TG-119 IMRT Commissioning Tests
Instructions for Planning, Measurement, and Analysis
Version 10/21/2009

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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.

The participants in TG119 performed these tests and analyzed the results in a standardized manner. If other users wish to compare their results to that of the Task Group, then it will be important to create comparable IMRT plans, perform similar measurements, and analyze the data in the same way.

General description of the tests

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 from http://www.aapm.org/pubs/tg119/default.asp. The specific options depend on the capabilities of the planning system. For example, it may be possible to register the center the CT of the local phantom to that of the downloaded phantom, and then transfer the structures to the local phantom for planning. It is preferable to start with structures defined on the local phantom and to directly plan the dose distribution on that phantom, as if it were a patient. Alternatively, one could plan the doses on the downloaded CTs and then do verification plans on the local phantom, as is commonly done for IMRT patient quality assurance measurements.

Each test includes a specification of dose goals for the IMRT planning and the beam arrangement to be used. Each test also specifies the measurements to be taken to test the accuracy of the dose delivery, how they are to be analyzed and what is to be reported.

Plans

The plans should be done with 6 MV in order to compare with TG119, although the tests can certainly be run for other energies if desired. The calculation grid should be 2 mm or finer. The target doses are specified for each plan; the dose per fraction should be 180 – 200 cGy. The plans should be run with the IMRT parameters typical for clinical use. These may include: number of intensity levels, smoothing parameters, minimum field width, minimum MU/segment, priority values, etc.

The TG119 report gives the dose-volume statistics obtained by the group for each plan. The Task Group attempted to control the complexity of the IMRT fields by specifying the plan goals, thus avoiding some groups pushing their IMRT systems harder than others. The aim was to be able to compile statistics about dosimetric accuracy for plans that were of comparable complexity. In order to compare measurement results with TG119's, the plans should have comparable dose volume statistics.

Measurements

Three types of measurements are to be performed: "points" with an ion chamber in phantom for the composite irradiation (i.e. all fields irradiated at the respective gantry angles), planar dose distributions for the composite irradiation with a detector such as film, and planar field-by-field dose distributions with a detector array, EPID, etc.

The phantom should permit point measurements (e.g. ion chamber) and planar dose measurements (e.g. film) to be done on coronal planes. The phantom should consist of slabs of water-equivalent plastic with a total thickness of about 15 – 20 cm, so that a chamber at its center is 7.5 – 10 cm below the anterior surface. It should be possible to have either film or chamber on the measurement plane, so that the film response may be normalized to the chamber measurements. Note that measurements will be made on the central plane and also above or below the central plane for some cases.

The chamber should be that used for IMRT commissioning and QA studies in the department. This typically will be smaller than a Farmer-type chamber, such as a 0.125 cm^3 scanning chamber. The sensitive volume of the chamber should be identified on the phantom study, and the reported dose to the chamber should be the mean dose to its sensitive volume. References herein to "point" doses actually refer to mean doses over the chamber volume.

Conversion of chamber readings to dose will be done by obtaining readings with parallel opposed 10x10 fields irradiating the phantom isocentrically and determining the ratio of reading to predicted dose. (See preliminary test P1 below.) This simple method reduces the effects of daily linac output variations and differences between the phantom and liquid water. Calculations may be done with heterogeneity corrections on or off (preferably on), but should be done consistently for all the tests.

For film measurements in phantom, the film response may be normalized to match that of the ion chamber measurement on the same plane. Either radiographic or radiochromic film may be used. The best available techniques should be used to maximize the precision of the measurement. The uncertainty associated with the measurement of dose at a point should be established before evaluating IMRT dose distributions with film. One way to do that is to use the best available film technique to measure several repetitions of doses that are well established and span the range of interest, e.g. 3 films at 200 cGy, 3 at 100 cGy, 3 at 50 cGy, and 3 at 20 cGy. Preliminary test P2 below also provides five low gradient regions that can be used to test the accuracy of the film

response. The doses in those regions can be confirmed with chamber measurements as part of the process.

For the field-by-field measurements, the technique employed locally should be used: diode array, chamber array, EPID, film, etc. This process typically involves calculating a predicted dose distribution on a plane perpendicular to the beam axis at some specified depth. The corresponding measurement is then made with the chosen detector.

Preliminary tests with a combination of open fields irradiating the phantom will be used to demonstrate the reliability of the assessment system for non-IMRT dose delivery.

Analysis and comparison to TG119 results

In order to compare the local results with that of the task group, it will be necessary to analyze the data as the task group did.

For the point doses, the comparison of measured to planned values will be done with respect to the prescribed dose, not the dose to that point. That is, record the ratio (Measured – Planned)/Prescribed.

Planar dose distributions (both composite, in-phantom and field-by-field) will be analyzed using gamma criteria of 3% dose and 3 mm distance to agreement. The percent of points with gamma ≤ 1.00 will be recorded. The results of a gamma analysis depend heavily on the details of the implementation. In order to compare the local results with that of the task group, it will be necessary to conform to the same implementation parameters as closely as possible.

For analysis of dose on a plane using film, a region of interest should be defined to exclude regions of low dose. How this is done will depend on the tools available in the analysis software. If a threshold dose may be defined, set that to 10% of the maximum dose on the plane. If a rectangular region of interest may be defined, that may be set to correspond to the jaw setting for a vertically oriented field.

Use of a gamma dose criterion of 3% for dose presumes that the uncertainty in the film measurement itself is not too high. If the uncertainty exceeds 2%, then a larger value for the gamma dose criterion should be used.

For the field-by-field analysis, many of the TG119 participants used a particular diode array (MapCHECK; Sun Nuclear Corporation, Melbourne, FL) that provides a number of options for the gamma analysis. This particular set was chosen as the standard for the group: Absolute Dose, 10% Threshold, Van Dyk On, Apply Measurement Uncertainty On, and normalizing to the maximum measurement point. "Absolute Dose" means that the dose distribution is not globally renormalized, so that the dose difference at a point is the (measured – planned) directly. "Van Dyk On" and "normalizing to the maximum measurement point" means that the denominator for the percent calculation is the value of the maximum measurement point, not the dose at the local point. The Task Group

does not endorse this particular dosimetry device. Users of other equipment should understand how the Task Group values were obtained in order to better compare with their own results.

TG119 used the concept of a "confidence limit" to describe how closely the set of measurements agreed with the planned values. For the point doses, where perfect agreement produces a difference ratio of 0.00, the confidence limit is defined as CL = |mean| + 1.96 σ, where the mean is the mean value for the set of measurements and σ is the standard deviation. 95% of a large number of such measurements should fall within the confidence limit. For the gamma analyses, where perfect agreement produces a passing rate of 100%, the confidence limit is defined as CL = (100-mean) + 1.96 σ, where mean is the mean percentage of points passing the gamma criteria and σ is the standard deviation. For a large number of gamma analyses, 95% of the tests should result in pass rates that exceed (100 - CL)%.

As an example, to determine the confidence limit for the point doses (i.e. ion chamber results) in the high dose regions, determine the fractional deviation for each measurement: (measured – planned)/prescribed [where "prescribed" would be 180 – 200 cGy per fraction]. There would be five such measurements in this test suite: MultiTarget isocenter, Prostate isocenter, HN isocenter, CShape (easy) anterior, CShape (hard) anterior. Find the mean and standard deviation of the five fractional deviation, and then find the confidence limit: CL = |mean| + 1.96 σ. Example data analysis sheets are shown following test descriptions.

TG119 recommends that a facility do this set of tests, determine the local confidence limits, and compare to the limits obtained by the TG119 group. If the local confidence limits exceed those from TG119, then that might be an indication that the IMRT modeling needs to be improved. However, that conclusion presumes that the analysis has been performed in a comparable manner and that the number of tests is sufficient to warrant a statistical judgment. Repetition of these tests is suggested in order to enlarge the sample size.

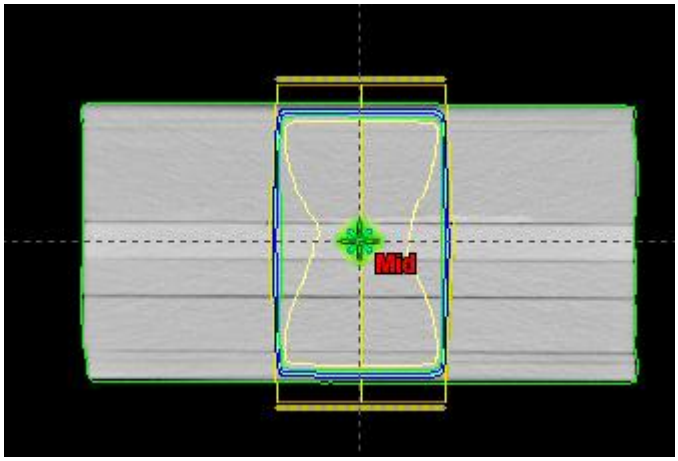
Preliminary tests

P1: AP:PA

Using 6 MV, calculate a simple parallel-opposed irradiation of the phantom using AP:PA 10x10 fields to a dose of 200 cGy at isocenter. Obtain readings at isocenter with the chamber. Measure the dose distribution on the central plane with film. Measure also the dose from the AP field with the technique to be used for field-by-field IMRT measurements.

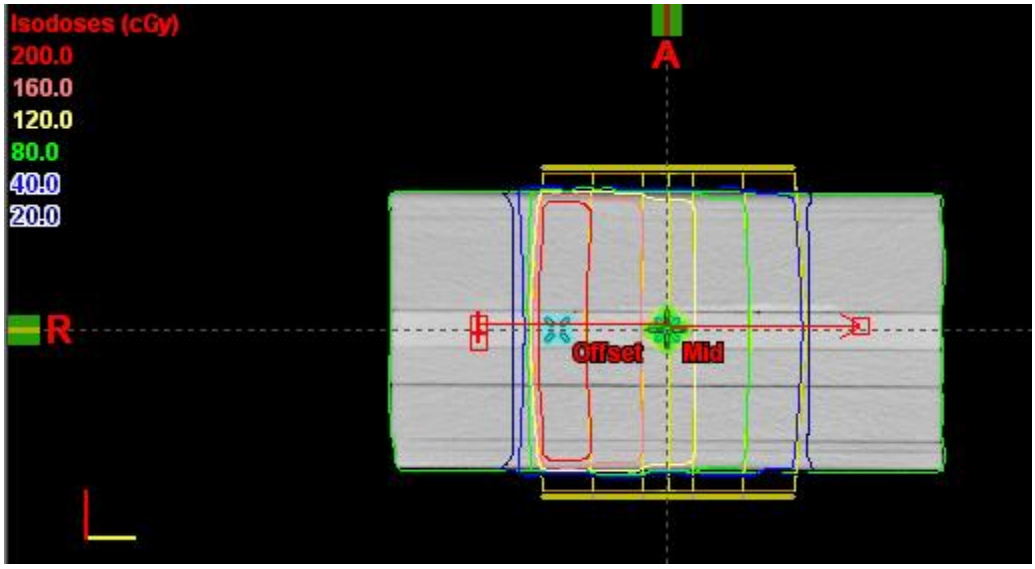
This geometry will be used to set the dose/chamber reading ratio for subsequent tests, so there is no agreement with predicted dose.

Determine the fraction of points passing the gamma criteria for the central film irradiated AP:PA and for the single AP field.

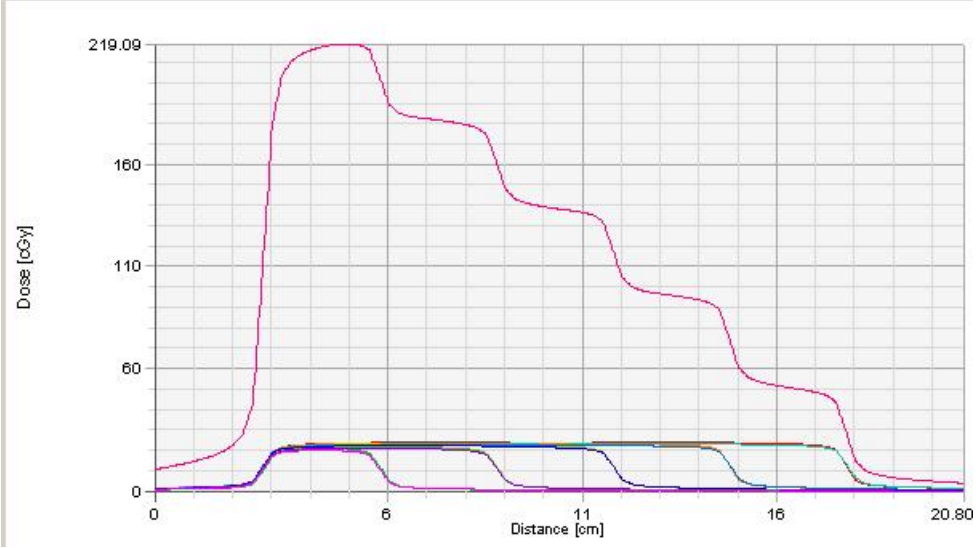


P2: Bands

Using 6 MV, 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

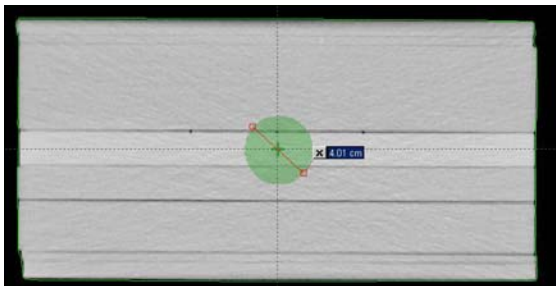


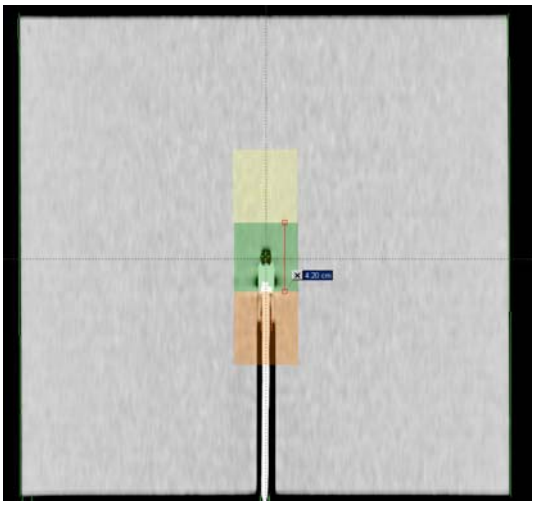
Measure the central dose with chamber and the dose distribution on the central plane with film. Measure also the dose from the AP field with the technique to be used for field-by-field IMRT measurements.

Determine the agreement between calculated dose to the chamber and the measurement. Determine the fraction of points passing the gamma criteria for the central film irradiated AP:PA. Determine the fraction of points passing the gamma criteria for the set of AP fields irradiating the device used for field-by-field IMRT measurements.

Commissioning tests

C1: MultiTarget
Structures
Three cylindrical targets are stacked along the axis of rotation. Each has a diameter of approximately 4 cm and length of 4 cm.





Dose goals

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

Beam arrangement
6 MV, 7 fields at 50^{o} intervals from the vertical

Chamber measurement points
High dose: Isocenter
Lower doses: 4 cm superior, 4 cm inferior

Planar film measurement
Mid phantom at isocenter

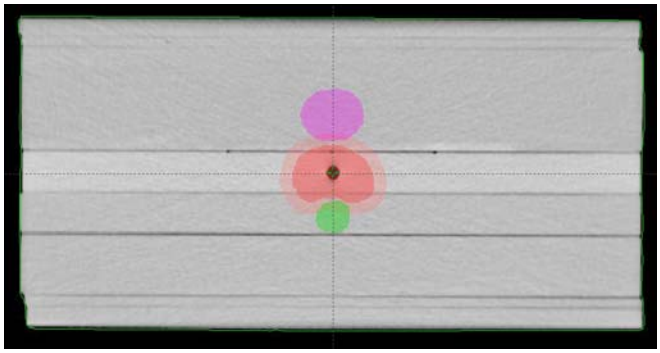
C2: Mock Prostate

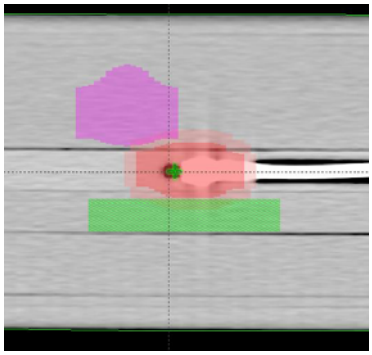
Structures

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 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.





Dose goals

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

Beam arrangement

6 MV, 7 fields at 50^{o} intervals from the vertical

Chamber measurement points

High dose: Isocenter

Lower dose: 2.5 cm posterior to isocenter

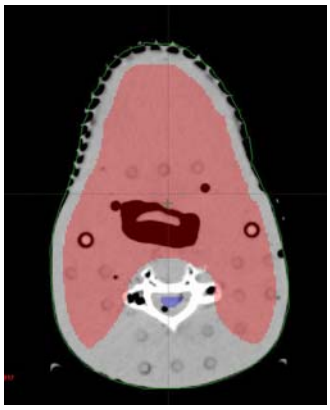
Planar film measurement

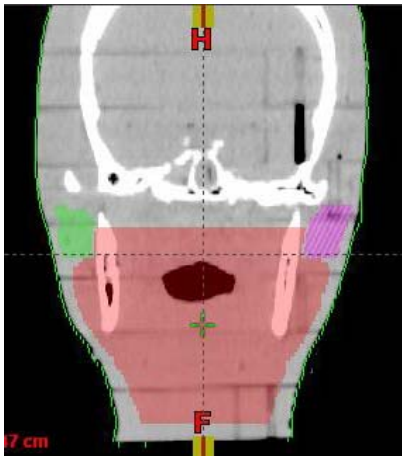
Mid phantom at isocenter

2.5 cm posterior to isocenter

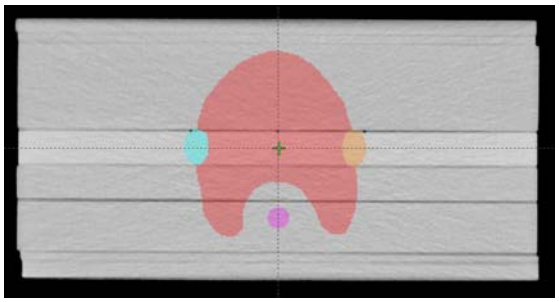
C3: Mock Head/Neck

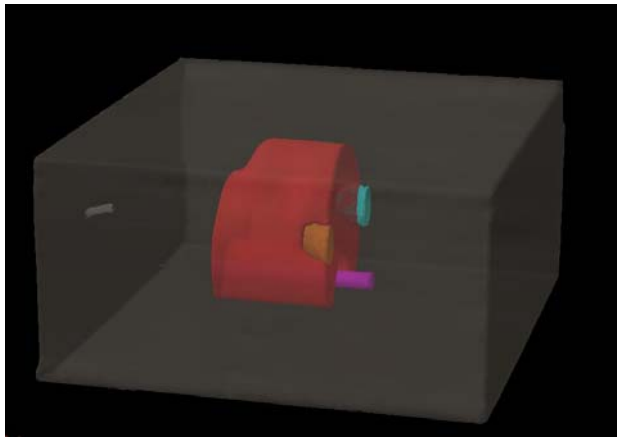
Structures
The HN PTV includes all anterior volume from the base of the skull to the upper neck, including the posterior neck nodes. The PTV is retracted from the skin by 0.6 cm. There is a gap of about 1.5 cm between the cord and the PTV.





Here a similar structure set is shown as recreated on a block phantom.





Dose goals

Structure		
HN PTV	90% of volume to receive at least 5000 cGy	99% of volume to receive at least 4650 cGy
	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	

Beam arrangement
6 MV, 9 fields at 40^{o} intervals from the vertical

Chamber measurement points
High dose: Isocenter
Lower dose: 4 cm posterior to isocenter

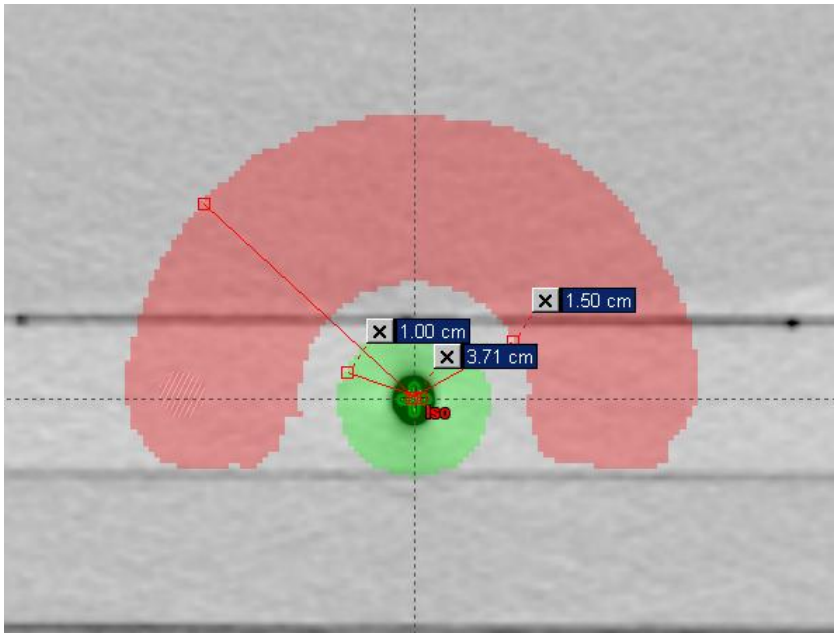
Planar film measurements
Mid phantom at isocenter, includes parotids
4 cm posterior to isocenter

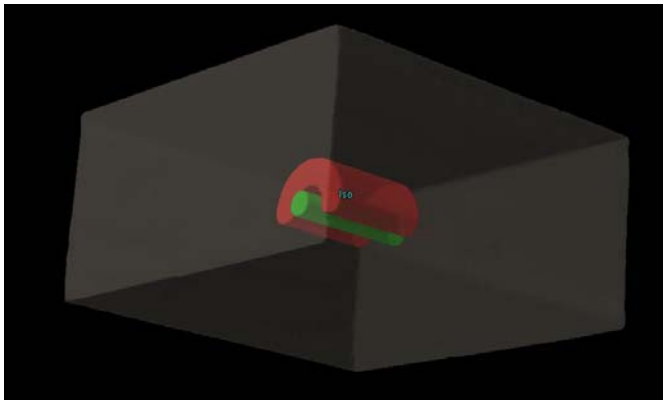
C4: C-Shape

Structures

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 10c m long.

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.





Dose goals (easier version)

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	

Beam arrangement
6 MV, 9 fields at 40^{o} intervals from the vertical

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Dose goals (harder version)

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 1000 cGy	

Beam arrangement
6 MV, 9 fields at 40^{o} intervals from the vertical

Chamber measurement points
Lower dose: isocenter
Higher dose: 2.5 cm anterior to isocenter

Planar film measurements
Mid phantom at isocenter
2.5 cm anterior to isocenter

Example data forms for confidence level calculations

Preliminary tests: the preliminary tests P1 and P2 are designed to help evaluate the accuracy of the planning and dosimetry systems before introducing IMRT uncertainties

Chamber measurements

test	prescribed dose/frac (at isocenter)	location	measured dose	planned dose	(meas-plan)/presc
P2		isocenter			
		1st band right			
		2nd band right			
		1st band left			
		2nd band left			

Film measurements in phantom

test	plane	% gamma pass
P1	isocenter	
P2	isocenter	

Field-by-Field % Gamma pass

Field	P1	P2
1		

IMRT test cases

Chamber measurements

test	prescribed dose/frac	location	measured dose	planned dose	high dose region (meas-plan)/presc	low dose region (meas-plan)/presc
MultiTarget		isocenter				
		4 cm superior				
		4 cm inferior				
Prostate		isocenter				
		2.5 cm posterior				
Head/Neck		isocenter				
		4.0 cm posterior				
CShape (easy)		isocenter				
		2.5 cm anterior				
CShape (hard)		isocenter				
		2.5 cm anterior				
		mean				
		standard deviation				
		confidence limit = |mean| + 1.96 σ				

Film measurements in phantom

test	plane	% gamma pass
MultiTarget	isocenter	
Prostate	isocenter	
	2.5 cm posterior	
Head/Neck	isocenter	
	4.0 cm posterior	
CShape (easy)	isocenter	
	2.5 cm anterior	
CShape (hard)	isocenter	
	2.5 cm anterior	
mean		
standard deviation		
confidence limit = (100 - mean) + 1.96 σ		

Field-by-Field % Gamma pass

Field	MultiTarget	Prostate	Head/Neck	CShape (easy)	CShape (hard)
1					
2					
3					
4					
5					
6					
7					
8					
9					
mean					
overall mean					
standard deviation					
confidence limit = (100 - mean) + 1.96 σ					