



Dynamic Anthropomorphic Eye Phantoms for Targeting and Dose Verification of a Novel Ophthalmic Radiosurgical Device

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Purpose

Wet age-related Macular Degeneration (AMD) is a leading cause of blindness in the U.S. affecting millions of people. It is a neovascular disease that is amenable to radiotherapy. The I-Ray™ (Figure 1) is a 100 kVp stereotactic radiosurgical (SRS) device that has recently been developed to treat AMD. We evaluate a set of anthropomorphic eye phantoms for verifying the targeting and dosimetric accuracy of the I-Ray.



Figure 1: The I-Ray System

Introduction

The I-Ray therapy consists of three 4 mm diameter beams delivered through the pars plana to converge on the fovea as shown in Figure 2. This geometry avoids the radiosensitive lens and also avoids the optic nerve head located only millimeters away from the fovea. To assist in targeting,

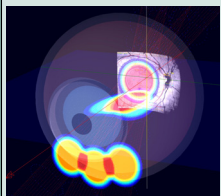


Figure 2: Three-beam geometry

an eye stabilizing and tracking device (the "I-Guide") is affixed to the patient's eye prior to treatment. It consists of suction-enabled scleral lens that gently holds the eye and a stabilizer bar mounted to a stationary structure. It features reflective fiducials that allow the I-Ray to align to the eye and track its motion. Because the scale is so small and the unsedated patient's eye is still somewhat mobile, new tools were needed to verify the targeting and dosimetric accuracy of the I-Ray system. To that end, eye phantoms were created that permitted testing the system targeting and dosimetry both with and without eye motion.

Methods

A series of Solid Water eye phantoms was developed to match human eyes in size and shape. The phantoms are mounted on gimbals and are free to move as would a human eye (Figure 3).

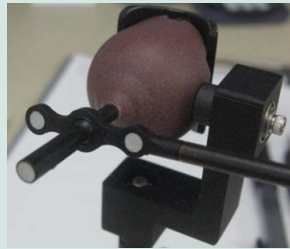


Figure 3: Eye Phantom and I-Guide assembly, with three fiducials

Films are scanned on a flatbed scanner and converted to pseudocolor dose maps using a calibration curve. Based on the position of the fiducial holes, retinal points of interest are calculated and beam targeting can be accurately assessed. Displacement from the foveal target, dose conformity and accuracy, and distance from the optic disc are all characterized.

Instead of a scleral lens, the I-Guide mounts to a post in the middle of the cornea.

At the "retina", cutouts were machined with two fiducial posts that support the precise mounting of laser-cut radiochromic film coupons matching this geometry. After irradiation of the phantom, the beam spot is visible on the film (Figure 4).



Figure 4: Eye Phantom and exposed film on the "retina"

Numerous treatments have been run on stationary phantoms to assess system precision and accuracy. In a typical example (Figure 5), the

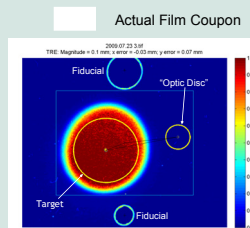


Figure 5: Dose map derived from scanned film of static eye

Irradiation during motion causes the beam spot on the film to spread out. The decrease in dose conformity can be compared to calculation (Figure 7) and evaluated against clinical expectations. The I-Ray also has a gating algorithm that turns the beam off in the event of excess motion; the accuracy and validity of this algorithm were verified using the dynamic phantoms.

nominal fovea (1.2 mm to the side and 0.5 mm down from center) was targeted. In this case, a targeting error of 0.1 mm was noted.

Stepper motors attached to the I-Guide stabilizer bar allow the gimballed phantom to be moved (Figure 6). Typical patient motion data obtained from volunteers in a feasibility trial were programmed into the stepper drivers to move the eye in a realistic fashion.

Results

Repeated treatments of static eye phantoms demonstrate that the I-Ray has a targeting accuracy of better than 0.2 mm with a measurement precision of 0.1 mm.

Analysis of films irradiated with dynamic eye phantoms shows that the system responds correctly to patient motion and that motion-induced dose spreading matches expectations. It also verified that the gating algorithm was suitable for protecting radiosensitive structures.

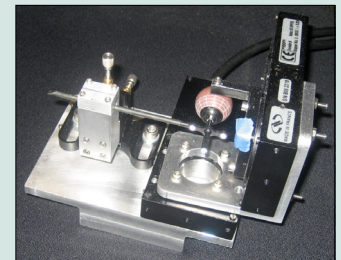


Figure 6: Stepper motor assembly for creating eye phantom motion

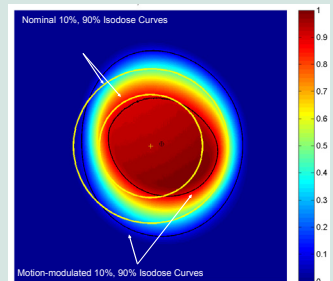


Figure 7: Simulated beam spot showing effects of substantial motion (0.4 mm)

Conclusions

Use of anthropomorphic eye phantoms has confirmed that the I-Ray can accurately target the fovea in stationary and moving eyes. Mobile-phantom tests also prove that the system's gating software is adequate to protect sensitive structures.