Post-Operative Eye Plaque Imaging Using Tomotherapy MVCT

Innovation/Impact: Ultrasound imaging is used during eye plaque placement to verify adequate tumor coverage and abutment of the plaque on the sclera. Imaging post-placement is not standardly performed however plaque movement and plaque tilt are known to occur and can ultimately compromise efficacy of the treatment. Post-operative volumetric imaging would be a beneficial quality assurance to verify tumor coverage and the plaques’ position with respect to the sclera (plaque tilt). Conventional diagnostic computed tomography, operated with a kilovoltage potential, results in unacceptable image artifacts due to the gold or gold-alloy material of the plaque. The purpose of this phantom study is to investigate the possibility of imaging eye plaque positioning using the megavoltage computed tomography (MVCT) system of the Tomotherapy radiation therapy machine. MVCT is not subject to artifacts from high-Z materials such as gold, because the photo-electric effect does not contribute to attenuation of megavoltage photon beams. Compared to conventional a-Si MVCT, the xenon gas detectors of the Tomotherapy MVCT have approximately 10-fold better quantum efficiency. Post-implantation magnetic resonance imaging (MRI) is possible, however MRI has the potential to injure the patient by radiofrequency heating of the gold plaque, and is contra-indicated for some patients due to implanted medical devices or other metal objects. Furthermore, MVCT is less time-consuming than MRI and is less expensive and logistically easier to schedule for radiotherapy patients because it is performed intra-departmentally.

Background: Episcleral eye plaque radiotherapy has been the treatment of choice for melanomas of the eye since the Collaborative Ocular Melanoma Study (COMS) demonstrated that plaque therapy results in equivalent overall survival compared to surgical enucleation of the eyeball. Plaque radiotherapy can be a vision sparing treatment, particularly in patients with small tumors located away from the optic disk and foveola. Efficacy of plaque therapy depends on the placement of the plaque with respect to the tumor. If the plaque is not centered on the tumor, dose delivered to the tumor could differ from the prescription dose and could result in lower tumor control probability. If the tumor base extends laterally beyond the edge of the plaque, gross under-dosing of the tumor will occur, with local failure a probable result. At our institution, a plaque is sized to extend such that a margin of at least 3 mm beyond the tumor exists in any direction, and ultrasound guidance is used intra-operatively to verify proper plaque placement. However, anterior tumors are difficult to measure with ultrasound. Plaque placement is further complicated by the fact that tumors may grow even during the time between diagnosis and plaque implantation (< 4 weeks, and typically < 2 weeks, at our institution). In our clinic, a small fraction of plaques have appeared to be “tilted” with respect to correct placement on the sclera (i.e. the plaque rim is not everywhere seated on the sclera). In a published report from another institution, plaque tilt was observed more frequently during the plaque removal procedure than during implantation, indicating that plaques may shift during the treatment time, which typically comprises 3-7 days.

Materials and Methods: Plaques were placed on a preserved cow’s eye (diameter 40 mm; Nebraska Scientific, Omaha, NE), and imaged with the megavoltage CT of a Tomotherapy linear accelerator (Accuray, Sunnyvale, CA) at Accuray’s research center in Madison, Wisconsin. Images produced with beam collimator set at 0.1 mm, resulting in a fan-beam width
of 3 mm. In order to ascertain whether plaque tilt could be visualized, an artificial space was created by wedging a piece of tissue between the rim of the plaque and the sclera. To ascertain whether tumor coverage could be visualized, since the cow’s eye did not contain an actual tumor, we used the lens as a proxy for a tumor, hypothesizing that if the lens could be visualized in a given image, then a tumor probably could be as well. The ability to resolve low-contrast objects in CT images depends on the image noise, which in turn depends on the integrated beam current used to produce the image. The Tomotherapy device at present allows imaging with a fixed beam current. In order to simulate higher beam current images, we took 10 sequential images of the same setup and averaged them.

**Results:** Figure 1a-d shows images of the eye plaque on the cow’s eye. The plaque, the lens of the eye, and the globe are visible in the images. The CNR of the eye lens was 5.6 for a single image. For 10 images averaged, the CNR was 9.2. Estimated dose from a single image was 1.3 cGy (body CTDIvol); even 10 times this dose would be acceptable image-guidance dose for radiotherapy patients. Each 1 mm slice required 12 seconds to acquire. Imaging the entire plaque and tumor could require up to a 20 mm transverse field of view, or 240 seconds for acquisition.

![Figure 1: Tomotherapy MVCT images of eye plaque on cow’s eye. a-b) single low-dose image; c-d) Simulated high-dose image (average of 10 images). Panes a) and c) displayed over HU window [-1000,1000] for best visualization of plaque relative to the globe of the eye. Panes b) and d) displayed using HU window [-250,250] to emphasize soft-tissue contrast.](image)

**Conclusions:** Tomotherapy MVCT imaging could be used to verify tumor coverage and plaque tilt after episcleral plaque implantation. Tumors should be visible in standard beam current images but high beam current images would be preferred if available. One limitation of the imaging procedure is the long scan time, during which any significant patient eyeball movement would lead to image artifacts. Human trials on eye plaque patients are planned.

