Quality Assurance of Ultrasound-Guided Radiotherapy: TG 154

Janelle A. Molloy, Chair, University of Kentucky
Gordon Chan, Odette Cancer Centre
Alexander Markovic, Evanston Northwestern Health Care
Shawn McNeeley, Princeton Radiology
Doug Pfeiffer, Boulder Community Hospital, Boulder, CO
Bill Salter, University of Utah, Salt Lake City, UT
Wolfgang Tome, University of Wisconsin, Madison, WI

Available technology

- BAT (B-mode acquisition and targeting system)
  - Articulating arm technology (original)
  - Optical marker tracking
- Sonarray (Varian Medical Systems)
  - Optical marker tracking
- Clarity (Resonant Medical)
  - Optical marker tracking
- I-Beam (CMS)
  - Transducer-mounted camera, backlit calibration plate

Technologies

Process considerations

- Patient selection
  - Body habitus
    - Very large patients *may* not image well (but they might)
    - Very thin patients may not image well
    - Unfavorable relative locations of targets and obstructions
    - Unfavorable tissue acoustics (very dense tissues)
  - Prescreen patients for suitability
  - Inability to maintain moderately full bladder

Process considerations

- CT simulation and target delineation
  - Structures must be contoured for dosimetric treatment planning and (separately?) for alignment
  - Asymmetric planning target volumes could lead to confusion during US alignment
  - Consider that US alignment may emphasize boundaries. Contrast and attention to sagittal views is important for sup/inf alignment
  - Acquire CT scans with as small a slice spacing as practical

Process considerations

- Treatment planning
  - Yields beam arrangements and isodose configurations
  - If isodose contours used for patient alignment need to remain mindful of possible deliberate asymmetries
- Patient positioning and treatment
  - Need departmental policies regarding management of unacceptable images (bladder refilling, alternative imaging modalities (MV, kV imaging)
  - Need departmental policies regarding minimum and maximum shifts.

Intra v. Inter modality alignment

- Soft tissues appearance is imaging modality dependent
- Residual spatial errors may be resolved/reduced via intra-modality alignment

Table 2. Differences (in millimeters) in the paired 217 CMVM and IMVM prostate displacements in the lateral (RL), anteroposterior (AP), and superoinferior (SI) directions

	CMVM minus IMVM		
	RL	AP	SI
Mean	0.9	0.1	6.0
SD	3.4	4.2	5.1
p value	<0.0001	0.604	<0.0001

Abbreviations: CMVM = cross-modality verification method; IMVM = intramodality verification method; SD = standard deviation.

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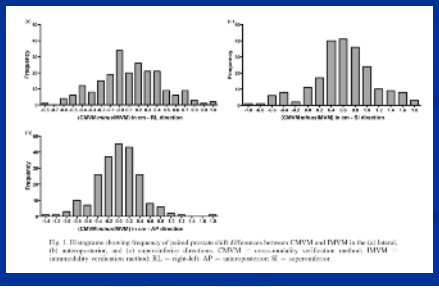
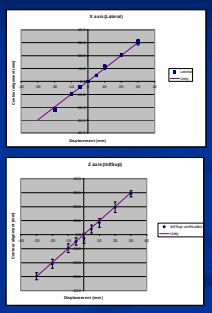
Intra v. Inter modality alignment

- Largest average discrepancy between CT/US and US/US alignment in SI direction (6 mm)



Uncertainty propagation

- Lasers
  - Simulation suite
  - Table sag
  - Drift
- CT imaging
  - Pixel size (400mm FOV/512 = 0.8 mm)
  - ***Slice thickness***
  - Soft tissue contrast (technique, dose, noise)



Uncertainty propagation

- Contouring
  - User precision, esp in sup/inf dimension
  - Treatment planning contours v. alignment contours
- US image resolution/quality
  - Function of depth, esp. for 3D systems
  - Non-isotropic
  - Noise
  - Compromised penetration depth
  - Artifacts
- US spatial registration/calibration
  - Mechanics (phantom, camera, arm, transducer/holder integrity)
  - User upkeep
- Target deformation, mobility

Recommended QA procedures Geometric/Spatial Accuracy

- Laser alignment (daily)
  - 1 mm
  - Treatment room and simulator suite
  - Especially true for Sonarray (camera calibration directly dependent on laser alignment)
- Positioning constancy (daily)
  - 2 mm
  - Test over range of interrogation angles
  - Specifics are vendor dependent

Recommended QA procedures Geometric/Spatial Accuracy

- Basic US unit controls (daily)
  - TGC, brightness/contrast
- IR camera verification (daily)
  - Typical 60 minute warm up required
  - < 4 mm deviation prior to warm up
  - Mechanical stability
- Phantom stability (quarterly)
  - Desiccation
  - Mechanical trauma
  - < 1 mm
  - Repeat CT scan

Recommended QA procedures Geometric/Spatial Accuracy

- Positioning constancy (monthly)
  - Performed by physicist
  - Helps ensure skill maintenance
  - Separate and overt camera calibration verification
  - Observe gradual shifts that may go undetected daily
  - < 2mm
- Phantom offset test (monthly)
  - Performed by physicist
  - Offset in 3 dimensions and verify that alignment procedures return it to correct position.
  - May be done daily
  - < 2mm

Recommended QA procedures Geometric/Spatial Accuracy

- Laser offset test (monthly)
  - Simulation suite, if applicable
  - Verifies proper alignment and transfer of isocenter information for systems used in the simulation suite
  - Phantom is offset from zero position by a clinically appropriate distance
  - Isocenter is set at this new position
  - Co-registration of CT/US image sets should produce good alignment
  - Alternate between zero and non-zero offsets

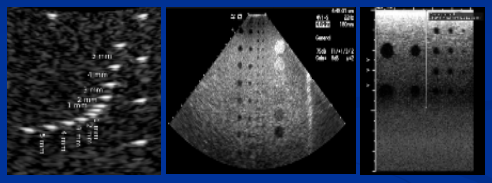
Recommended QA procedures Geometric/Spatial Accuracy

- End-end testing (annually)
  - Acquire reference CT (and reference US if applicable)
  - Structure segmentation
  - Set up in treatment room using lasers
  - Perform US alignment
  - < 2mm
  - Test for objects near isocenter and those displaced from isocenter by at least 3 - 5 cm.

Image quality checks

- Did not provide *quantitative* guidelines
- Frequency is semi-annual, consistent with ACR practices
- All criteria are in comparison to baseline
  - Spatial resolution
  - Low contrast resolution
  - Sensitivity
  - Hardware degredation

Imaging phantoms



Training

- Experienced users
  - have improved reproducibility
  - Better structure recognition
- Initial manufacturer training
  - Trainers should have significant clinical experience
  - Involve local US experts during initial training period
- Continuing Clinical Training
  - Define regular meeting schedule for quality improvement/image review
  - May want to keep user log of number of cases

To do US right

- Use intramodality matching
- Use matching contours, not treatment planning contours
- High resolution CT, esp in the Sup/inf dimension
- Consider whether interfaces or prostate center of mass is the desired matching objective
- Screen patients at sim and do not use for patients that don't image well
- Find prostate using lots of probe pressure, then back off until just visible.
- Do a lot of it

Conclusions

- US localization can be accurate and provide good soft tissue detail not available with other systems
- Accuracy depends on details of total clinical procedure train
- Frequent use and training are key