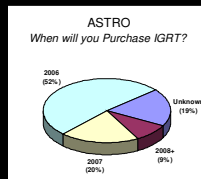
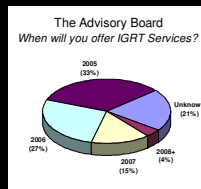
IGRT and IMRT QA

- IGRT Positional
- IGRT Dose
- TG-119
- Summary



IGRT Quality Assurance

- Image-Guided Radiation Therapy is rapidly becoming the Standard-of-Care in the United States
- In 2006, the Advisory Board Company estimated that 75% of radiation oncologists would be providing IGRT services by the end of 2007
- At the 2006 ASTRO IGRT Symposium, the audience indicated that 72% would be purchasing IGRT by 2007
- Furthermore, 64% responded that IGRT would be part of *all* radiation therapy treatments by 2011



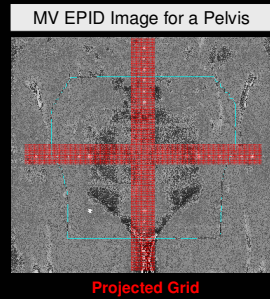
IGRT Quality Assurance

- There are a wide-range of IGRT techniques used clinically
 - kV Orthogonal Imaging
 - kV Cone Beam CT
 - MV Orthogonal Imaging
 - MV Cone Beam CT
 - Tomotherapy
- It is the responsibility of the medical physicist to ensure safe and accurate patient treatment with this technology



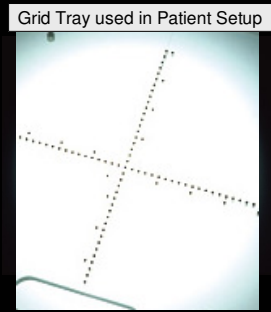
Portal Imaging QA (Accuracy)

- Although IGRT usage has increased dramatically, the majority of patients are still aligned with MV portal images
- Radiation oncologists compare the portal images with DRRs or Simulation images to verify that the patient is positioned correctly
- Errors in this process can lead to systematic errors throughout the course of treatment for many patients



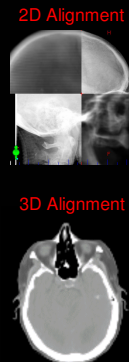
Portal Imaging QA (Accuracy)

- Grid trays slide into the shadow tray slot and project reference dots on both simulation and port films
- The reference dot scale is calibrated to project precise reference dots 1-cm or 2-cm apart at the isocenter of the treatment machine
- Grid trays must be calibrated and adjusted frequently to ensure that the grid is aligned with isocenter

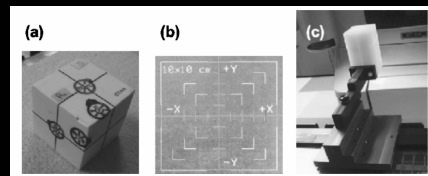


IGRT QA (Accuracy)

- Most IGRT systems use an automatic image fusion algorithm to compare the reference images from treatment planning to images acquired prior to treatment
- The medical physicist **MUST** ensure that the imaging system(s) are correctly calibrated
- Errors in this process can lead to systematic errors throughout the course of treatment for many patients



IGRT QA (Accuracy)

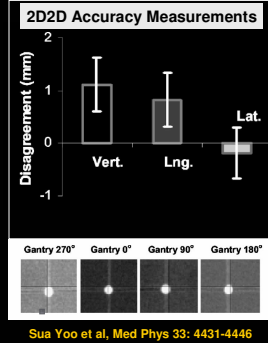


Sua Yoo et al, Med Phys 33: 4431-4446

- If the 2D imaging device does not have a physical graticule, an independent check of the digital graticule must be performed
- Yoo *et al* recommended phantoms that contains a small well-defined central radio-opaque structure (such as cube phantoms, printed circuit boards, or marker phantoms)

IGRT QA (Accuracy)

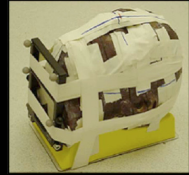
- Yoo *et al* reported the 2D2D Match and couch shift accuracy for a Varian OBI over an 8-month period
- The average disagreements were 1.1 ± 0.5 mm, 0.8 ± 0.5 mm, and -0.2 ± 0.5 mm in the vertical, longitudinal, and lateral directions
- Yoo *et al* also reported variation in OBI isocenter accuracy with gantry rotation



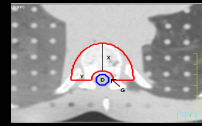
Sua Yoo *et al*, Med Phys 33: 4431-4446

IGRT QA (Accuracy)

- Sarah Boswell *et al* tested tomotherapy imaging accuracy by acquiring 104 MVCT scans of an anthropomorphic head phantom
 - The phantom was moved known amounts relative to the planning image set
- Ben Robison *et al* tomotherapy imaging accuracy by acquiring 70 MVCT scans of an anthropomorphic body phantom
 - The phantom was correctly positioned at isocenter and shifts were calculated

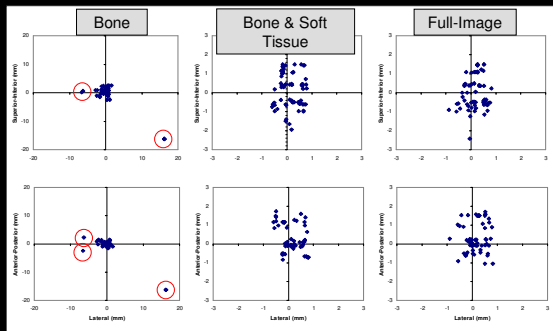


Sarah Boswell *et al*, Med Phys 33: 4395-4404



Ben Robison *et al*, Med Phys 33: 1992

IGRT QA (Accuracy)



- Robison and Boswell reported periodic automatic image fusion errors greater than 1-cm

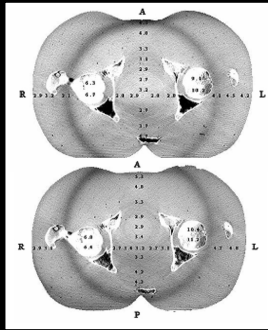
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Varian CBCT QA (Dose)

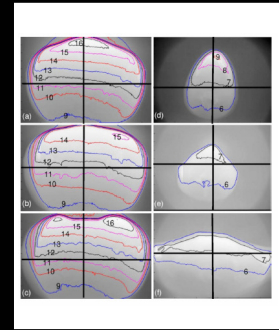
- Wen *et al* measured doses from Varian CBCT in phantom and In-Vivo using TLDs
- AP skin doses ranged from 3-6 cGy for 20-23 cm separation
- The Lt Lat skin dose was 4.0 cGy, while the Rt Lat skin dose was 2.6 cGy (due to gantry rotation)
- The left hip received 10-11 cGy, while the right hip received 6-7 cGy



Wen *et al* / Phys Med Biol 52: 2267-2276

Siemens CBCT QA (Dose)

- Gayou *et al* measured doses from CBCT on a Siemens system using ionization chambers, film, and TLDs
- The 15 MU protocol on a pelvis phantom resulted in the whole pelvis receiving at least 9 cGy with a max dose of 17 cGy
- The 8 MU protocol on a head phantom resulted in the whole pelvis receiving at least 5 cGy with a max dose of 9 cGy



Gayou *et al* / Med Phys 34: 499-506

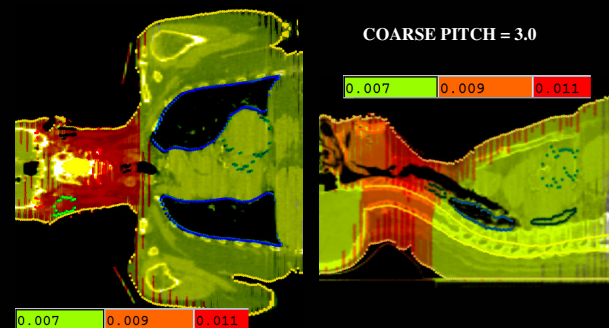
Tomotherapy MVCT QA (Dose)

- Shah *et al* studied MVCT doses for a helical tomotherapy system
- Pitch in helical tomotherapy imaging is inversely proportional to dose
- Relative to pitch of 2.0 (normal)
 - Pitch of 1.0 (fine) is 2.0 times higher in dose
 - Pitch of 3.0 (coarse) is 0.67 times the dose

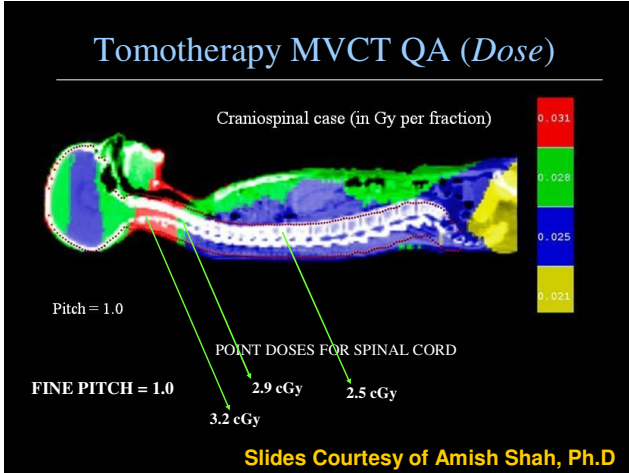


Slides Courtesy of Amish Shah, Ph.D

Tomotherapy MVCT QA (Dose)



Slides Courtesy of Amish Shah, Ph.D



Tomotherapy MVCT QA (Dose)

Head and Neck patient		Normal Pitch Dose (cGy)		Dose from Normal Pitch relative to Rx dose	
Possible Organ of Interest	Average	Max	Average Dose	Max Dose	
Lacrimal	1.48	1.66	0.74%	0.83%	
Optic nerve	1.42	1.58	0.71%	0.79%	
Chiasm	1.38	1.47	0.69%	0.73%	
Brainstem	1.36	1.50	0.68%	0.75%	
Parotid	1.45	1.75	0.72%	0.87%	
Cord Superior	1.51	1.69	0.76%	0.84%	
Brain	1.07	1.64	0.53%	0.82%	
Pediatric Craniospinal		Normal Pitch Dose (cGy)		Dose from Normal Pitch relative to Rx dose	
Trachea	1.56	1.80	0.86%	1.00%	
Lens	1.47	1.50	0.82%	0.83%	
Spinal Cord	1.33	1.69	0.74%	0.94%	
Stomach	1.28	1.51	0.71%	0.84%	
Heart	1.35	1.47	0.75%	0.82%	
Liver	1.26	1.46	0.70%	0.81%	
Kidney	1.26	1.35	0.70%	0.75%	
Lung	1.30	1.50	0.72%	0.83%	
Parotid	1.54	1.62	0.86%	0.90%	

Slides Courtesy of Amish Shah, Ph.D

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TG-119: IMRT Test Cases

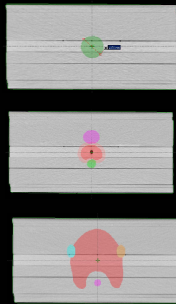
Task Group No. 119 Writing group on IMRT QA

The overall aim of this task group report is to provide a single resource for a clinical physicist that describes a comprehensive quality assurance program for IMRT

Jay Burmeister, Nesrin Dogan, Gary A. Ezzell, Thomas J. LoSasso, Andrea Molineu, Jatinder R. Palta, Chester Ramsey, Bill Salter, Michael B. Sharpe, Jason Sohn, Ping Xia, Ning Yue and Ying Xiao (Chair)

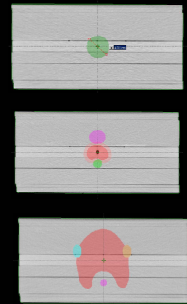
TG-119: IMRT Test Cases

- TG-119 is in the process of developing standard IMRT planning “problems” that physicists can use to test the accuracy of their IMRT planning and delivery systems
- Each test includes target and normal structure shapes that a physicist can create on a phantom of his/her choosing
- Alternatively, the CTs and RT structure set can be downloaded, imported and planned, and then the plan transferred to the local phantom for dose measurement



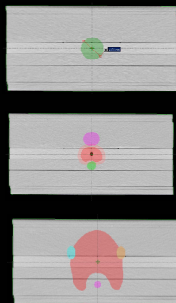
TG-119: IMRT Test Cases

- The phantom should permit point measurements (*e.g. ion chamber*) and planar dose measurements (*e.g. film, mapcheck, EPID, etc.*)
- The chamber should be smaller than a Farmer-type chamber, such as a 0.125 cc scanning chamber
- Point dose measurements will be normalized to readings taken for 10x10 fields irradiating the phantom isocentrically in order to reduce the effects of daily linac output variations and differences between the phantom and water



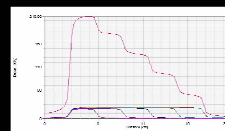
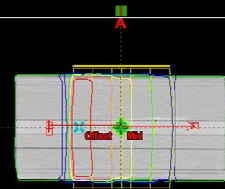
TG-119: IMRT Test Cases

- Each test includes a specification of dose goals for the IMRT planning and the beam arrangement
- Calculations may be done with heterogeneity corrections on or off (*preferably on*), but should be done consistently for all the tests
- Dose distributions will be analyzed using gamma criteria of 3% dose and 3 mm distance to agreement
- Doses below 10% of the maximum may be discarded



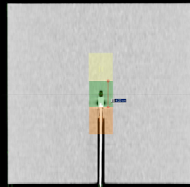
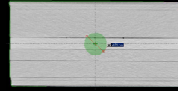
TG-119: IMRT Test Cases

- Calculate a parallel-opposed irradiation of the phantom using a series of AP:PA fields to create a set of five bands receiving doses from roughly 40 – 200 cGy
- The following image shows 15 cm long fields with widths from 3 to 15 cm, each given 25 MU
- Measure the central dose with chamber and the dose distribution on the central plane
- Report the fraction of points passing the gamma criteria



TG-119: IMRT Test Cases

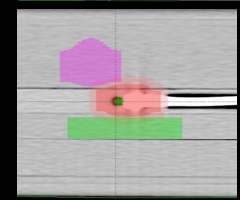
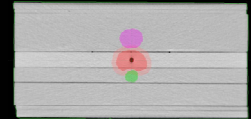
- Three cylindrical targets are stacked along the axis of rotation. Each has a diameter of approximately 4 cm and length of 4 cm
- Beam arrangement: 6 MV, 7 fields at 50° intervals from the vertical



Structure		
Central target	99% of volume to receive at least 5000 cGy	10% of volume to receive no more than 5300 cGy
Superior target	99% of volume to receive at least 2500 cGy	10% of volume to receive no more than 3500 cGy
Inferior target	99% of volume to receive at least 1250 cGy	10% of volume to receive no more than 2500 cGy

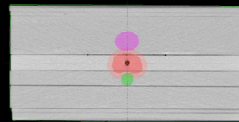
TG-119: IMRT Test Cases

- The prostate CTV is roughly ellipsoidal with RL, AP, and SI dimensions of 4.0, 2.6, and 6.5 cm
- The prostate PTV is expanded 0.6 cm around the CTV
- The rectum is a cylinder with diameter 1.5 cm that abuts the indented posterior aspect of the prostate
- The PTV includes about 1/3 of the rectal volume on the widest PTV slice



TG-119: IMRT Test Cases

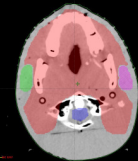
- The bladder is roughly ellipsoidal with RL, AP, and SI dimensions of 5.0, 4.0, and 5.0 cm, respectively, and is centered on the superior aspect of the prostate
- Beam arrangement: 6 MV, 7 fields at 50° intervals from the vertical



Structure		
Prostate PTV	95% of volume to receive at least 7560 cGy	5% of volume to receive no more than 8300 cGy
Rectum	30% of volume to receive no more than 7000 cGy	10% of volume to receive no more than 7500 cGy
Bladder	30% of volume to receive no more than 7000 cGy	10% of volume to receive no more than 7500 cGy

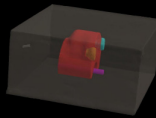
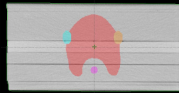
TG-119: IMRT Test Cases

- The HN PTV includes all anterior volume from the base of the skull to the upper neck, including the posterior neck nodes
- The PTV is retracted from the skin by 0.6 cm
- There is a gap of about 1.5 cm between the cord and the PTV
- Beam arrangement: 6 MV, 9 fields at 40° intervals from the vertical



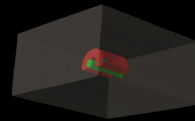
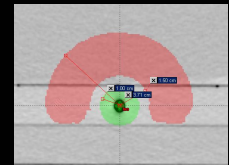
TG-119: IMRT Test Cases

Structure		
HN PTV	90% of volume to receive at least 5000 cGy	99% of volume to receive at least 4650cGy
	No more than 20% of volume to receive more than 5500 cGy	
Cord	No part of volume to receive more than 4000 cGy	
Parotids	50% of volume to receive less than 2000 cGy	



TG-119: IMRT Test Cases

- The target is a C-shape that surrounds a central avoidance structure
- The center core is a cylinder 1 cm in radius
- The gap between the core and the PTV is 0.5 cm, so the inner arc of the PTV is 1.5 cm in radius
- The outer arc of the PTV is 3.7 cm in radius. The PTV is 8 cm long and the core is 10cm long



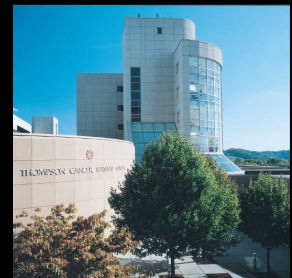
TG-119: IMRT Test Cases

- Two versions of the problem are given. In the easier, the central core is to be kept to 50% of the target dose
- In the harder, the central core is to be kept to 20% of the target dose
- This latter goal is probably not achievable and tests a system that is being pushed very hard
- Beam arrangement: 6 MV, 9 fields at 40° intervals from the vertical

Structure		
CShape PTV	95% of volume to receive at least 5000 cGy	10% of volume to receive no more than 5500cGy
Core	5% of volume to receive no more than 2500 cGy	

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Summary

Image-Guided Radiation Therapy

- An quality assurance program must be created by the medical physicist to evaluate their IGRT system
- The medical physicist should have a good understanding of the additional patient received during IGRT

Intensity Modulated Radiation Therapy

- Task Group-119 is developing IMRT test cases, which should be published in 2008

