DOSIMETRIC STUDY OF A NEW SURFACE APPLICATOR FOR THE XOFT AXXENT SYSTEM

S. Axelrod, L. Kelley, A. Walawalkar, S. Yao, T.W. Rusch, Xoft Inc., Sunnyvale, CA

BACKGROUND

Over the past two years, the Axxent® Electronic Brachytherapy (eBrx) System has been used to deliver accelerated partial breast irradiation (APBI) using a balloon placed into the patient's breast while using permanent post-implant seeds.

- The FDA cleared the Axxent® eBrx System for more general treatment of “lesions, tumors and conditions in or on the body where radiation is indicated”.
- Xoft has developed a set of surface applicators for use with the Axxent® electronic brachytherapy (eBrx) system. The applicators are conically shaped, with a linear channel for introduction of the source catheter, and are made of stainless steel (Figure 1). The set consists of 10, 20, 35 and 50 mm diameter versions.
- These surface applicators were designed for use in treating superficial sites on the head and neck as well as extremities, especially hands and legs.
- 10 million actin keratosis and 1 million basal cell carcinoma cases occur each year.
- Radiation oncologists currently see a small but growing demand for APBI to this body region.

PURPOSE

The development of each surface applicator for use with the Axxent® eBrx system included an aluminium flattening filter, to create a uniform dose distribution across the output plane. The filter also served to harden the beam to provide a depth dose relationship which is similar to that obtained with HDR systems. Heights of the cones were selected to provide dose delivery rates similar to HDR based systems.

The Axxent® eBrx System has the potential to be equivalent to external beam radiation in its range of applications and sophistication of use.

Measurement of depth dose is critical to planning treatment.

METHODS

- Measurements of dose rate, dose profiles and percent depth dose (PDD) were made using two techniques, ion chamber and radiochromic film, for the 35 mm applicator.
- Laboratory measurements were made using standard Xoft Axxent® sources running at the nominal 50 kVp, 300 μA operating point used in most indications of the system. It was taken with a 35 mm diameter applicator, the first of four applicator sizes: 10, 20, 35 and 50 mm. Film measurements (Image EBT) were made in a water phantom at several distances from the surface, in an orientation parallel to the surface. Film was also exposed in the perpendicular orientation, along the central axis of the applicator.

IMMCHAMBER

- Absolute dose rate was measured in a water phantom using a PTW 34013 ion chamber calibrated to dose in water. The ion chamber was enclosed in a Solid Water® jacket to make it watertight. It was mounted on a computer-controlled linear stage, allowing transverse scanning for measurement of dose profiles. The applicator was mounted on a linear stage as well, to set the distance from the ion chamber (Figure 3).
- Measurements were made at distances of 2, 5, 10 and 15 mm from the face of the applicator to the ion chamber. The applicator was disposable and end caps were used to position the tissue. To prevent water from entering the cone volume, the end cap was held with a watertight bond to the applicator cone. This apparatus thus provides dose profiles, absolute dose and depth dose information.

- Radiochromic film

- Gall-Chromic EBT radiochromic film was used to supplement the ion chamber measurements and to simulate what will likely be used in clinical settings for routine QA. Film provides high spatial resolution but must carefully be calibrated to the radiation quality in use. Such calibrations were performed at several distances from the source in water to investigate the effect of a variegated spectrum. No dependence on distance was found over the range from 1 to 4 cm. Accuracy of the calibration fits in terms of residual error was below 2% (2) above 0.5 Gy.

DATA COLLECTION

- Data with a scanning PTW 34013 ion chamber was taken for 10 sources, using a single applicator. Data was also taken with a single source and 3 different applicators, and no significant differences were observed. These measurements were made as part of a formal Design Verification protocol.

- The average profiles of the 10 sources at distances of 2, 5 and 10 mm in water are shown in Figure 4. Vertical lines delineate the 80% width boundaries (at 14 mm). Dose was taken at 1 mm intervals. Note that the ion chamber has an active diameter of 3 mm, so sharp edges will be convolved with the response function and thus broadened.

- Table 1 shows maximum and minimum values in the central 80% region for the average profile, in percentage of the average dose rate. Also shown is the standard deviation (σ) across the profile, representing the RMS deviation from flat response.

- Individual source runs naturally show greater variation than the average, attributable to small differences in source spatial characteristics. Figure 5 shows individual profiles at 2 mm distance for the 10 sources, normalized to 1.0 over the central 80% region. Comparable amounts of variation are seen at distances of 5, 10 and 15 mm.

- Depth dose data was derived from ion chamber measurements taken at distances of 2, 5, 10 and 15 mm in water.

- The average dose over 80% of the defined applicator width was calculated at each distance, and a 4th order polynomial fit was applied. The fit allowed extrapolation to 0 mm, and interpolation of intermediate distances up to 15 mm.

- Table 2 and Figure 6 show percent depth dose (PDD) results, derived from the average of measurements with ten sources. Also shown are the standard deviations calculated over the 10 measurements.

- Depth dose rate data at each depth shows prediction of percent depth dose values at various distances from the surface.

- Absolute dose rate, normalized to the nominal Axxent® 50 kVp source strength of 110,000 U, is approximately 1.45 Gy/min at the surface. At 5mm depth the dose rate is 62% of that at the surface.

- Film data was taken both in the course of product development and as part of a formal Design Verification protocol. The film’s high spatial resolution and complete coverage was a complement to the scanning ion chamber data.

- The exposed film was scanned as a 48 bit RGB image, at 150 DPI. An example is shown in Figure 7. Being the most sensitive, the red component was selected for further analysis. The 16 bit pixel values were inverted and had a background image, based on the unexposed film, subtracted. A profile across the center of the image at this stage of processing is shown in Figure 8.

- A 5th order polynomial calibration was then applied to get dose values in Gray, and the average dose over 80% of the diameter was calculated.

SUMMARY

- A new set of cone-style applicators has been developed for use in treating surfaces in conjunction with the Axxent® Electronic Brachytherapy System. The applicator comes with a diameter of 35 mm and is one of a set that spans a range from 10 to 50 mm.

- The cone wall is approximately 1 mm thick stainless steel, which provides adequate shielding for the 50 kVp radiation while keeping overall weight low.

- Ion chamber data show good flatness at all depths, with small changes in the overall shape with depth, attributed to geometry and the hardening effect of the flattening filter. Scans made with the ion chamber provide reliable depth-dose data.

- A fit to the dose rate results at each depth allows prediction of percent depth dose values at various distances from the surface.

- Absolute dose rate, normalized to the nominal Axxent® 50 kVp source strength of 110,000 U, is approximately 1.45 Gy/min at the surface. At 5mm depth the dose rate is 62% of that at the surface.