TG-128: Quality Assurance for Prostate Brachytherapy Ultrasound *-plus TG-154 on US-guided EBRT*

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Educational Objectives

- To briefly review the recent publication of "TG-154: Quality assurance of U.S.-guided external beam radiotherapy for prostate cancer."
- To describe the methods of "TG-128: Quality assurance tests for prostate brachytherapy ultrasound systems."
- To highlight special techniques which may be used to accomplish the tests described in TG-128.
- To assess the relative likelihoods and significance of potential QA findings.
- To review the materials and time needed to complete the TG-128 tests.

Outline

- TG-154 (US-guided EBRT for Prostate) review
- TG-128 (QA Tests for Prostate Brachytherapy US)
  - Ultrasound physics
  - Equipment
  - QA tests
  - Tolerances
  - Time estimates
  - Materials

TG-154 US-guided EBRT for Prostate

Quality assurance of U.S.-guided external beam radiotherapy for prostate cancer: Report of AAPM Task Group 154

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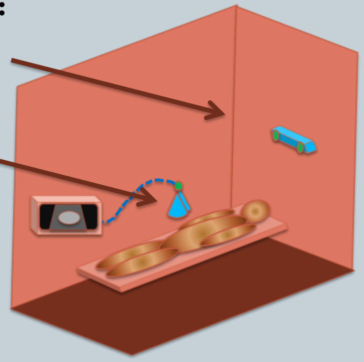
Schematic of US-guided EBRT

System Components:

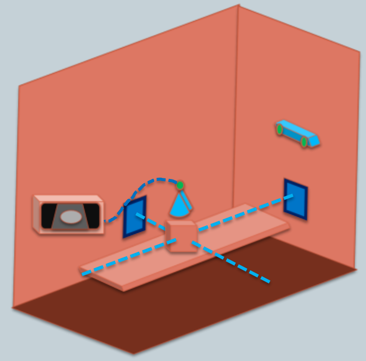
- In-room registration cameras.
- External US-probe with fiducials.
- Image analysis and repositioning hardware and software (not shown).
- Linear accelerator (not shown).



Schematic of US-guided EBRT

QA Components:

- Room lasers.
- In-room registration cameras.
- External US-probe with fiducials.
- Phantom.
- Image analysis and repositioning hardware and software.



QA tests, tolerances and frequencies for U.S. guided RT.

QA Test	Tolerance	Frequency
Laser alignment (Room lasers)	1 mm	Daily
Daily positioning constancy	2 mm	Daily
Depth and gain controls (US)	Functional	Daily
IR Camera warm up (Camera)	Manu. Spec.	Daily
Phantom stability (CT scan)	<1 mm	Quarterly
Monthly positioning constancy	2 mm	Monthly
Phantom offset test (Software)	2 mm	Monthly
Laser offset (in Sim)	2 mm	Monthly
Image quality constancy (US)	See Table	Semiannually
End-to-end testing	2 mm	Annually*

Decline in Use of US-Guidance for EBRT

- "The introduction into the market of alternative image-guided localization strategies such as implanted fiducial markers, kV planar imaging, and cone-beam CT (CBCT) have reduced the use of U.S. imaging for this purpose."
- "U.S. images can be difficult to interpret, particularly for the untrained user, and concerns about tissue deformation have been raised by the user community."

Accuracy of US-guidance versus Implanted Seeds

- "[Early] studies established the accuracy of [**U.S. localization systems**] to be **within 5 mm** as compared to CT localization."
- "The accuracy of **seed alignment techniques** has been estimated to be on the order of **1–2 mm**. Intrafraction motion, anatomical deformation, seed migration, and limitations in the reference image precision e.g., 2.5 mm DRR resolution in the craniocaudal dimension also contribute to potential inaccuracies in gold seed alignment."

TG-128 Report

AAPM Task Group 128: Quality assurance tests for prostate brachytherapy ultrasound systems

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US equipment

- Probe

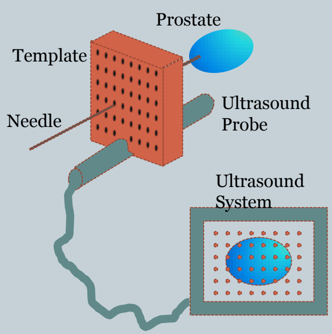
US equipment

- System

Prostate Brachytherapy US QA

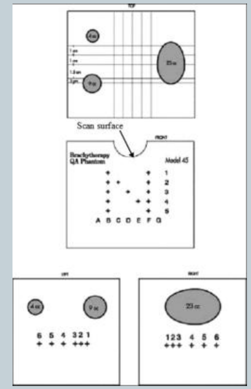
Complete QA will include:

- Ultrasound unit
- Needle template
- Treatment planning system
- Fluoroscope
- CT for post implant

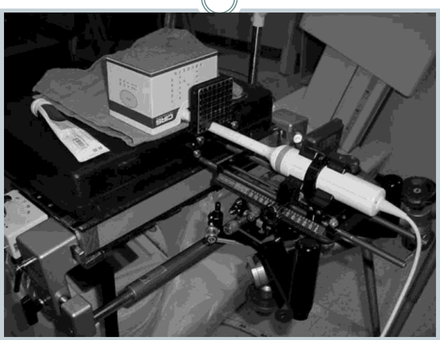


The Phantom

- CIRS Model 45 phantom.
  - Used here for illustrative purposes only; no endorsement is implied.
  - Wires spaced at known intervals.
  - Volumetric objects.
- TG128 report recommends a phantom design, but no manufacturer has implemented it yet.



Setup for Phantom Measurements



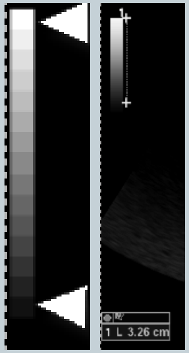
Clinical perspective, but coupling gel can leak out

Setup for Phantom Measurements

Coupling gel stays in place, but image can be confusing

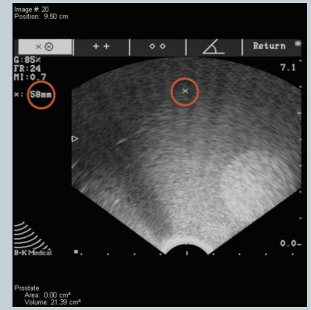
Test 1: Grayscale visibility

- Locate the gray scale strip on the side of the ultrasound screen.
- Depending on the type of strip, count the number of gray levels or measure the length of the gradation.



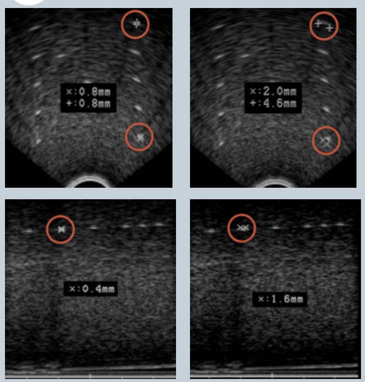
Test 2: Depth of penetration

- Find a relatively homogeneous region in the phantom.
- Using the digital calipers, determine the maximum depth that the static ultrasound speckle pattern of the phantom can be clearly distinguished from the dynamic electronic noise.



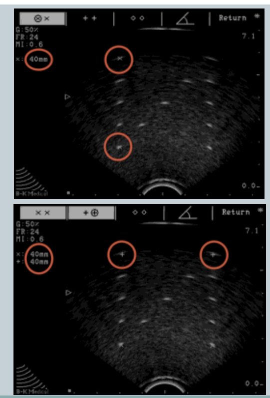
Test 3: Spatial resolution

- Find a region of the phantom having single filament targets at various depths.
- Measure the dimensions of the filament image in both the axial and lateral directions.
  - These dimensions are effectively the axial and lateral resolution limits.
- Switch the probe to the orthogonal direction and repeat.



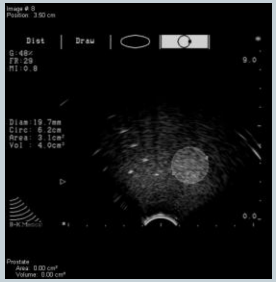
Test 4: Distance measurement accuracy

- *Axial measurement:*
  - Align a column of fiber targets near to the center of the image, if possible. Freeze the image.
  - Using the electronic calipers, measure the distance between the most proximal and the most distal targets.
- *Lateral measurement:*
  - Repeat using a row of targets, measuring most lateral targets.



Test 5: Area measurement accuracy

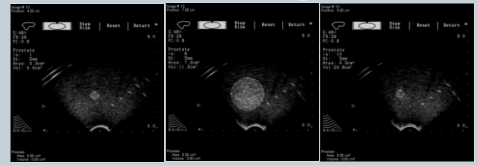
- Scan an object of known dimension such that the ultrasound beam intercepts it normally.
- Using the appropriate tool on the ultrasound system, carefully trace the boundary of the object and record the calculated area of the object.



Measured area = 3.1

Nominal area = 3.05

Test 6: Volume measurement accuracy



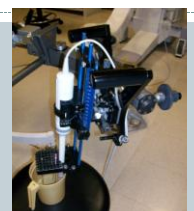
Measured volume: 20.8 cc

Certified volume: 20.6 cc

- Locate the "base" and "apex" of the phantom target; zero the stepper at the base.
- Using the typical clinical procedure, perform a volume study.
- After contouring the entire target, record the calculated volume.

Test 7: Needle template alignment

- Place the probe with the needle template attached vertically in the water bath.
- Place needles at each corner of the needle template and one at the center.
- On the US system, verify that needle flashes in the image correspond to locations of needles on electronic grid overlay.



Test 8: TPS volume accuracy

- Perform a volume study of 3D target in the US phantom.
- Import ultrasound images into treatment planning computer
- Retrace contours in treatment planning software.
- Compare TPS volume to volume calculated by US system.

Variseed volume: 21.4 cc (3.9%)

US Measured volume: 20.8 cc

Certified volume: 20.6 cc

Tolerances

Test #	Test name	Tolerance
1	Grayscale visibility	Δ > 2 steps or 10% from baseline
2	Depth of penetration	Δ > 1 cm from baseline
3	Axial and lateral resolution	Δ > 1 cm from baseline
4	Axial and lateral distance accuracy	Error > 2 mm or 2%
5	Area measurement accuracy	Error > 3 mm or 3%
6	Volume measurement accuracy	Error > 5%
7	Needle template alignment	Error > 3 mm
8	TP computer volume accuracy	Error > 5%

Time Estimates (Annual*)

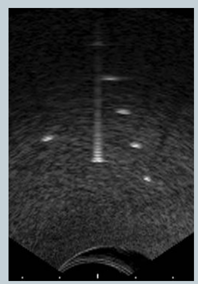
Test #	Test name	Duration
0	Gather and filling in preliminary information	10 minutes
1	Grayscale visibility	2 minutes
2	Depth of penetration	2 minutes
3	Axial and lateral resolution	1-5 minutes
4	Axial and lateral distance measurement accuracy	5 minutes
5	Area measurement accuracy	5 minutes
6	Volume measurement accuracy	10 minutes
7	Needle template alignment	15 minutes
8	Treatment planning computer volume accuracy	15 minutes
	Total:	**70 minutes**

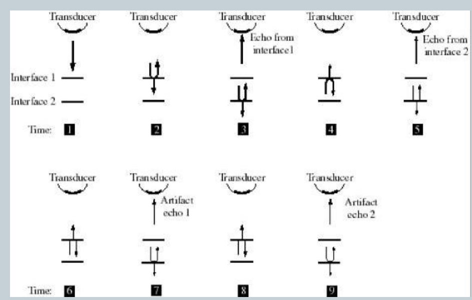
Materials

#	Test name	Equipment
1	Grayscale visibility	Phantom
2	Depth of penetration	Phantom
3	Axial and lateral resolution	Phantom
4	Axial and lateral distance measurement accuracy	Phantom
5	Area measurement accuracy	Phantom
6	Volume measurement accuracy	Phantom
7	Needle template alignment	Water bath
8	TP computer volume accuracy	TPS, Phantom

Ring-down artifact

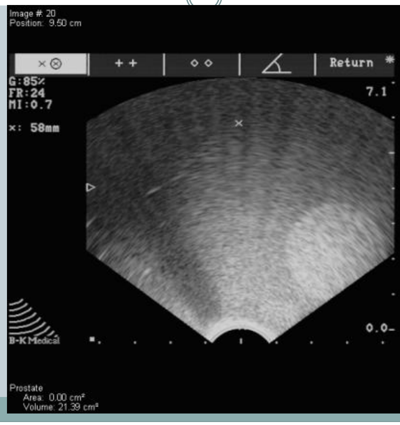
- The signal is reflected multiple times within the needle.





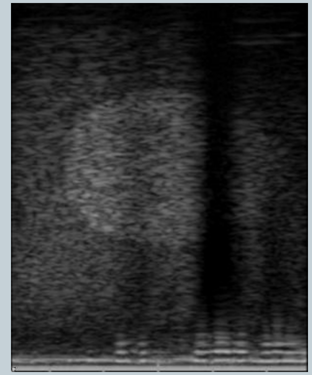
Electronic artifact

Moisture in probe connection



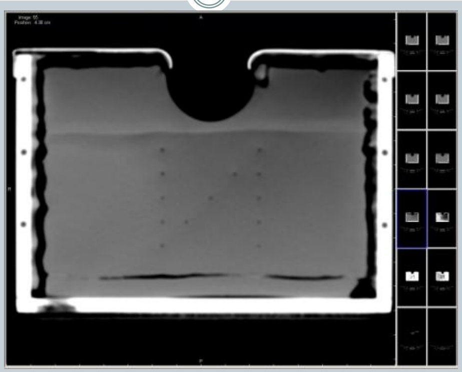
Contact artifact

Poor contact between probe and object



Aging of Phantom

Desiccation of phantom due to age.



Concluding Remarks

- Each of the tests rely on establishing a set of baseline measurements against which future measurements can be compared.
- The overall time commitment is manageable: the full set of measurements should be performed annually and will take about 90 minutes.