Design, development, and evaluation of a modified, anthropomorphic, head and neck, quality assurance phantom for use in stereotactic radiosurgery

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Figure 1: Image of phantom (left) evaluated with dosimetric insert (center) and imaging insert (right)

Innovation/Impact:

By designing a simulated human shaped (anthorpomorphic) plastic phantom with targets, organs at risk (OAR) and heterogeneities, the overall radiotherapy treatment process may be more effectively evaluated. For this reason, the Radiological Physics Center has designed and developed an anthropomorphic head phantom to evaluate from start to finish, the treatment process, from imaging to planning to setup to treatment delievery, for stereotactic radiosurgery delivery from a Gamma Knife system, standard linac based radiosurgery system, and a CyberKnife robotic radiosurgery system. This evaluation is used to credential institutions wishing to participate in NCI funded clinical trials.

Methods:

A phantom was constructed from a water equivalent, plastic, head-shaped shell. Modifications, from an exisitng QA phantom design containing only a single spherical target, included the addition of structures resembling a nonspherical target (pituitary) and an adjacent (within 2mm) OAR (optic chiasm) simulating structures encountered when treating acromegaly. A separate dosimetry insert for treatment delivery evaluation contained 2 thermoluminescent dosimeters (TLD) for absolute dosimetry and radiochromic film (sagittal and coronal planes) for relative dosimetry. The target and OAR proximity provided a more realistic and challenging treatment planning and dose delivery exercise than the original simpler design. The spatial relation between the target and center of the dosimetry insert was verified through two CT scans of the phantom, one for each insert, which were then fused together.
An Elekta stereotactic head frame was used for stabilization and reproducibility between CT scans and irradiation. To create an achievable planning criterion, the volume of the OAR receiving ≥8Gy was limited to 10%. The rigor of the treatment planning process, reproducibility of the dosimeters, and agreement with calculated doses were assessed through three Gamma Knife irradiations.

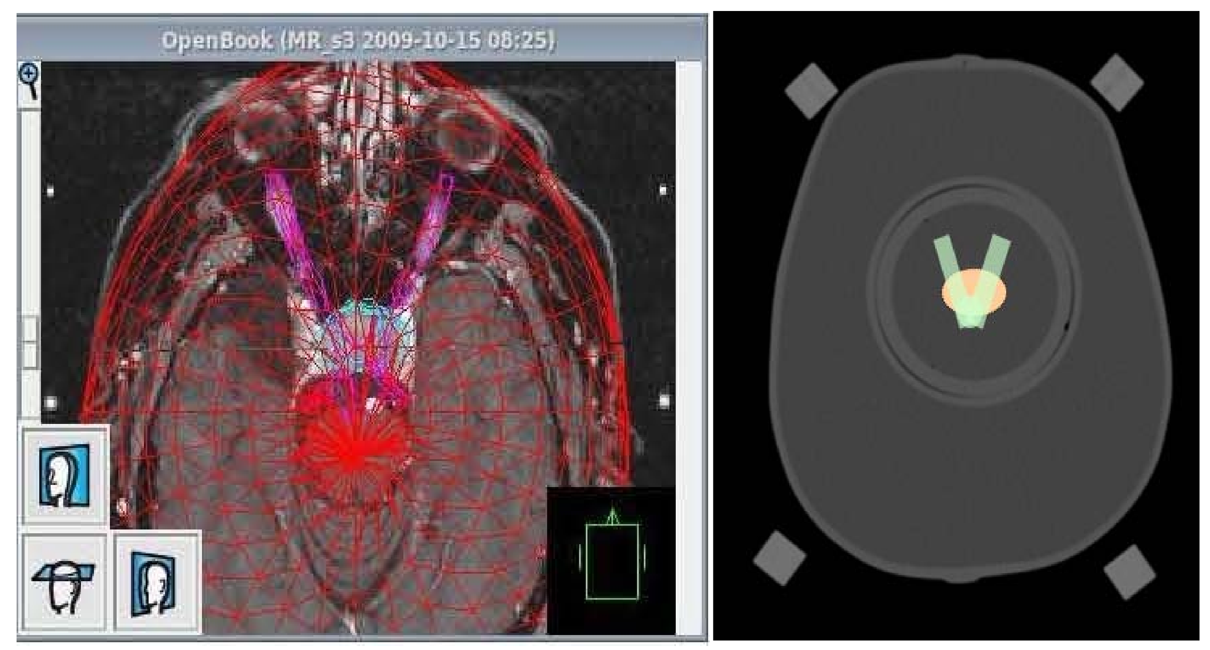

Figure 2: Transverse view of patient MRI (left) with pituitary (blue) and optic apparatus (purple) contoured and transverse view of phantom with proposed target (red) and OAR (green).

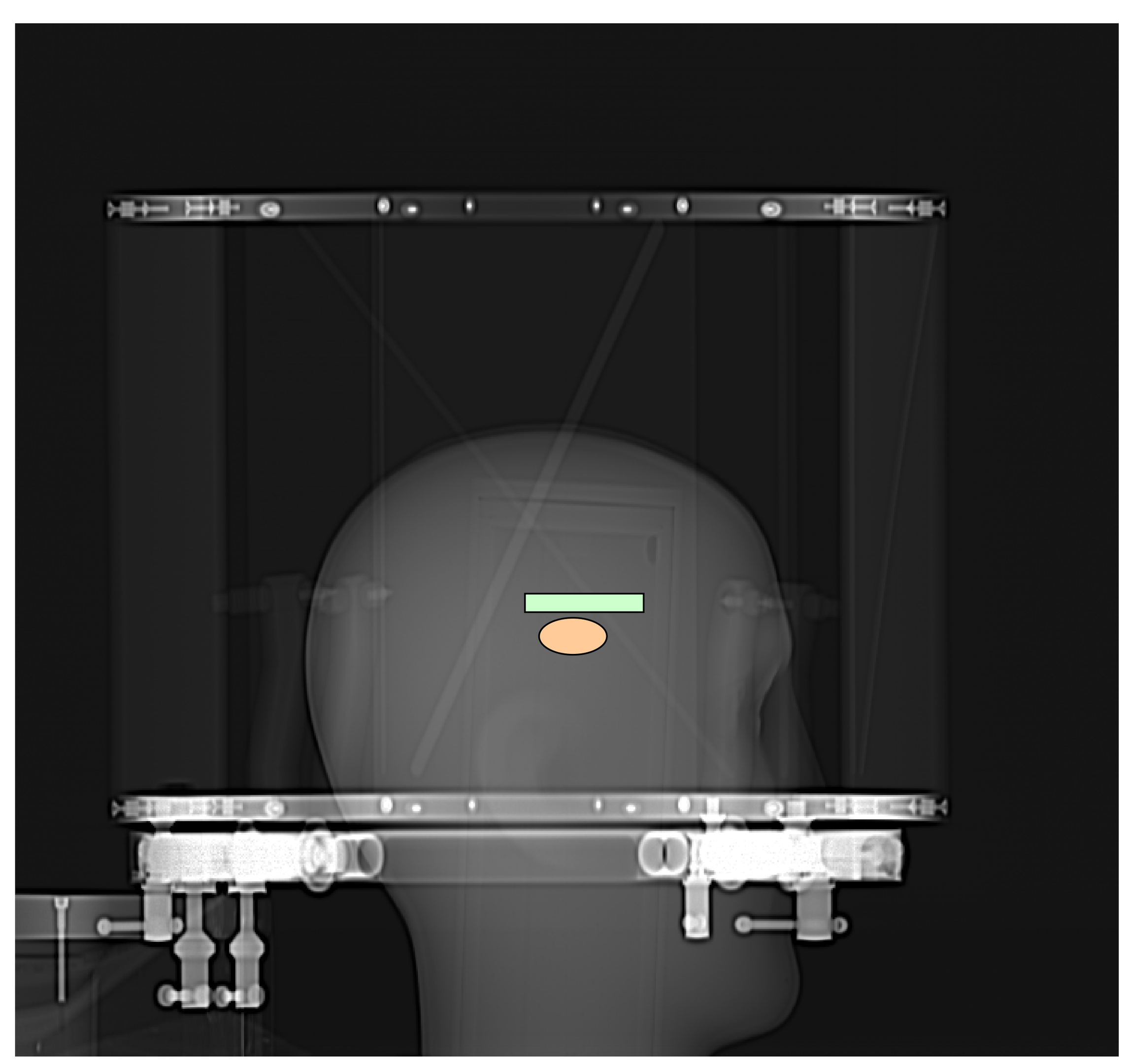

Figure 3: Sagital view of original phantom design with proposed addition of target (red) and organ at risk (green).

Table 1: Dose limits for treatment of pituitary adenoma according to RTOG report 0930 (unpublished)

Structure	RTOG 0930 Specification	Modified Dose Limits
Pituitary Adenoma	25 Gy (RBE) to at least 90% of GTV	25 Gy (RBE) to at least 90% of GTV
Optic Apparatus (chiasm and optic nerves)	< 10 Gy (RBE) maximum dose (0.01cc)	< 10 Gy (RBE) maximum dose (0.01cc)
	<=1% volume should receive 8 Gy (RBE)	<=10% volume should receive 8 Gy (RBE)

Results:

The TLD results from the three irradiations agreed with the calculated target dose to within 4.3% with a coefficient of variation of ±2.0%. Gamma analysis using a ±5%/3mm criteria in the film planes showed an average point by point passing rate of 99.9% and 99% in the coronal and sagittal planes, respectively. A gamma analysis using 3%/2mm criteria showed the percent of total pixels passing to be 87% and 79%, respectively.

TLD	Measured	Difference	σ	% Difference
Left Post. Sup.	18.38	-0.68	0.29	3.7
Right Ant. Inf.	22.31	-0.95	0.46	4.3

Table 2: TLD results including measured dose (Gy) and difference in measurement and reported (Gy)

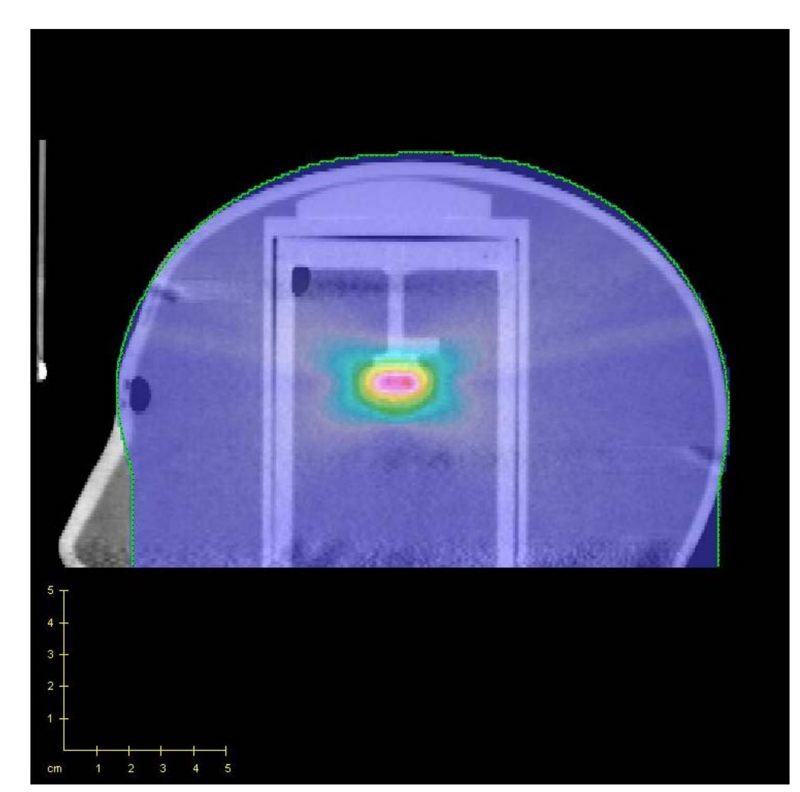

Figure 4: Sagital view of Gamma Knife treatment plan

Conclusions:

A modified anthropomorphic QA SRS phantom has been designed that can measure the dose delivered accurately and precisely while providing a more realistic clinical planning and delivery challenge that can be used to credential institutions wanting to participate in NCI funded clinical trials.

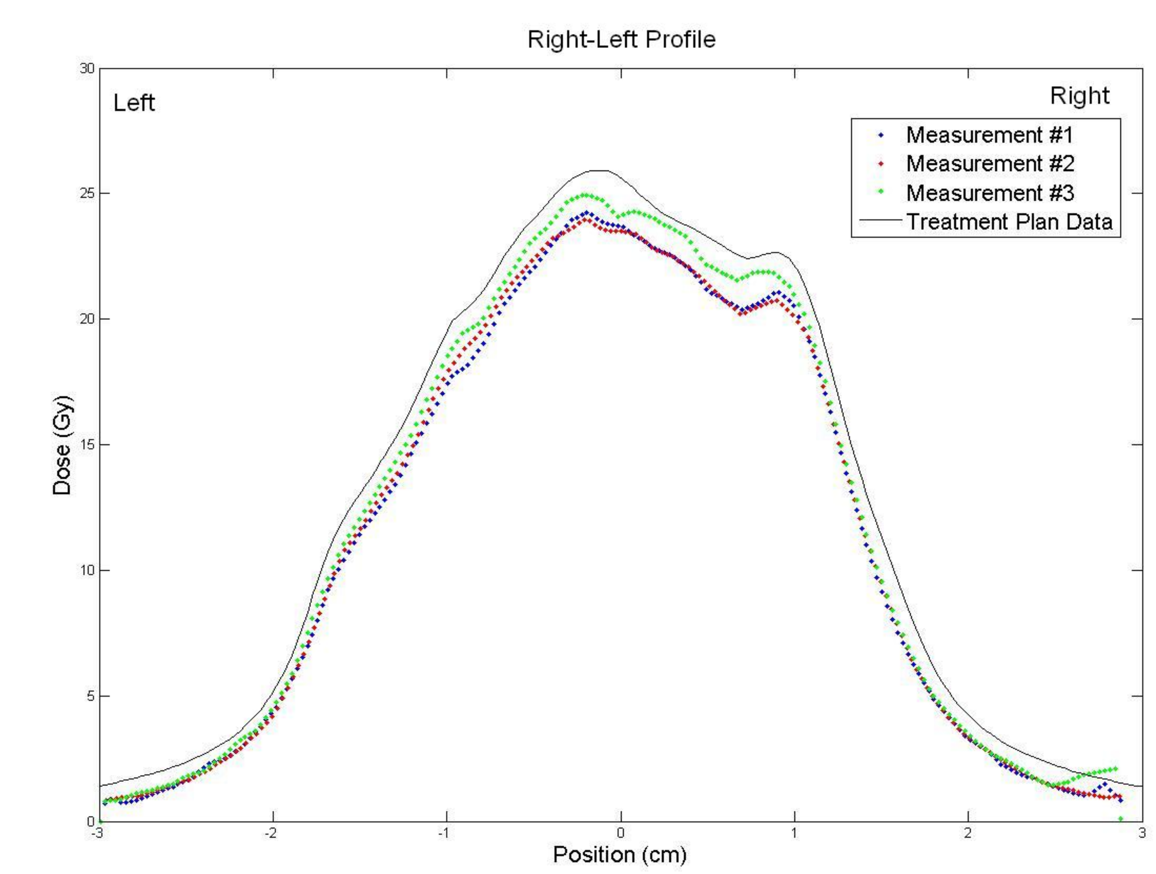

Figure 5: A plot of right-left profile measurements taken from the coronal film of all three irradiations compared to institution data taken from the treatment plan

Future Work:

Currently, the phantom is undergoing evaluation on a standard linear accelerator based treatment system and a CyberKnife robotic radiosurgery system.

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