Commissioning a new anthropomorphic spine and lung phantom for the remote validation of treatment plans for institutions participating in RTOG 0631

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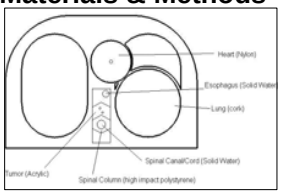
Purpose

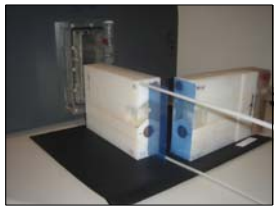
To evaluate the accuracy of planning and delivery of radiation therapy for spinal metastases, a new spine/lung phantom was developed by the Radiological Physics Center (RPC). This phantom will be utilized to credential institutions participating in a new Radiation Therapy Oncology Group protocol (RTOG 0631). This protocol will investigate the efficacy of dose escalation in the radiosurgery of spinal metastases.

The spine/lung phantom was constructed to simulate the anatomy and inhomogeneities in the critical areas for spinal radiation therapy. These tissues include lung, bone, soft tissue, and vessels. The close proximity of these structures of varying density poses a challenge to the accurate calculation of dose by the treatment planning system. Potential discrepancies between the planned dose and measured dose will be found by comparing thermoluminescent dosimeter (TLD) and gafchromic film measurements against the planned dose in the treatment planning system. The direct measurements with film and TLD should agree with 95% of the the planned dose at a gamma index of 5% of the reference dose with a distance to agreement of 3mm.

Materials & Methods

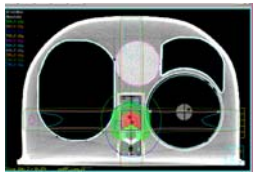


The schematic shows a cross section of the spine/lung phantom. The spine insert is removable, and the tumor volume is loaded with gafchromic film and TLD's.

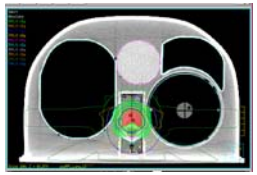


This image shows the film planes relative to the spine insert.

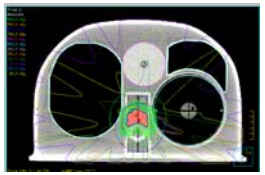
Three different treatment plans were designed in Philips Pinnacle 7.6 and administered to the spine/lung phantom: a 4 field box, a seven posterior beam conformal plan, and a seven posterior beam IMRT plan. 8 Gy was prescribed to 95% of the tumor volume in each administration. The following images show the relative dose distributions in each treatment plan; the dark blue contour is the 8 Gy prescription line.



Treatment 1: Four-field box

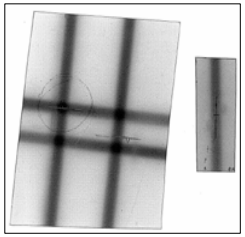


Treatment 2: Seven-beam conformal



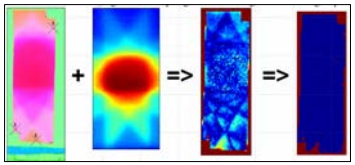
Treatment 3: Seven beam IMRT

For each treatment administration, it was necessary to localize the physical isocenter to the radiation field isocenter with a high degree of accuracy. This was accomplished using marked gafchromic film that bisected the physical isocenter. Small shifts were made until the physical isocenter was in the middle of a 1 mm planar field. The following image shows the film utilized to accomplish this localization:



Results

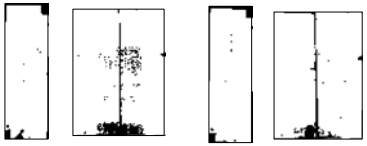
After each irradiation, the exposed films were registered to the planned dose distributions using custom software tools designed for the RPC. These tools allow direct registration to the planned dose distribution with pin-prick locations. The figure on the right shows the generation of a Binary Agreement Map (BAM) for an axial film plane: (A) film scanning and pin prick identification, (B) generation of a planar dose from the planned distribution, (C) generation of an agreement map with a gamma index of +/- 5% within 3 mm, and (D) a threshold applied for passing/failing pixels. The following show the BAM's created for each trial:



(A) (B) (C) (D)

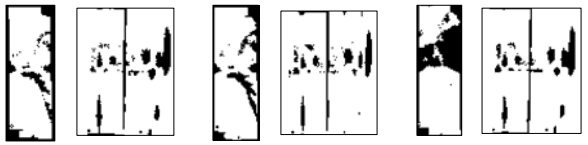
Four-field box: Axial and Sagittal fields, Trials 1, 2, and 3

4-Field	% Passing	*n*
Axial	98.83	3
Sagittal	95.15	3



Seven beam Conformal: Axial and Sagittal fields, Trials 1 and 2

Conformal	% Passing	*n*
Axial	99.251	2
Sagittal	95.44225	2



Seven beam IMRT: Axial and Sagittal fields, Trials 1, 2, and 3

IMRT	% Passing	*n*
Axial	88.9255	2
Sagittal	91.182	3

These tables show the absolute dose measured from the TLD for the IMRT administration. When the BAM's were calculated, the dose on the film was linearly scaled to the dose measured with the TLD adjacent the film. The correction was near 1 for each sagittal film measurement, but was higher for the axial films.

IMRT Axial Film Dose Corrections

Trial 1	**TLD (Gy)**	**Correction**
Ant	8.2	1.06
Post	7.8	1.08
Trial 2		
Ant	8.1	1.06
Post	7.9	1.1
Trial 3		
Ant	8.23	1.05
Post	7.92	1.09

IMRT Sagittal Film Dose Corrections

Trial 1	**TLD (Gy)**	**Correction**
Ant Sup	8.4	0.96
Post Sup	7.8	1.01
Ant Inf	8	0.98
Post Inf	7.9	1.01
Trial 2		
Ant Sup	8.1	0.95
Post Sup	7.9	1.03
Ant Inf	8.1	1
Post Inf	7.9	1.02
Trial 3		
Ant Sup	8.4	0.98
Post Sup	7.9	1.04
Ant Inf	8.1	1
Post Inf	7.9	1.03

Conclusion

The planned and measured dose distributions for the relatively simple beam geometries of the 4-field box and seven beam conformal plans were found to be acceptable at the 5%/3mm gamma index, as greater than 95% of each binary agreement map was passing. The IMRT administration did not meet this minimum requirement. However, this may be due to the use of too many small segments in the IMRT plan. If the prescription requirements set out in RTOG 0631 can be met with a more uniform IMRT plan, this phantom will likely measure an administration to an acceptable level.

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References

1. Jacobs et al, *Evaluation and treatment of spinal metastases: an overview*, Neurosurgical Focus 11 (6): Article 10, 2001.

2. Ryu et al, RTOG protocol 0631 (preliminary draft, not publicly available)