A Novel Iris Quality Assurance Phantom for the CyberKnife Radiosurgery System

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Introduction

The CyberKnife radiosurgery system is a linear accelerator mounted on a robotic manipulator. The robot enables the delivery of radiation from hundreds of non-coplanar, non-isocentric pencil beams aimed at the tumor, achieving highly conformal dose distributions.

The radiation beam is collimated either by 12 interchangeable tungsten cones with diameter ranging from 5 mm to 60 mm, or by a variable aperture collimator (called Iris) with the same set of field sizes. Field size is defined at a source-to-axis distance (SAD) of 800 mm. The Iris collimator consists of two hexagonal banks of tungsten, producing a twelve-sided aperture diverging toward the patient. The mechanical uncertainty of the Iris field sizes is 0.2 mm

This report examines the use of a scintillator-based imaging system to measure the the field sizes and beam divergence of the Iris collimator.

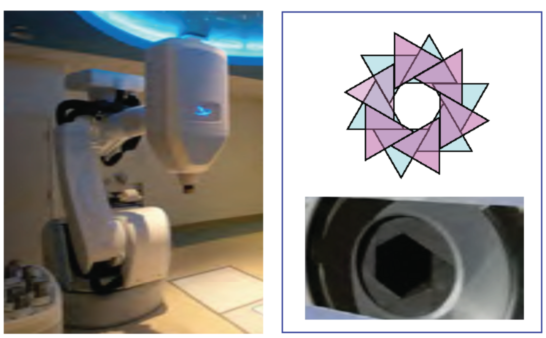

Fig. 1: The CyberKnife system (left) and the Iris variable aperture collimator (right)

Aims

To develop a robust, fast and comprehensive method for Iris quality assurance (QA)

- Today, Gafchromic EBT3 films are used to measure the reproducibility of Iris field sizes.
- Film measurements are time consuming and may vary depending on the quality and handling of the film, making reliable measurements at the 0.2 mm level challenging.
- We tested the performance of a scintillator detector to measure the field sizes and beam divergence of the Iris collimator.

Method

The XRV-124 imaging system

The XRV-124 phantom developed by Logos Systems consists of a conical x-ray phosphor scintillator attached to a radiation-shielded digital camera.

As the radiation beam passes through the scintillator cone, two beam spots of visible light are formed by Compton scattering. The digital image of these two spots is then processed to determine the vector, position, intensity, timing, and diameter of the beam.

The two beam spots in the integrated image are dewarped from the conical view into a 2D bitmap and measured. Beam diameters are measured using a FWHM algorithm averaging 72 diameters passing through the center of the dewarped image.

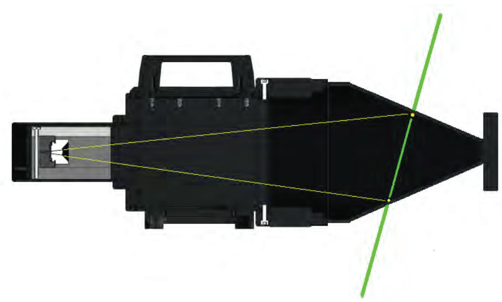

Fig. 2: The XRV-124 converts x-ray beam fluence (green) to visible light (yellow) using a scintillator imaging cone

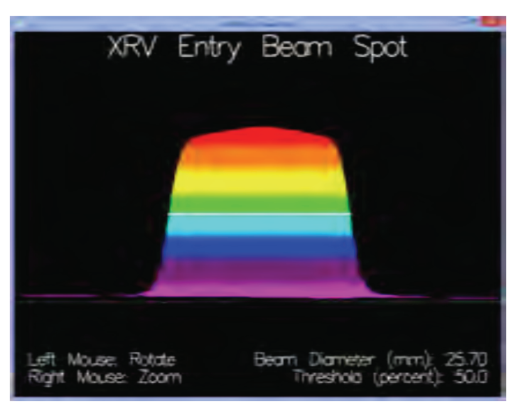

Fig. 3: XRV-124 beam side profile

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Method

Measurement setup

The XRV-124 phantom was placed on the CyberKnife treatment couch and the robot position was adjusted to obtain an anterior-posterior beam perpendicular to the cone's central axis.

Fig. 4: Measurement setup

The FWHM of the 12 Iris apertures (5, 7.5, 10, 12.5, 15, 20, 25, 30, 35, 40, 50, and 60 mm) were measured from the beam flux map on the conical scintillator surface as seen by the digital camera. For each measurement 30 MU were delivered to the phantom at a dose rate of 1000 MU/min.

The measurements were repeated at 4 SAD between 75 and 85 cm, by adjusting the height of the couch. These readings were used to project the aperture size as if the flux map on the scintillator were located 80 cm from the source. The projected FWHM were compared to the field size commissioning data measured with films.

A series of 12 beam divergence equations were obtained from the 4 sets of data and used to project the FWHM measurements at 80 cm SSD.

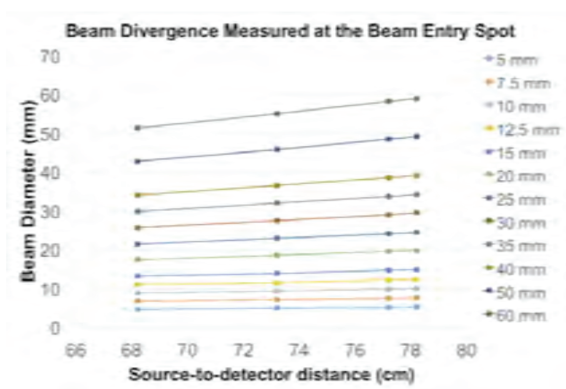

Fig. 5: CyberKnife AP beam divergence measured at the XRV-124 beam entry spot

Results

The average aperture accuracy for beams from 5 through 40 mm was 0.08 mm. The accuracy for the 50 and 60 mm beams were 0.33 and 0.58 mm when compared to film commissioning data.

Nom. FS	Div. slope	Div. intercept	Entry spot at 80 SAD	Std. data	Delta
60	0.7616	-0.7616	60.17	59.59	0.58
50	0.6398	-1.0296	50.15	49.82	0.33
40	0.5053	-0.5174	39.91	39.76	0.15
35	0.4387	-0.2379	34.86	34.78	0.08
30	0.3735	0.1039	29.98	30.00	-0.02
25	0.3077	0.3186	24.93	25.01	-0.08
20	0.2416	0.8147	20.14	20.03	0.11
15	0.1785	0.8185	15.10	14.95	0.15
12.5	0.1452	0.913	12.53	12.52	0.01
10	0.1139	0.9369	10.05	10.07	-0.02
7.5	0.0831	0.9799	7.63	7.61	0.02
5	0.0648	0.0846	5.27	5.09	0.18

Table 1: Linear regression coefficients used to predict beam FWHM diameter at 80 cm SDD

Conclusions

The beam fluence divergence slopes in air for the twelve Iris apertures have been measured.

The experimental results for ten apertures from 5 mm to 40 mm agree with the stated Iris accuracy of ±0.2 mm at 80 cm SAD.

The results for the 50 and 60 mm beam aperture were repeatable and can serve as a reliable trend indicator of any deviations away from the commissioning values.

Contact

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