Background: 

106Ru eye plaques manufactured by BEBIG (Berlin, Germany) are widely used for treatment of intraocular malignancies, providing a good alternative to brachytherapy.

Prior to 2002 BEBIG provided dose information based on standards of the former German Democratic Republic with a stated uncertainty of ±30%. The measurements were done using a large 2 mm height, 2 mm diameter plastic scintillator.

Our routine hospital-based clinical dosimetry using radiochromic film and a Scanditronix stereoratic silicon diode found dose disagreements of 50%-110% with manufacturer’s data on the central axis perpendicular to the plaque’s inner surface as well as highly non-uniform and asymmetric dose distributions in the peripheral plane.

In 2002 BEBIG started using a small 1 mm height, 0.5 mm diameter plastic scintillator with a calibration traceable to the U.S. National Institute of Standards and Technology (NIST).

In the last few years Workgroup 22 (Dosimetry and Related Protocols in Medical Applications of Ionizing Radiation) of Subcommitte 2 of the Technical Committee 85 on Nuclear Energy of the International Standardization Organization (ISO) prepared a new standard "Clinical Dosimetry — Beta Radiation Sources for Brachytherapy".

The standard defines what information and calibration data should be provided by the manufacturer as well as requirements for acceptance, testing, commissioning, and quality assurance by the user, along with recommended measurement equipment and methods.

As per the new standard acceptance testing of a new applicator shall include:

- Absolute dose rate at a reference point and relative dose rate along the central axis of the plaque. Alternatively, absolute dose rate along the central axis of the plaque can be measured at convenient points and interpolated to the reference point.
- Non-uniformity and asymmetry of the dose rate distribution.
- Assessment of the active area of the plaque.
- Geometrical dimensions and radioactive contamination tests.

Commissioning:

- The user should collect additional dosimetric data as required by the treatment planning program.

Equipment recommended by the new standard:

- Small plastic scintillators with active volume less than 1 mm in any dimension — not available commercially, difficult to calibrate independently in a hospital setting.
- Radiochromic film — used in this work.
- Small silicon diode with active volume less than 1 mm in any dimension. The Scanditronix stereoratic diode is being used by the authors.
- TLD's — very work intensive, low spatial resolution.

Purpose/Objectives:

- We present a 3D treatment planning program which utilizes commissioning data collected using radiochromic film in a Solid Water phantom and either MRI or CT scans of the diseased eye.

Materials/Methods:

- Concave 106Ru eye plaques of the following three types underwent dosimetric evaluation since 2001: CCX with a diameter of 11.6 mm, CCA and CIA (notched) with a diameter of 15.3 mm (Figure 1).

- A full 3D dosimetric characterization of a CCX type 106Ru eye plaque was performed in this work using specially manufactured single layer version of GAFCHROMIC EBT film (ISP, Wayne, New Jersey, USA) sandwiched in our Solid Water eye phantom (Figure 2).

- The film was calibrated in Solid Water using a 6 MeV linear accelerator electron beam.
- 8 radiochromic films at increasing distance from the eye plaque were acquired (Figure 4).

- All films were scanned 24 hours after exposure using an Epson Expression 1680 scanner in 48 bit color mode, the red channel was extracted, and the data analyzed using MSKCC’s Contour film dosimetry program.
- Solid Water to water correction (average 0.98) based on Monte-Carlo calculation (1) was applied.
- The resulting dose distributions were interpolated in order to conform to the image slice resolution of 1 mm resulting in a 25x25x25mm dose matrix.
- BrachyVision (Varian, Palo Alto, CA) was used to contour the PTV and OARs of the MRI of an eye with a choroidal metastasis (8.4 mm largest basal diameter and 4 mm apical height) and also export the resulting structures in DICOM RT format.
- The DICOM Toolkit (DCMTK) and Visualization Toolkit (VTK) libraries were used to read in the MRI study along with the PTV and OAR.
- Using ROOT (CERN, Geneva, Switzerland) the structures were rotated, translated and overlaid on the interpolated dose distribution matrix (Figure 5) in order to calculate the DVHs and doses to OARs (Figure 6).

Results:

- For a 100 Gy prescription to the tumor apex, the scleral dose is 732 Gy, well within acceptable tolerance.
- From the DVH, 95% of the tumor volume is covered by 73.5% of the prescription dose, which shows that the CCX plaque with 10.5 mm active area diameter is insufficient to cover the tumor.

Conclusions:

- We have built a 3D treatment planning tool enabling to view the dosimetric distribution superimposed on pre-MRI images of the eye.
- With this system one is able to calculate the DVH of the PTV and OARs in order to precisely assess the tumor coverage and doses to the sclera and other organs at risk.

References: