A simple Phantom for Treatment Planning QA

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ACR/ASTRO Radiation Oncology Accreditation requirements for Treatment Planning:

Evidence of annual Treatment Planning systems quality assurance program (TG53)

Need to have a Policy and Procedure for it and actually do it

TG 53

American Association of Physicists in Medicine Radiation Therapy Committee Task Group 53: Quality assurance for clinical radiotherapy treatment planning

Received 15 December 1997; accepted for publication
4 August 1998!

What percentage of physicists have read it without falling asleep and actually use it?

- *TG 53 was published in 1998 When was it actually started?*

<u>Long before IMRT</u>

We do a lot of Treatment Planning QA every day when we perform IMRT QA

The ACR / ASTRO in their accreditation program needs to rely on AAPM to provide them with recommendations for QA standards

However if AAPM reports take 10 years or more to be published, they may be obsolete at the time of publication.

Furthermore they are sometimes over 10 years old (like TG 53)

No ACR / ASTRO physics surveyor will or should fault you, if you do not follow TG53 in its entirety
- Nobody can

Many Sites struggle to establish their ***own*** *TPS QA program*
- So did I

Besides TG53 I reviewed IAEA's, and ESTRO's Treatment Planning QA recommendations

AAPM TPS QA recommendations

American Association of Physicists in Medicine Radiation Therapy Committee Task Group 53: Quality assurance for clinical radiotherapy treatment planning

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Fox Chase Cancer Center, Philadelphia, Pennsylvania
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London Regional Cancer Center, London, Ontario, Canada

(Received 15 December 1997; accepted for publication 4 August 1998)

In recent years, the sophistication and complexity of clinical treatment planning and treatment planning systems has increased significantly, particularly including three-dimensional (3D) treatment planning systems, and the use of conformal treatment planning and delivery techniques. This has led to the need for a comprehensive set of quality assurance (QA) guidelines that can be applied to clinical treatment planning. This document is the report of Task Group 53 of the Radiation Therapy Committee of the American Association of Physicists in Medicine. The purpose of this report is to guide and assist the clinical medical physicist in developing and implementing a comprehensive but viable program of quality assurance for modern radiotherapy treatment planning. The scope of the QA needs for treatment planning is quite broad, encompassing image-based definition of patient anatomy, 3D beam descriptions for complex beams including multileaf collimator apertures, 3D dose calculation algorithms, and complex plan evaluation tools including dose volume histograms. The Task Group recommends an organizational framework for the task of creating a QA program which is individualized to the needs of each institution and addresses the issues of acceptance testing, commissioning the planning system and planning process, routine quality assurance, and ongoing QA of the planning process. This report, while not prescribing specific QA tests, provides the framework and guidance to allow radiation oncology physicists to design comprehensive and practical treatment planning QA programs for their clinics. [S0094-2405(98)03410-5]

Both of these are superior to TG53

IAEA-TECDOC-1583

Commissioning of Radiotherapy Treatment Planning Systems: Testing for Typical External Beam Treatment Techniques

Report of the Coordinated Research Project (CRP) on Development of Procedures for Quality Assurance of Dosimetry Calculations in Radiotherapy

IAEA
International Atomic Energy Agency

January 2008

QUALITY ASSURANCE OF TREATMENT PLANNING SYSTEMS
PRACTICAL EXAMPLES FOR NON-IMRT PHOTON BEAMS

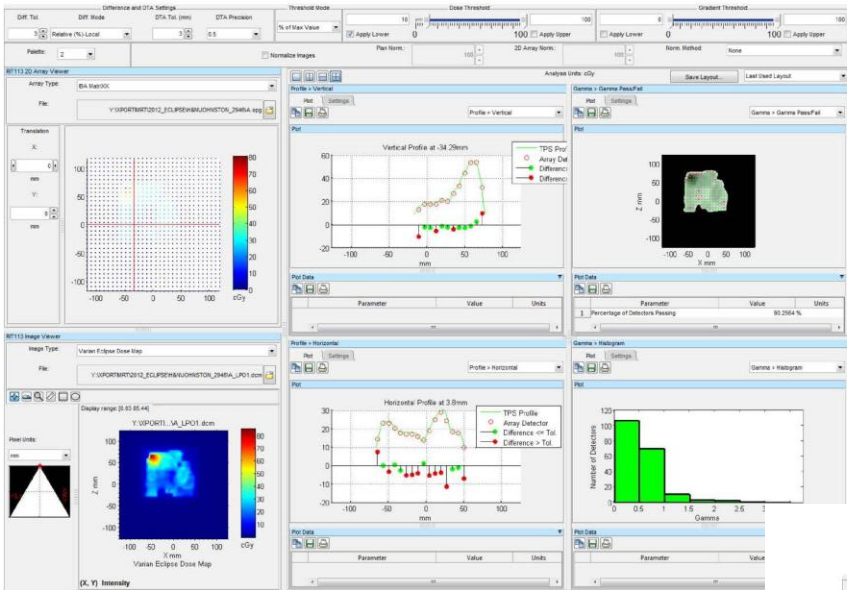
Ben Mijnheer
Agnieszka Olszewska
Claudio Fiorino
Guenther Hartmann
Tommy Knöös
Jean-Claude Rosenwald
Hans Welleweerd

2004 – First edition
ISBN 90-804532-7

ESTRO
Mounierlaan 83/12 – 1200 Brussels (Belgium)

- *However none of these provide IMRT QA planning tests*
All are 3D

- *We do IMRT Treatment Planning and QA every day, which tests our Planning System and our capability to measure correctly*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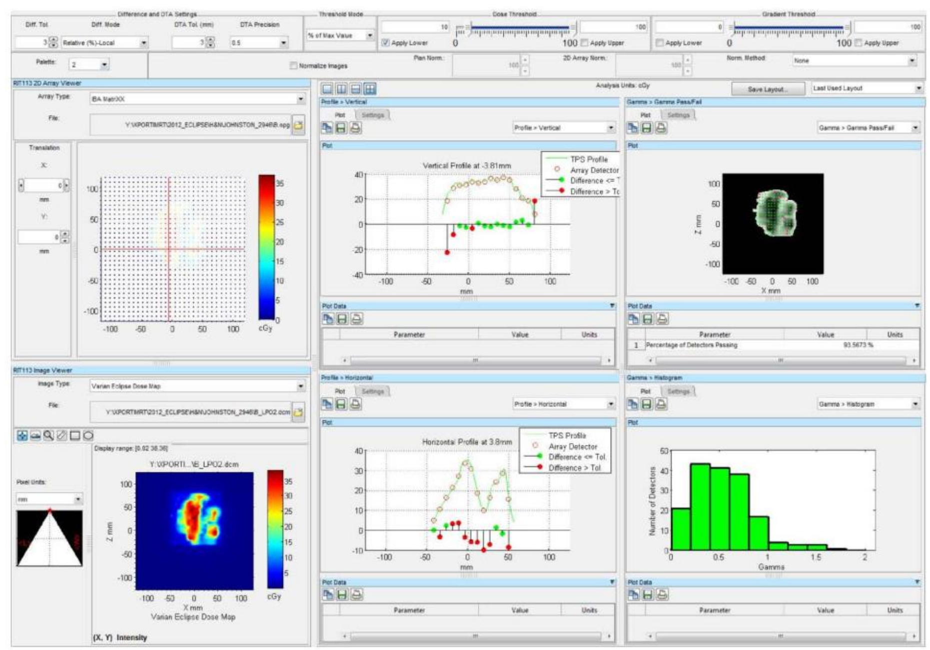
Varian Eclipse Dose Map
Number of Detectors
Gamma
X mm
cGy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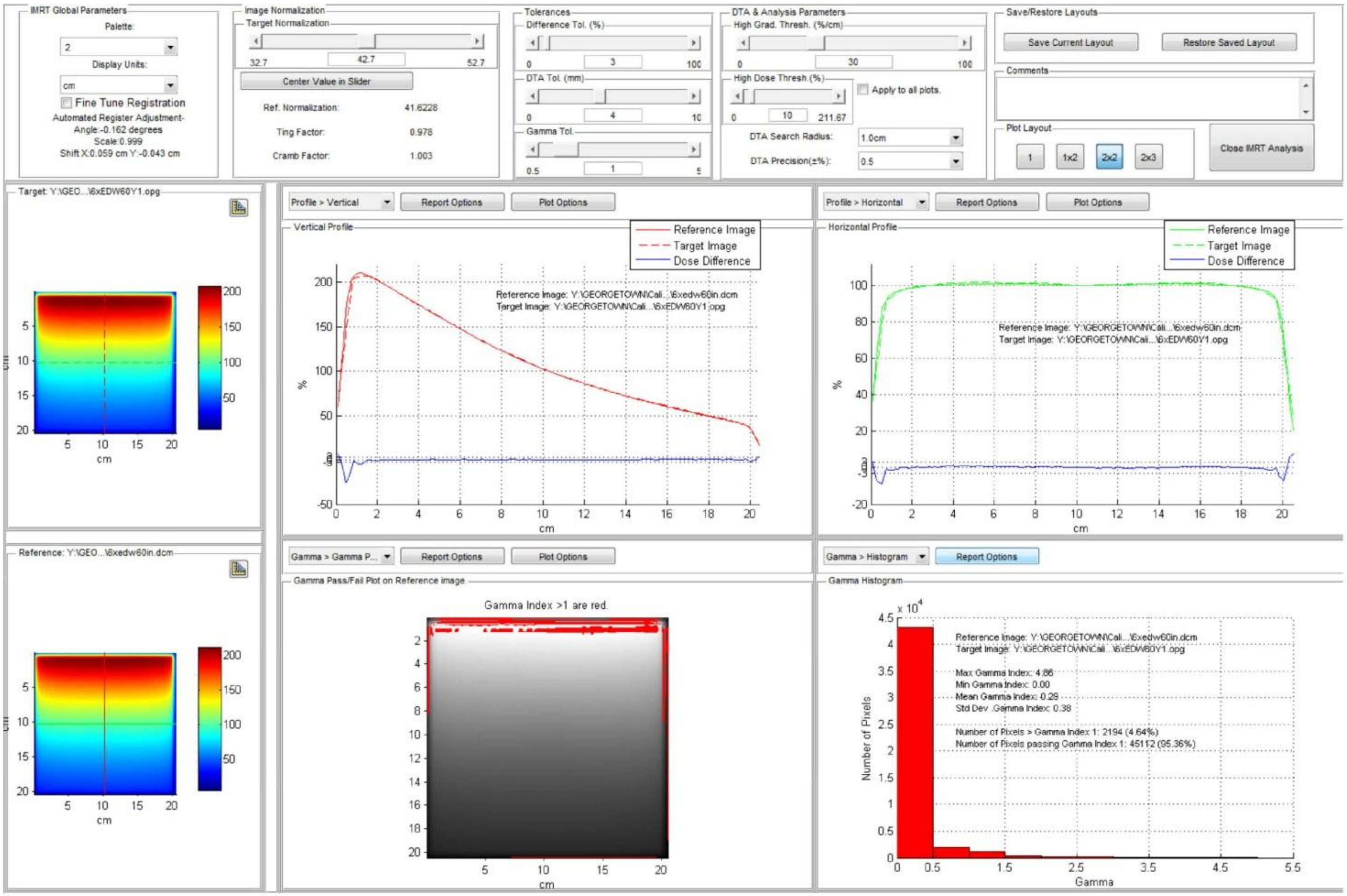
Difference > Tol
Varian Eclipse Dose Map
Number of Detectors
Gamma
X mm
cGy



IMRT Global Parameters
Palette:
Display Units:
Fine Tune Registration
Automated Register Adjustment-
Angle:-0.162 degrees
Scale:0.999
Shift X:0.059 cm Y:-0.043 cm
Image Normalization
Target Normalization
Center Value in Slider
Ref. Normalization: 41.6228
Ting Factor: 0.978
Cramb Factor: 1.003
Tolerances
Difference Tol. (%)
DTA Tol. (mm)
Gamma Tol.
DTA & Analysis Parameters
High Grad. Thresh. (%/cm)
High Dose Thresh.(%)
Apply to all plots.
DTA Search Radius: 1.0cm
DTA Precision(±%): 0.5
Save/Restore Layouts
Save Current Layout
Restore Saved Layout
Comments
Plot Layout
Close IMRT Analysis
Target: Y:\GEO...\6xEDW60Y1.opg
Reference: Y:\GEO...\6xedw60in.dcm
Profile > Vertical
Report Options
Plot Options
Vertical Profile
Reference Image
Target Image
Dose Difference
Reference Image: Y:\GEORGETOWN\Cali...\6xedw60in.dcm
Target Image: Y:\GEORGETOWN\Cali...\6xEDW60Y1.opg
Profile > Horizontal
Horizontal Profile
Gamma > Gamma P...
Gamma Pass/Fail Plot on Reference image
Gamma Index >1 are red.
Gamma > Histogram
Gamma Histogram
Max Gamma Index: 4.86
Min Gamma Index: 0.00
Mean Gamma Index: 0.29
Std Dev .Gamma Index: 0.38
Number of Pixels > Gamma Index 1: 2194 (4.64%)
Number of Pixels passing Gamma Index 1: 45112 (95.36%)
Number of Pixels
Gamma
cm

- **For some Treatment Planning QA, especially IMRT commissioning, I recommend the TG119 report**

IMRT commissioning:
Multiple institution planning and dosimetry comparison, a report from AAPM Task Group 119
Medical Physics, Vol. 36, No. 11, November 2009

Facilities interested in using this test suite can download the DICOM-RT images and structure sets from
http://www.aapm.org/pubs/tg119/default.asp
along with a detailed description of the planning, measurement, and analysis process.

TG-119 is the **best** TG report available and probably least known… in my opinion

- ***TG-119 Commissioning Plans and Measurements*** *by G. Ezzell et al.*

Introduction

The purpose of this exercise is to ***define standard IMRT planning "problems"*** *that physicists can use to test the accuracy of their IMRT planning and delivery systems.*

These represent ***total system checks*** *of different types and complexity. Differences between measurement and prediction may be caused by measurement uncertainty, limitations in the accuracy of dose calculations, and limitations in the dose delivery mechanisms. These tests will not serve to distinguish between these sources, but will serve to test the overall accuracy of the IMRT system.*

From TG119: 3D

Preliminary tests

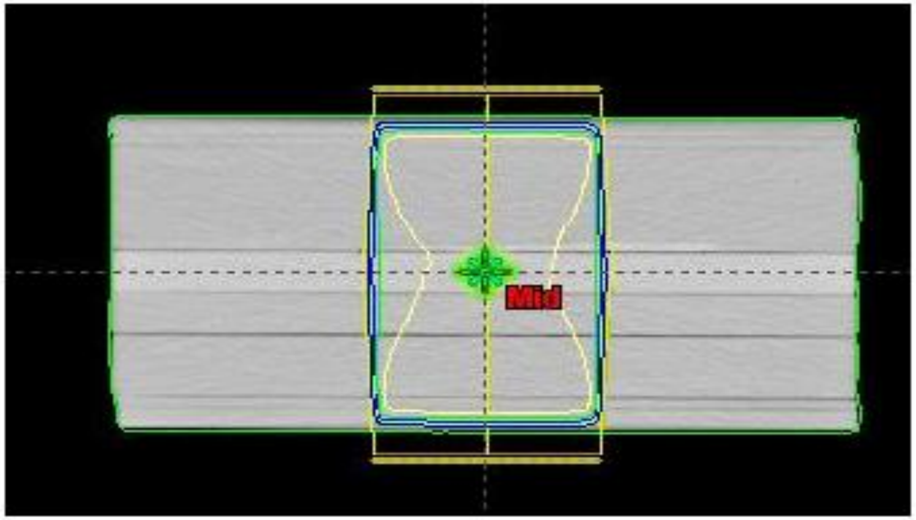
P1: AP:PA

Calculate a simple parallel-opposed irradiation of the phantom using AP:PA 10x10 fields to a dose of 200 cGy.

Measure the central dose with chamber and the dose distribution on the central plane.

This geometry will be used to set the dose/chamber reading ratio for subsequent tests.

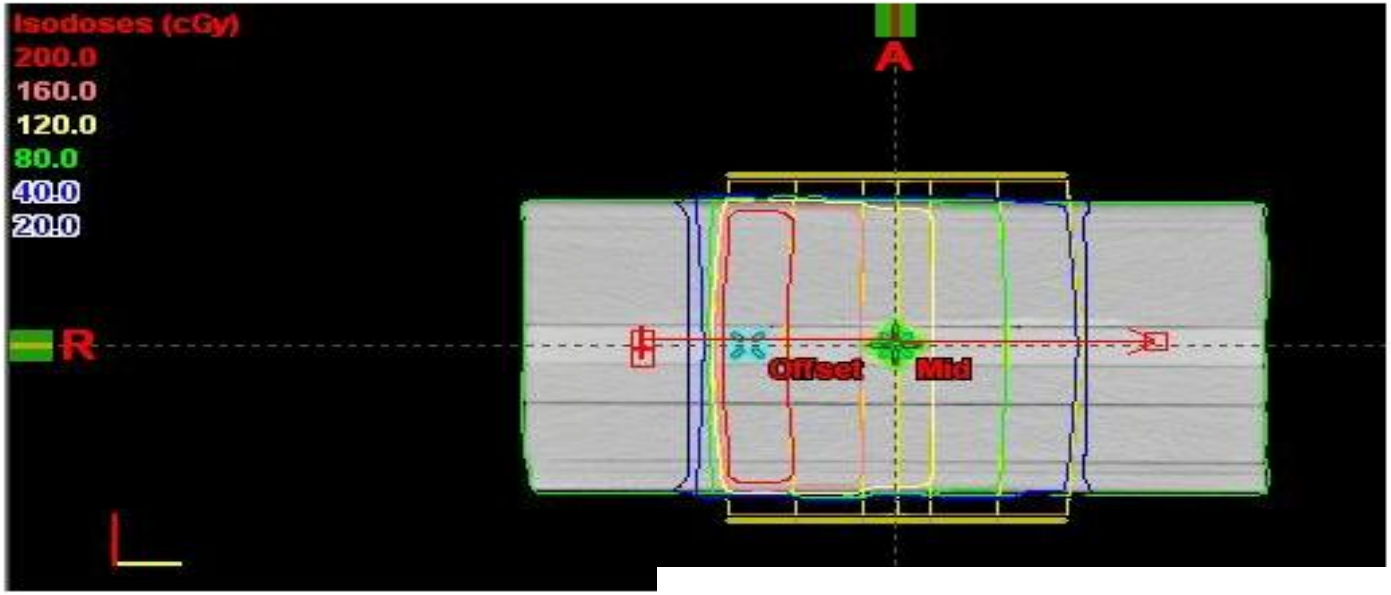
Report the fraction of points passing the gamma criteria.



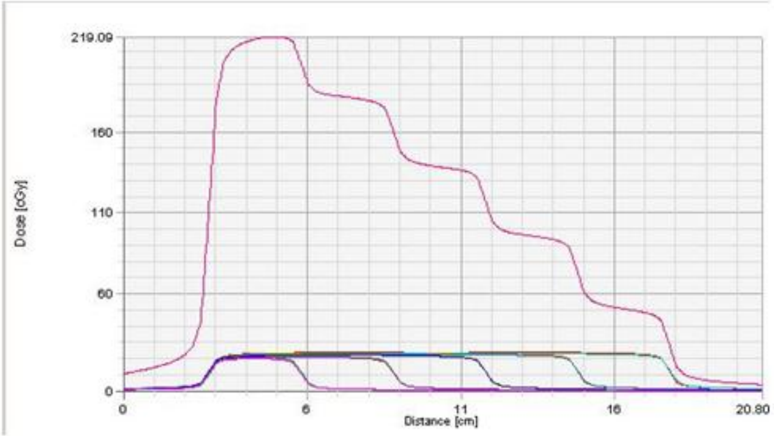
APPA

P2: Bands

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. This can be done using asymmetric jaws. The following image shows 15 cm long fields with widths from 3 to 15 cm, each given 25 MU.



Dose profile through central plane



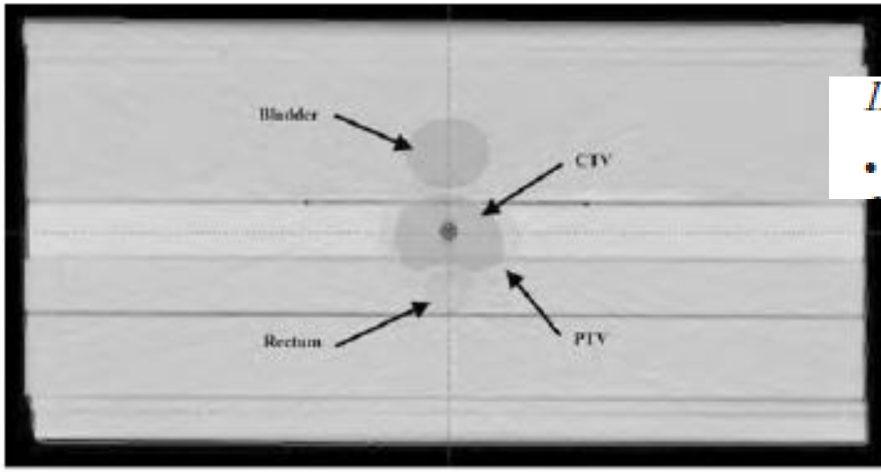
Measure the central dose with chamber and the dose distribution on the central plane. Report the fraction of points passing the gamma criteria.

From TG119: Moving Jaw

From TG119: Prostate

II.E.4.c. Beam arrangement.

- 6 MV, seven fields at 50° intervals from the vertical.



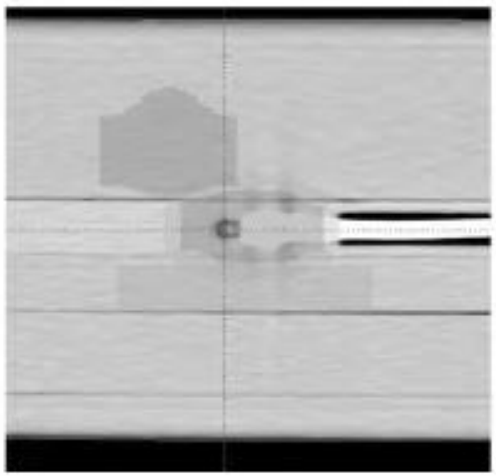
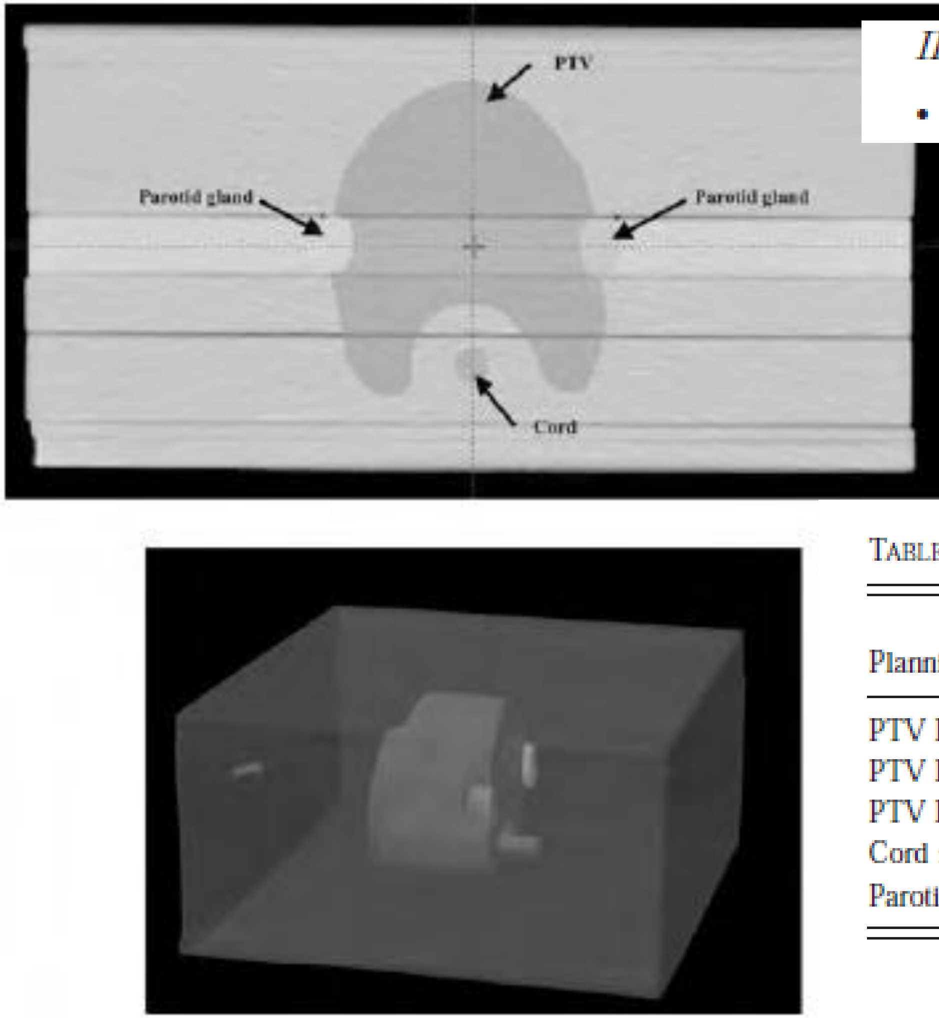


FIG. 3. Mock prostate structures: The prostate CTV, PTV, rectum, and bladder. The prostate CTV is roughly ellipsoidal with RL, AP, and SI dimensions of 4.0, 2.6, and 6.5 cm, respectively. The prostate PTV is expanded 0.6 cm around the CTV. The rectum is a cylinder with diameter of 1.5 cm that abuts the indented posterior aspect of the prostate. The PTV includes about 1/3 of the rectal volume on the widest PTV slice. 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. Transverse and coronal views are shown.

TABLE III. Treatment plan statistics for mock prostate.

Planning parameter	Plan goal (cGy)	Mean (cGy)	Standard deviation (cGy)	Coefficient of variation
Prostate D95	>7560	7566	21	0.003
Prostate D5	<8300	8143	156	0.019
Rectum D30	<7000	6536	297	0.045
Rectum D10	<7500	7303	150	0.020
Bladder D30	<7000	4394	878	0.200
Bladder D10	<7500	6269	815	0.130



II.E.5.c. Beam arrangement.

- 6 MV, 9 fields at 40° intervals from the vertical.

From TG119: Head & Neck

TABLE IV. Treatment plan statistics for mock head and neck.

Planning parameter	Plan goal (cGy)	Mean (cGy)	Standard deviation (cGy)	Coefficient of variation
PTV D90	5000	5028	58	0.013
PTV D99	>4650	4704	52	0.011
PTV D20	<5500	5299	93	0.018
Cord maximum	<4000	3741	250	0.067
Parotid D50	<2000	1798	184	0.102

FIG. 4. Mock head/neck structures: HN PTV, cord, and parotid glands. 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. The parotid glands are to be avoided and are at the superior aspect of the PTV. Transverse and 3D views are shown.

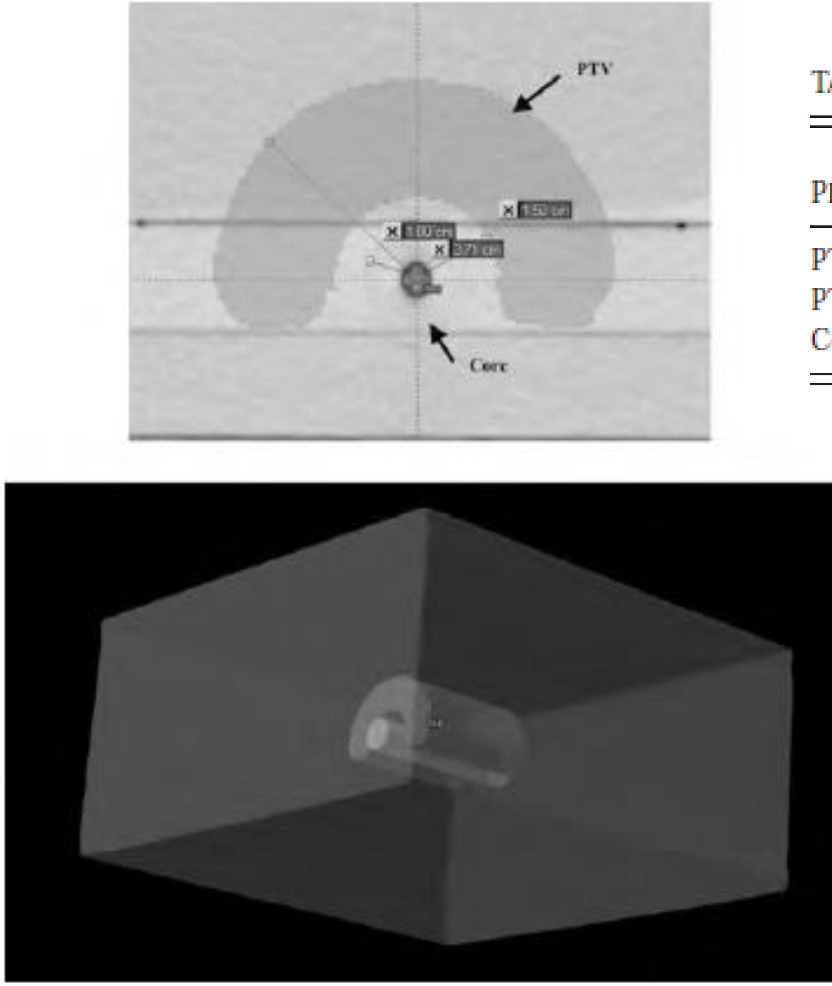


FIG. 5. CShape structures: CShape PTV and core. The center core is a cylinder 1 cm in radius. The gap between the core and the PTV is 0.5 cm, so the inner arc of the PTV is 1.5 cm in radius. The outer arc of the PTV is 3.7 cm in radius. The PTV is 8 cm long and the core is 10 cm long. Transverse and 3D views are shown.

TABLE V. Treatment plan statistics for CShape (easier).

Planning parameter	Plan goal (cGy)	Mean (cGy)	Standard deviation (cGy)	Coefficient of variation
PTV D95	5000	5010	17	0.003
PTV D10	<5500	5440	52	0.010
Core D10	<2500	2200	314	0.141

II.E.6.c. Beam arrangement.

- 6 MV, 9 fields at 40° intervals from the vertical.

From TG119: C-Shape

So…

We do have recommendations for 3D and IMRT planning QA

What we cannot easily check are: Heterogeneity and DVH

There are a several QA phantoms available to test heterogeneity corrections such as:

Best Medical /CNMC

Standard Imaging

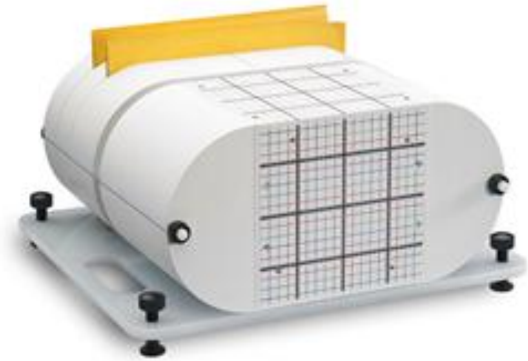
Sun Nuclear

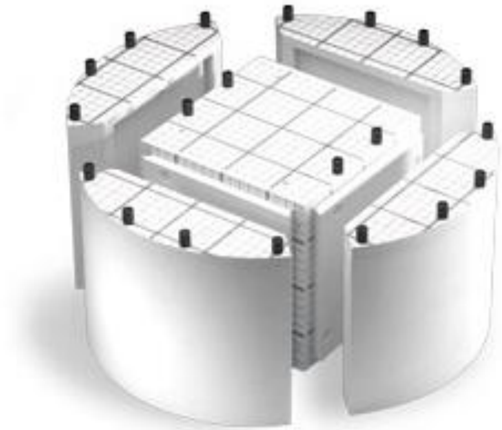
EasyCube

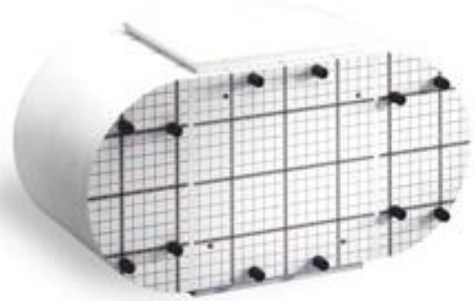
EasyCube is a cubic phantom that can be used to verify dose distributions in IMRT, including head and neck and stereotactic applications.

Applications

- Dose measurements
  - Ionization chambers
  - TLD´s
  - Film
- Simulation of heterogeneities
  - Bones / adipose / muscle / lung
  - Cavities
  - Artifacts (e.g. titanium)
- CT scanner QA
  - Calibration of Hounsfield scale
- Stereotactic QA





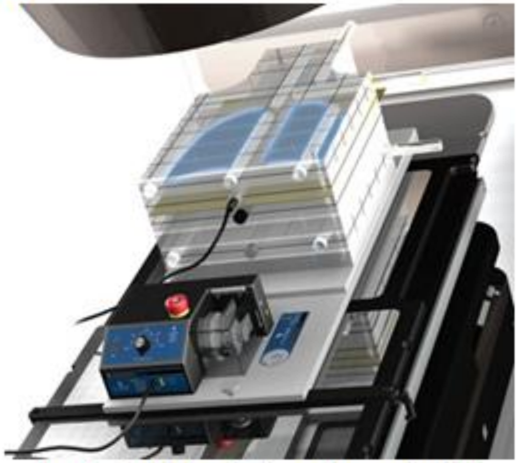


Sun Nuclear

IMRT DOSE VERIFICATION PHANTOM

ASSURE ACCURACY IN RESPIRATORY GATING WITH THE OPTIONAL RESPIRATORY GATING PLATFORM

The unique Respiratory Gating Platform [REF 72249] simulates breathing providing the means to create a comprehensive program for commissioning, training, quality assurance, and dose verification of gated IMRT treatments.

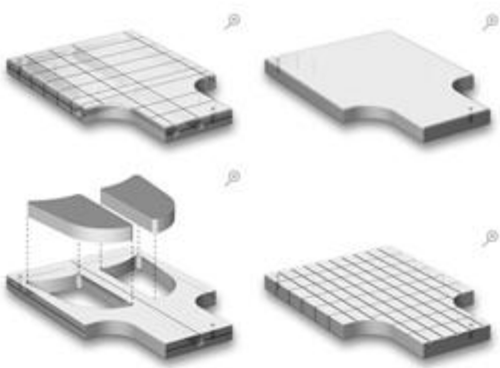


Respiratory Gating Platform shown with IMRT Dose Verification Phantom

Standard Imaging

Features and Benefits

- Solid Acrylic (Virtual Water™) **Ion Chamber Slab** has six cavities for thimble ion chamber measurement. The diameter of each cavity is 19 mm. Solid acrylic (Virtual Water) plugs are included to fill the cavities for simulated patient thickness. One solid acrylic (Virtual Water™) plug is drilled for the ion chamber of choice. A bone equivalent plug is included for bone simulation of heterogeneity measurements.



Ion Chamber Slab, Blank Slab, Lung Phantom Slab, MOSFET Diode/TLD Slab

Best Medical / CNMC

▼ PRODUCTS

- Radiation Physics
- Dosimetry Phantoms
- Physics Accessories
- Accelerator QA
- Dose Monitors
- Treatment Accessories
- Brachytherapy
- Diagnostic Radiology
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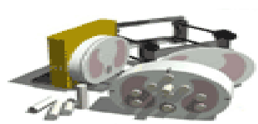
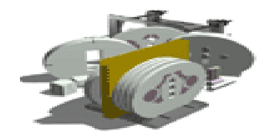
MODEL IMRT-2H5
IMRT Homogeneous Phantom
Product Overview ▶ | Download Product Sheet ▶

MODEL IMRT-2H9K
Point Dose Measurement Phantom
Product Overview ▶ | Download Product Sheet ▶

MODEL IMRT-2HN
IMRT Head & Neck Phantom
Product Overview ▶ | Download Product Sheet ▶

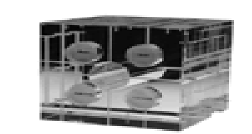


MODEL IMRT-2LFC
IMRT Thorax Phantom
Product Overview ▶ | Download Product Sheet ▶



MODEL IMRT-2PRA
IMRT Pelvic 3D Phantom
Product Overview ▶ | Download Product Sheet ▶

I'mRT PHANTOM
Universal IMRT Phantom
Product Overview ▶ | Download Product Sheet ▶



ISIS QA-1
Geometric QA Phantom
Product Overview ▶ | Download Product Sheet ▶

MODEL DTP-008
Dynamic Thorax 4D QA Phantom
Product Overview ▶ | Download Product Sheet ▶

Very good and useful devices

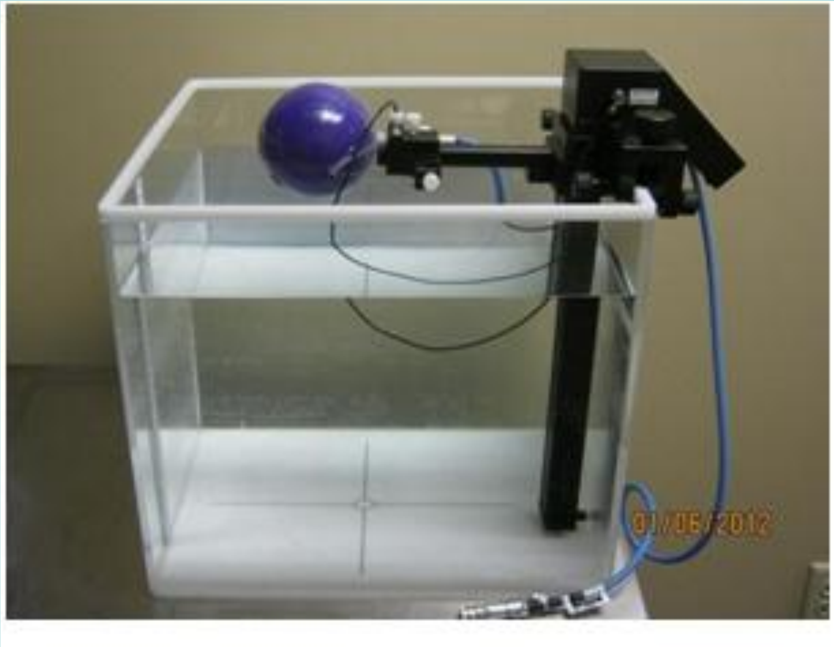
BUT

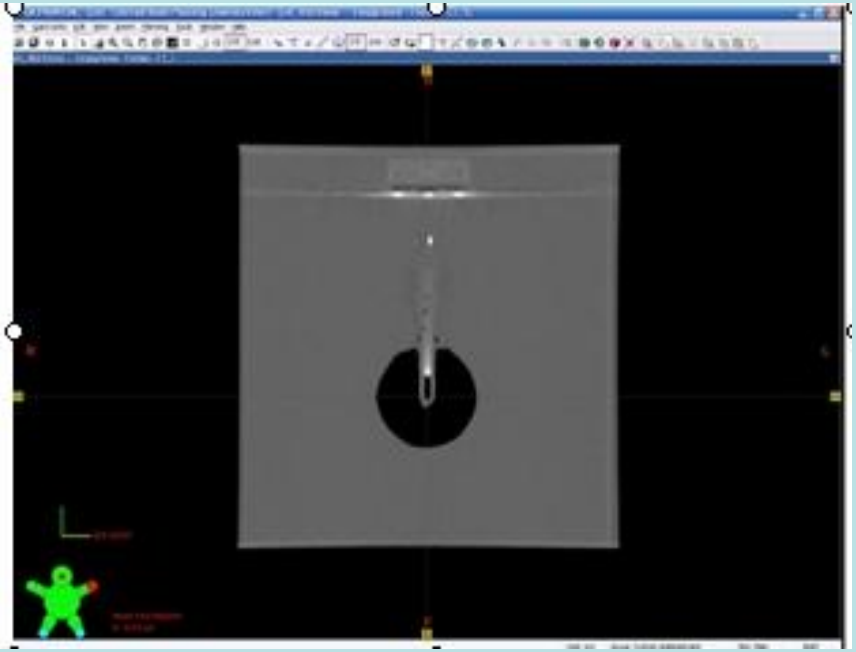
$$$$$$$$

- **What else can we use???**

- ***Nerf® Ball***

Nerf ball





I know the volume and diameter of ***Nerf®*** *Ball*

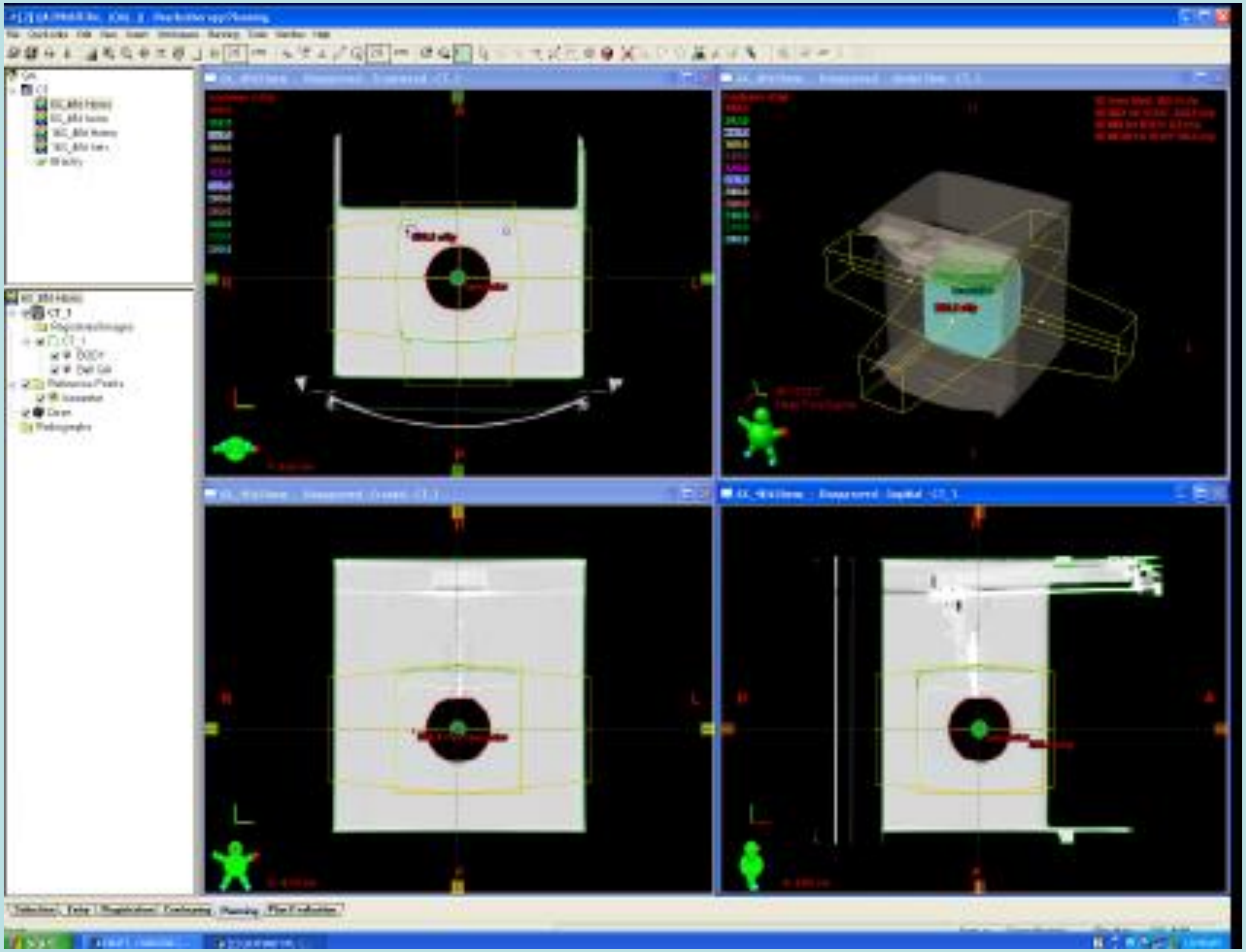
- *Can check measurements against many TP systems*

- *Can check equivalent depth*

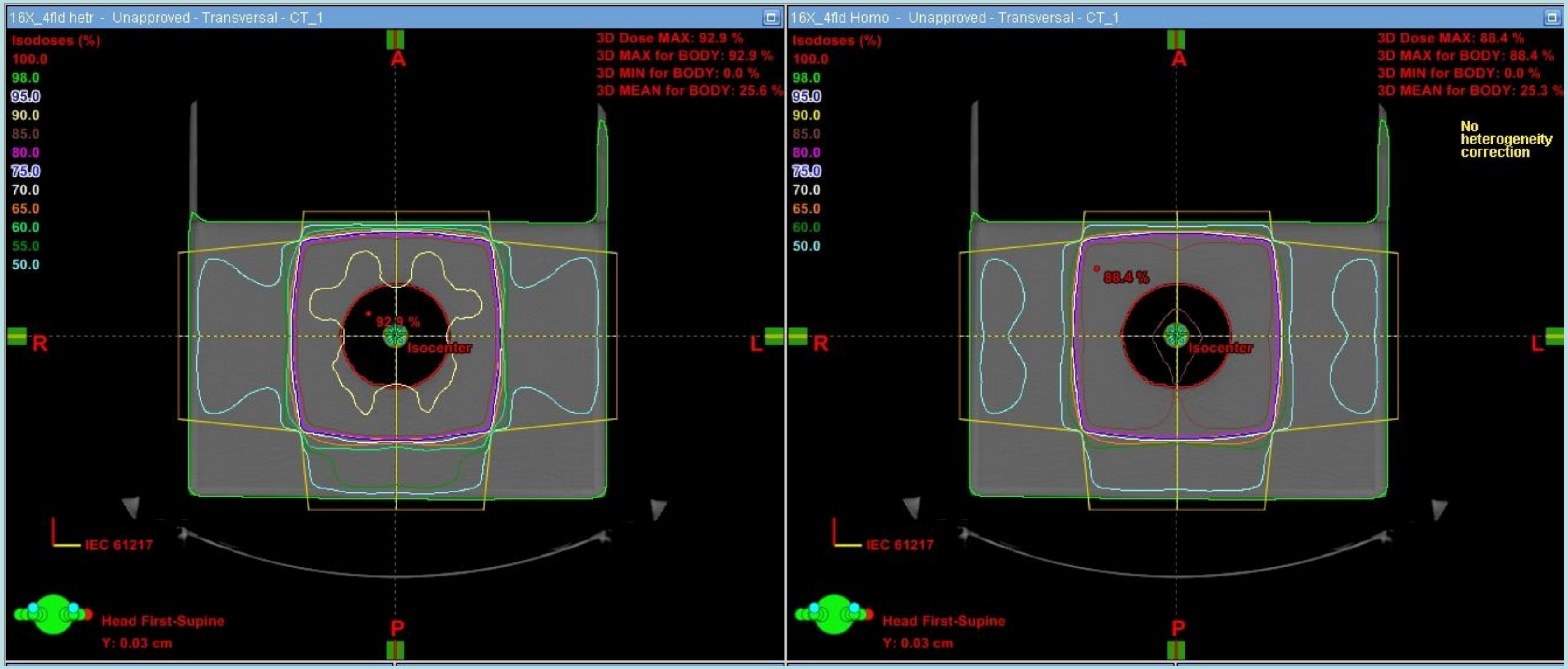
- *Can check dose with and with and without heterogeneity correction*

- *Can check CT numbers*

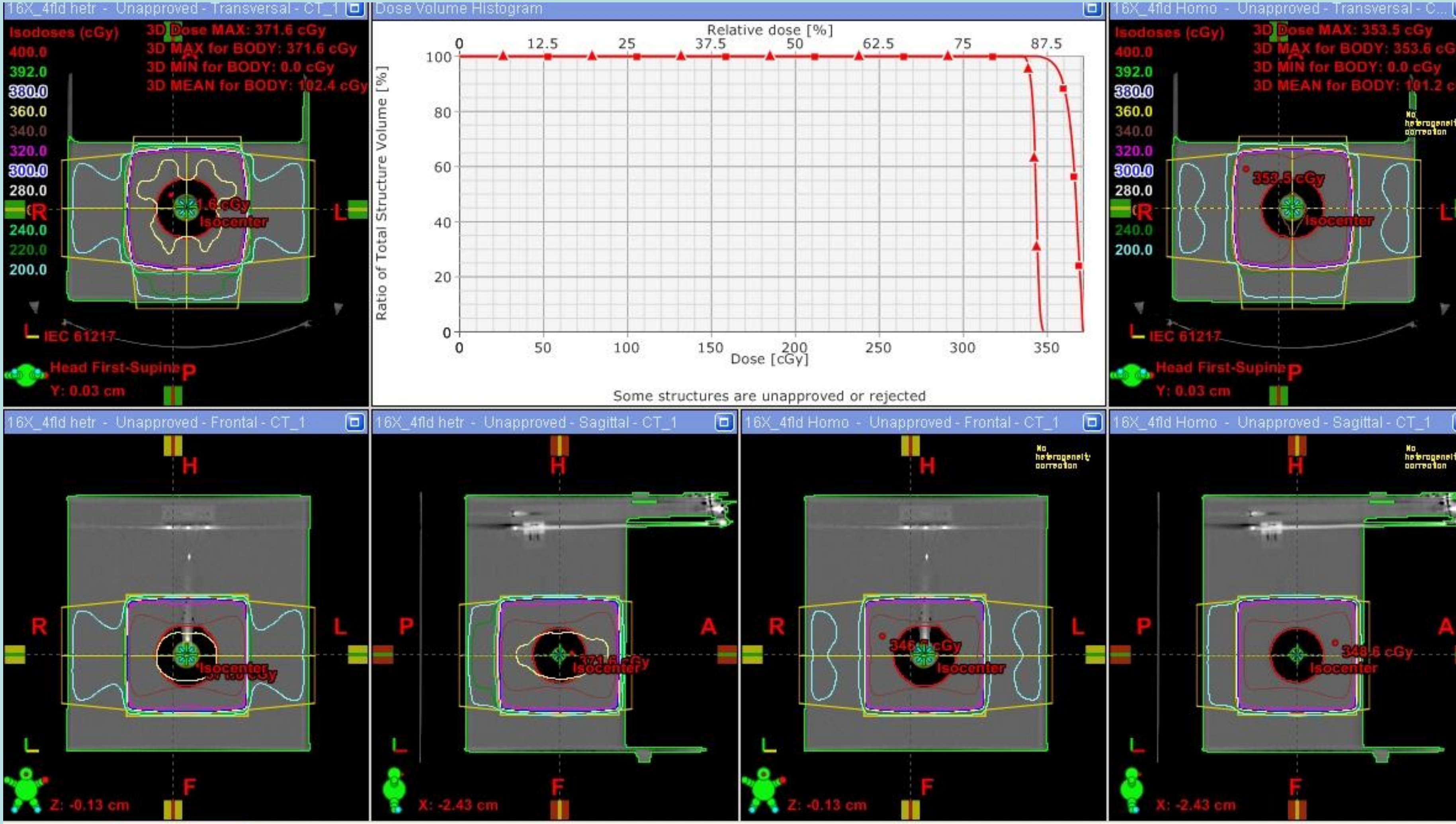
4 fields AP/PA and laterals 100MU each field



Calculating dose with and without Heterogeneity correction



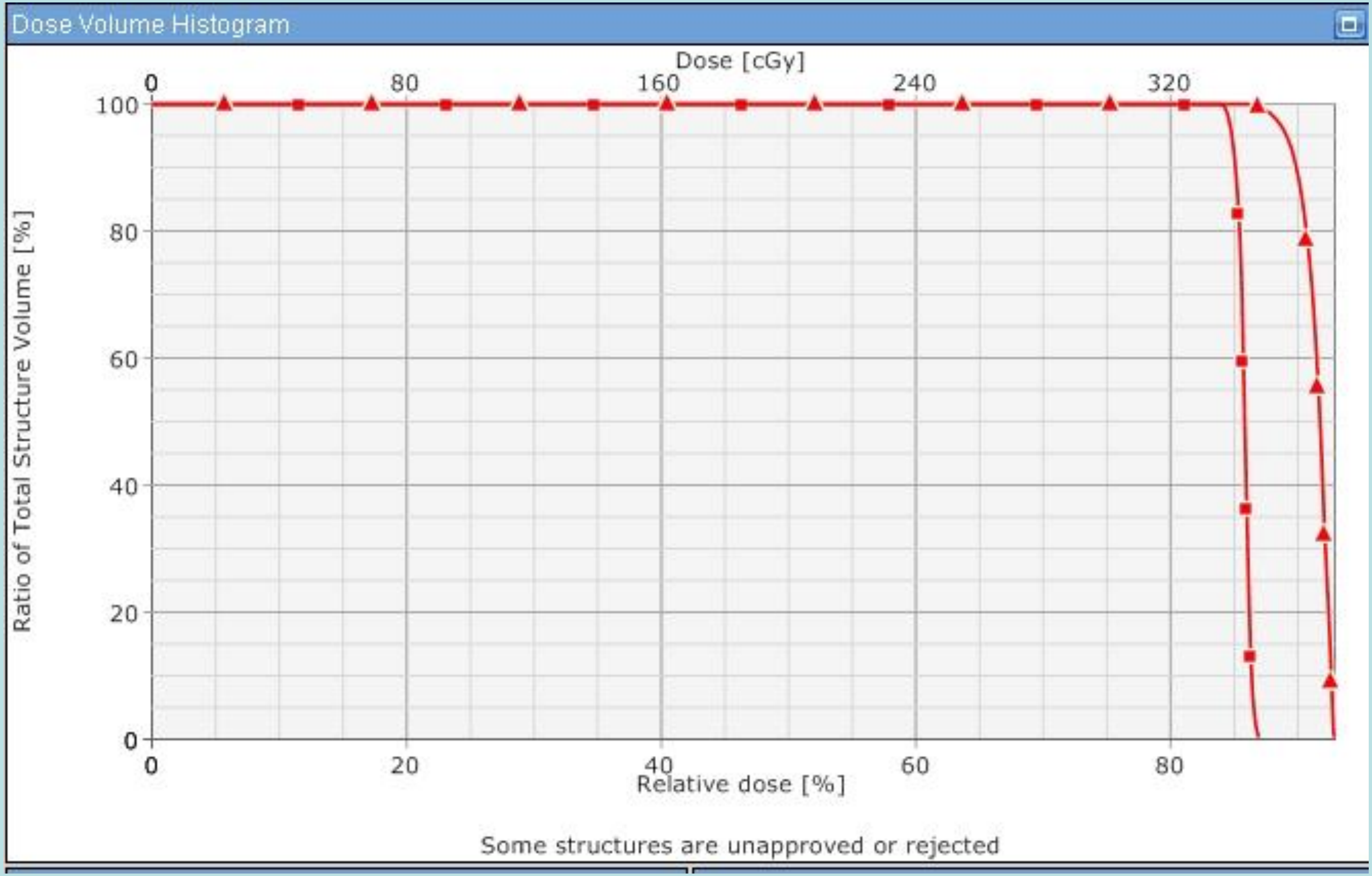
Heterogeneous *Homogenous*



se Prescription | Dose Statistics

Line	Structure	Approval St...	Plan	Course	Volume [cm³]	Dose Cover...	Sampling C...	Min Dose [c...	Max Dose [...	Mean Dose...	Modal Dos...	Median Do...	STD [cGy]
	BODY	Unapproved	16X_4fld hetr	C1									
	Ball QA	Unapproved	16X_4fld hetr	C1	541.1	100.0	100.0	343.2	371.6	365.8	370.7	366.9	4.6
	BODY	Unapproved	16X_4fld Ho...	C1									
	Ball QA	Unapproved	16X_4fld Ho...	C1	541.1	100.0	100.0	335.9	348.4	343.1	342.8	343.3	2.0

DVH for fixed 4 fields x 100 MUs



Dose comparison with and without heterogeneity correction

Nerf ball, 10cm PTW chamber with buildup in the middle.

16X 100 MU

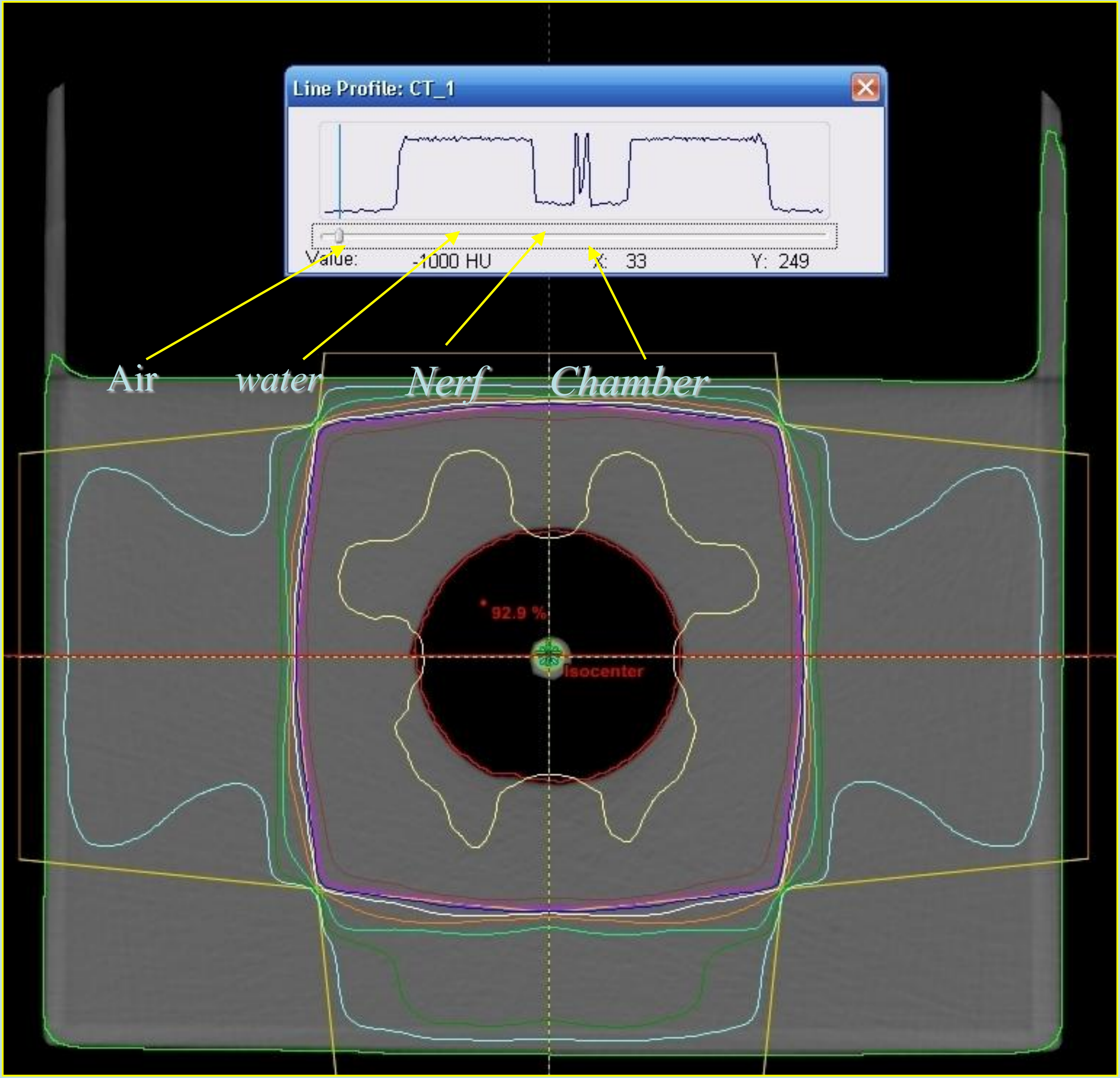
Gantry	**0**	**90**	**180**	**270**		**Dose (cGy)**	**% difference**
Measured	91.72	84.29	105.84	83.99	Total	365.8	1.44
Eclipse	-	-	-	-		371.1	

PTW chamber with buildup in watertank same position as with ball

16X 100 MU

Gantry	**0**	**90**	**180**	**270**		**Dose (cGy)**	**% difference**
Measured	91.61	76.25	94.60	80.88	Total	343.3	-2.37
Eclipse	-	-	-	-		335.2	

CT number profile

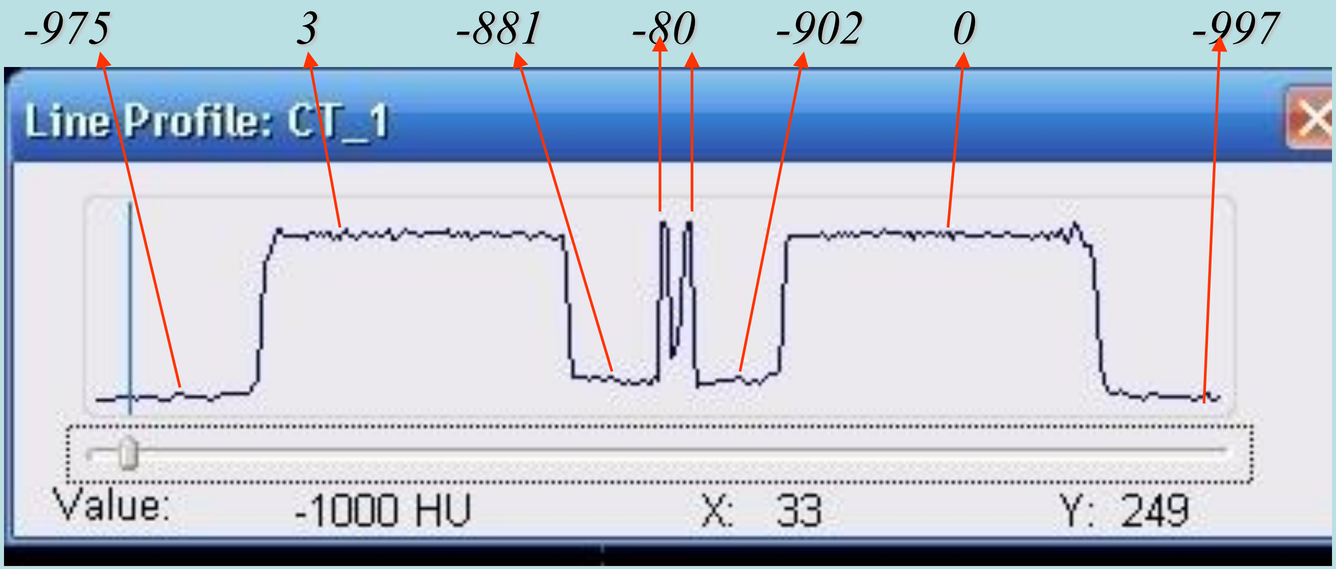


Air: -996

Water: 0

Nerf : -890

CT numbers through phantom



Can add DRR and verify dimensions

Volume measurement / calculation

Need to overwrite density of Nerf ball with air

	physical measurements	GE-AW	Eclipse	Variseed
Volume	555.65	586.3	541.1	545
Diameter	10.2	10.38	10	9.9-10.1
Radius calculated from volume	5.1	5.19	5.06	5.07

Equivalent Depth in Eclipse

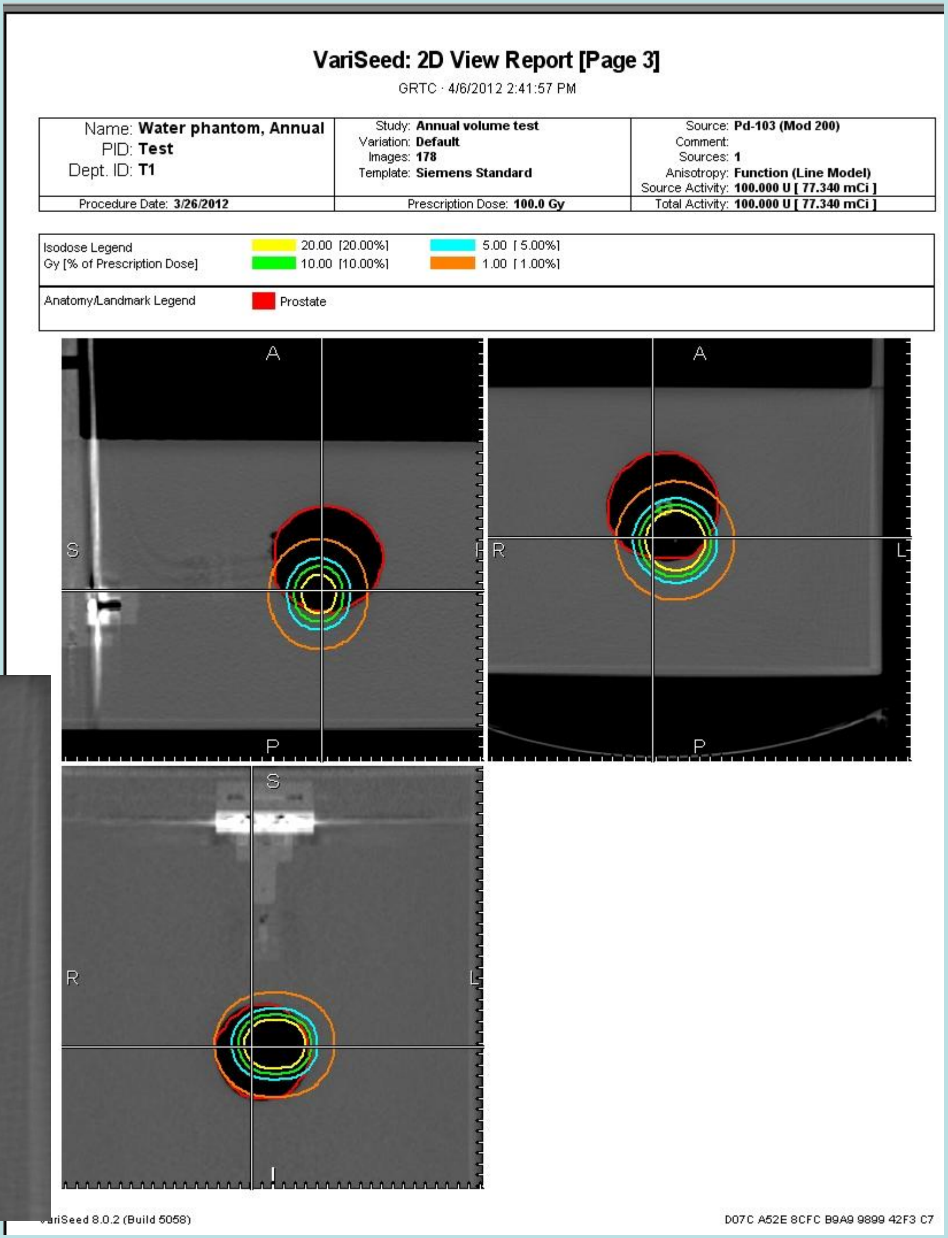
Gantry	depth	deq	diff
180	10.9	5.7	5.2
0	15.5	10.5	5
270	19.7	14.4	5.3
90	20.1	14.8	5.3
	average		5.2

Brachytherapy TPS QA

- Variseed
- Brachyvision

In Variseed

- ***Add 100 U Pd103 source***
- ***Add several Dose points***


VariSeed: 2D View Report [Page 3]

GRTC · 4/6/2012 2:41:57 PM

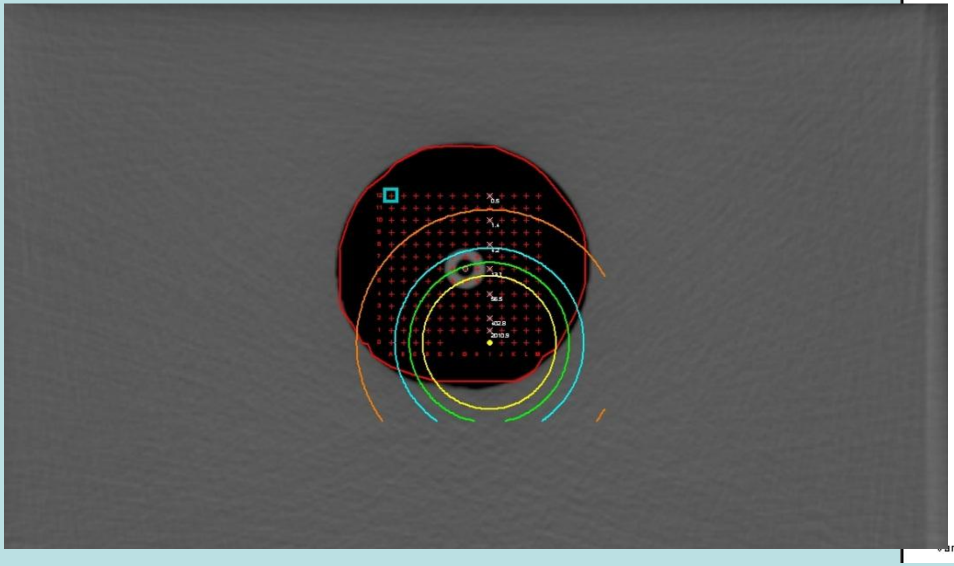
Name: **Water phantom, Annual** PID: **Test** Dept. ID: **T1**	Study: **Annual volume test** Variation: **Default** Images: **178** Template: **Siemens Standard**	Source: **Pd-103 (Mod 200)** Comment: Sources: **1** Anisotropy: **Function (Line Model)** Source Activity: **100.000 U [77.340 mCi]**
Procedure Date: **3/26/2012**	Prescription Dose: **100.0 Gy**	Total Activity: **100.000 U [77.340 mCi]**

Isodose Legend
Gy [% of Prescription Dose]
20.00 [20.00%]
5.00 [5.00%]
10.00 [10.00%]
1.00 [1.00%]

Anatomy/Landmark Legend
Prostate

VariSeed 8.0.2 (Build 5058)

D07C A52E 8CFC B9A9 9899 42F3 C7

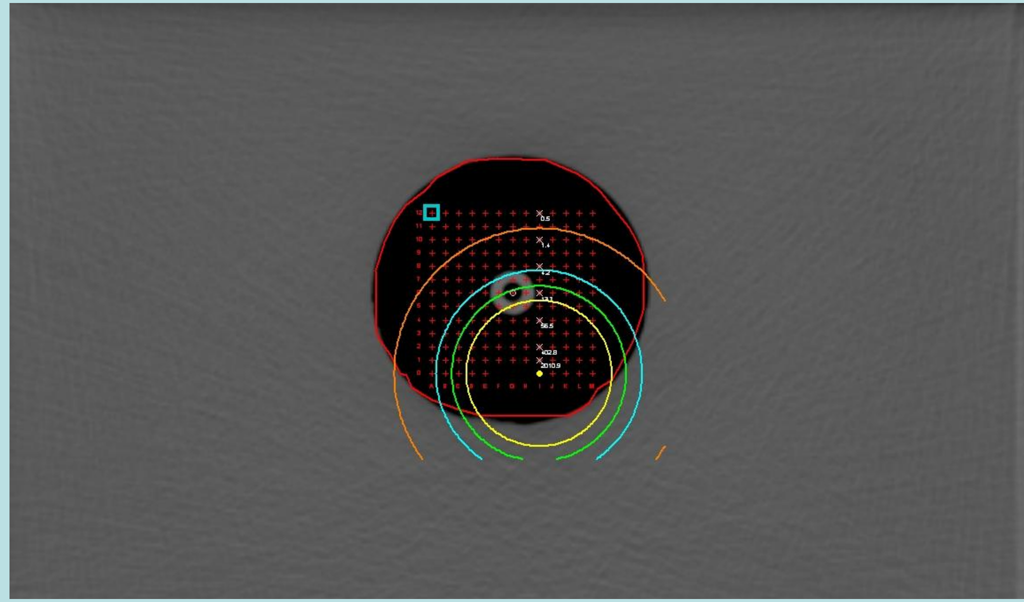


Test 1: Dose Point Calculation Test

Use the Dose Point Calculation Test to verify that your VariSeed system is functioning prope
the dose calculations match expected results. This test uses a dose point to verify dose calcul
tables in this section provide the numbers you need to verify the Pd–103 (Mod 200) source as
with your VariSeed system.

Table 1: Total Dose (Gy) for a 100 U source

Distance (cm)	Dose (Gy) Anisotropy Factors (Point Model)	Dose (Gy) Anisotropy Factors (Line Model)	Dose (Gy) Anisotropy Function
0.50	1769.60	1769.56	2010.87
1.00	344.42	344.42	402.83
1.50	116.58	116.59	135.18
2.00	49.15	49.16	56.51
2.50	23.46	23.46	26.75
3.00	12.11	12.11	13.69
3.50	6.61	6.61	7.43
4.00	3.72	3.72	4.16
4.50	2.27	2.27	2.54
5.00	1.30	1.30	1.45
5.50	0.83	0.81	0.92
6.00	0.50	0.48	0.55
6.50	0.33	0.31	0.36
7.00	0.20	0.19	0.22



VariSeed: Dose Points Report [Page 2]

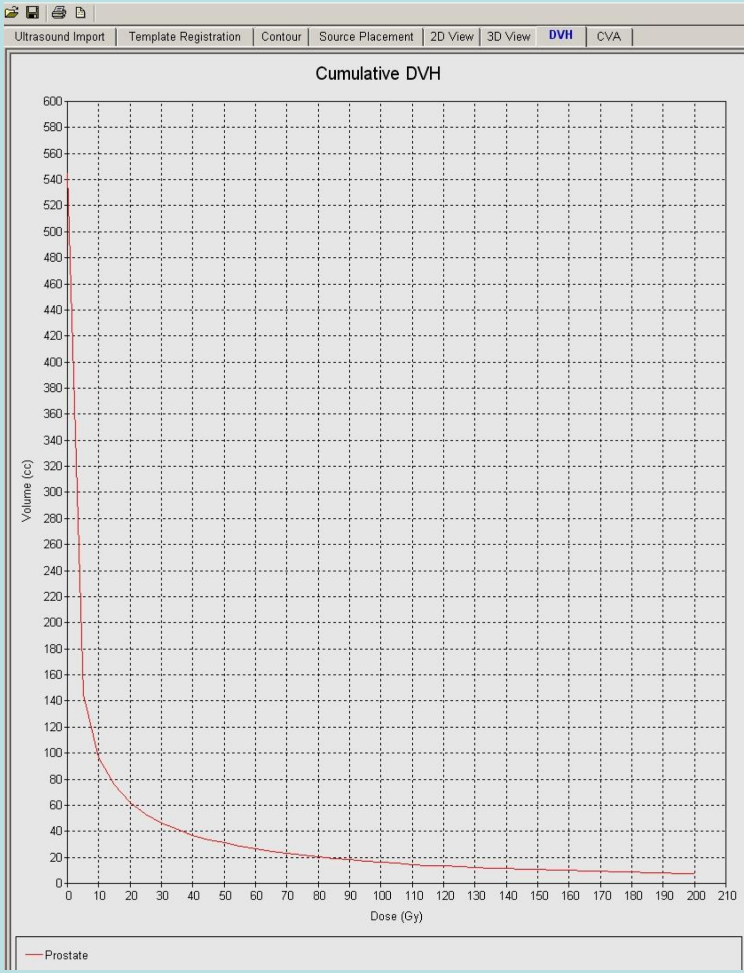
GRTC · 4/6/2012 3:50:40 PM

Name: **Water phantom, Annual** PID: **Test** Dept. ID: **T1**	Study: **Annual volume test** Variation: **new** Images: **178** Template: **Siemens Standard**	Source: **Pd-103 (Mod 200)** Comment: Sources: **1** Anisotropy: **Function (Line Model)** Source Activity: **100.000 U [77.340 mCi]**
Procedure Date: **3/26/2012**	Prescription Dose: **100.0 Gy**	Total Activity: **100.000 U [77.340 mCi]**

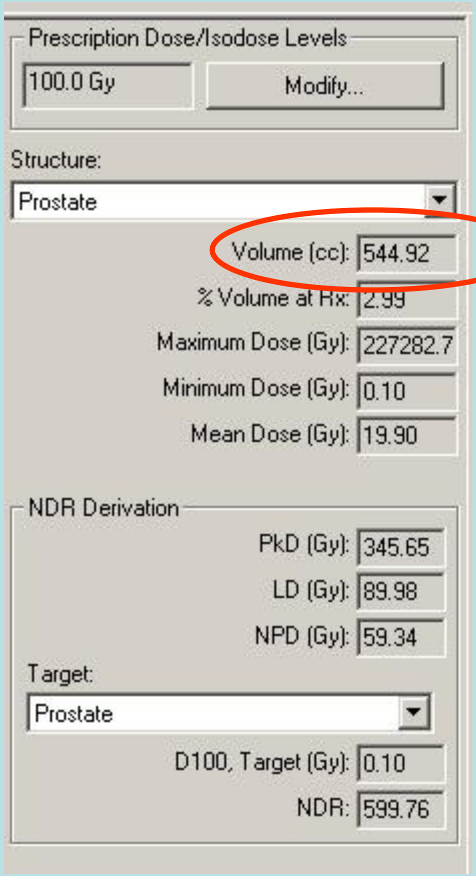
Point Dosage Summary

#	Name	Position X (cm)	Y (cm)	Z (cm)	Dose (Gy)	% of Prescription Dose
1	0.5cm	31.12	31.80	-1.00	2010.87	2010.87
2	1.0cm	31.12	31.30	-1.00	402.83	402.83
3	1.5cm	31.12	30.80	-1.00	135.18	135.18
4	2.0cm	31.12	30.30	-1.00	56.51	56.51
5	2.5cm	31.12	29.80	-1.00	26.75	26.75
6	3.0cm	31.12	29.30	-1.00	13.69	13.69
7	4.0cm	31.12	28.30	-1.00	4.16	4.16
8	5.0cm	31.12	27.30	-1.00	1.45	1.45
9	6.0cm	31.12	26.30	-1.00	0.55	0.55

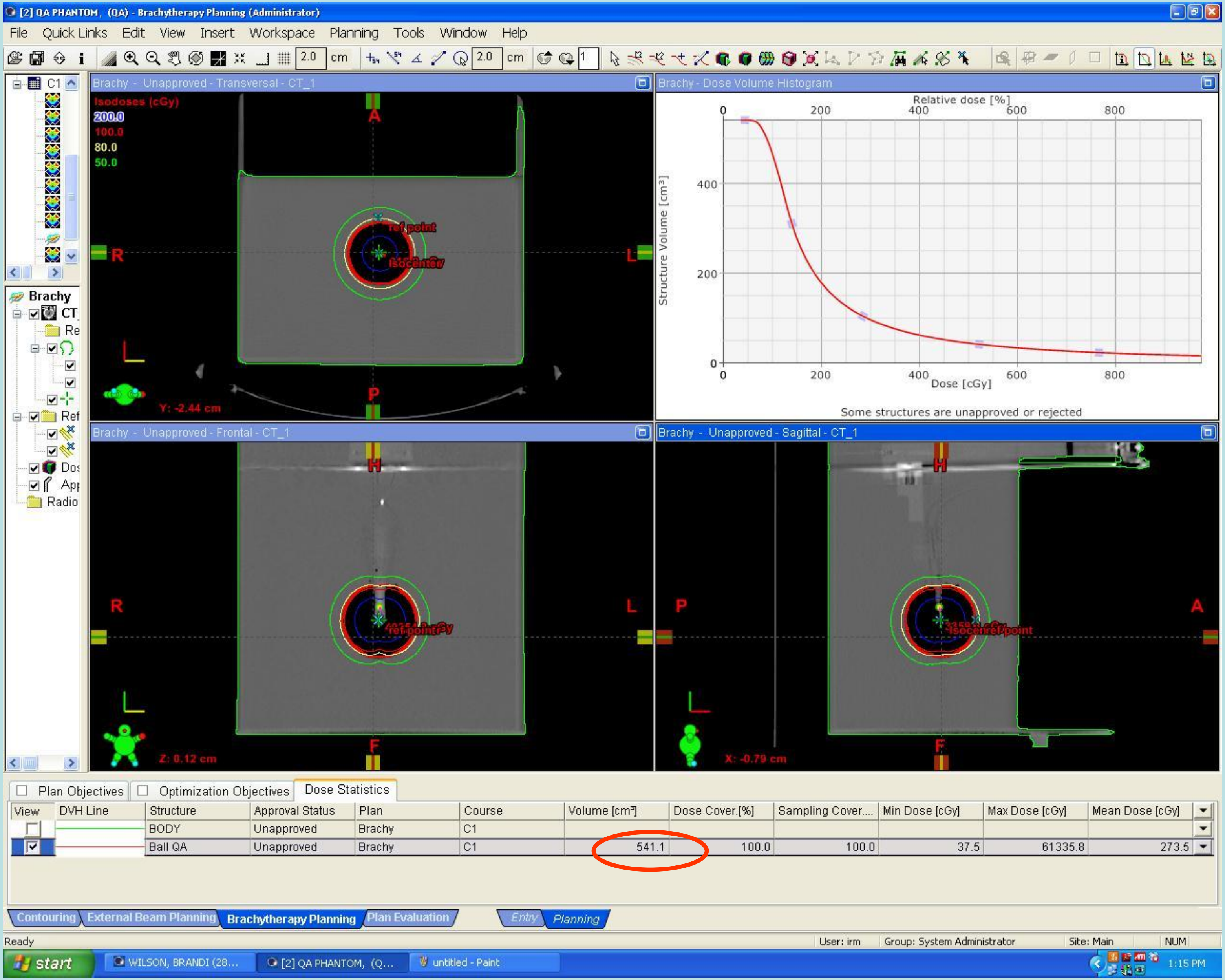
DVH verification



		Prostate			
Dose		Cum. DVH		Diff. DVH	
Gy	%	cc	%	cc	%
0.00	0.00	544.92	100.00	400.19	73.44
5.00	5.00	144.73	26.56	47.94	8.80
10.00	10.00	96.79	17.76	21.53	3.95
15.00	15.00	75.26	13.81	13.43	2.46
20.00	20.00	61.84	11.35	8.81	1.62
25.00	25.00	53.03	9.73	7.02	1.29
30.00	30.00	46.01	8.44	4.74	0.87
35.00	35.00	41.27	7.57	4.27	0.78
40.00	40.00	37.00	6.79	3.35	0.62
45.00	45.00	33.65	6.18	2.62	0.48
50.00	50.00	31.03	5.70	2.39	0.44
55.00	55.00	28.65	5.26	2.39	0.44
60.00	60.00	26.26	4.82	1.87	0.34
65.00	65.00	24.38	4.47	1.55	0.28
70.00	70.00	22.83	4.19	1.28	0.24
75.00	75.00	21.55	3.95	1.13	0.21
80.00	80.00	20.42	3.75	1.11	0.20
85.00	85.00	19.31	3.54	0.95	0.17
90.00	90.00	18.36	3.37	1.19	0.22
95.00	95.00	17.17	3.15	0.89	0.16
100.00	100.00	16.28	2.99	0.94	0.17
105.00	105.00	15.34	2.81	0.71	0.13
110.00	110.00	14.63	2.68	0.67	0.12
115.00	115.00	13.96	2.56	0.62	0.11
120.00	120.00	13.34	2.45	0.44	0.08
125.00	125.00	12.90	2.37	0.53	0.10
130.00	130.00	12.37	2.27	0.48	0.09
135.00	135.00	11.89	2.18	0.36	0.07
140.00	140.00	11.53	2.12	0.40	0.07
145.00	145.00	11.13	2.04	0.34	0.06
150.00	150.00	10.78	1.98	0.35	0.06
155.00	155.00	10.43	1.91	0.41	0.07
160.00	160.00	10.02	1.84	0.36	0.07
165.00	165.00	9.66	1.77	0.33	0.06
170.00	170.00	9.33	1.71	0.35	0.06
175.00	175.00	8.98	1.65	0.42	0.08
180.00	180.00	8.56	1.57	0.23	0.04
185.00	185.00	8.33	1.53	0.28	0.05
190.00	190.00	8.05	1.48	0.35	0.06
195.00	195.00	7.70	1.41	0.24	0.04
200.00	200.00	7.45	1.37	0.13	0.02



Brachyvision



Thank You