Comparative Dosimetry of the Xoft Axcent Electronic Brachytherapy Skin Applicator at 50 kVp with Film, Chamber, and Diode in Various Backscatter Media

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Abstract

Introduction: The Xoft Axcent Electronic Brachytherapy Skin Applicator is a miniature x-ray source that delivers superficial dose to shallow depths using 50 kVp x-rays over small target areas (< 20 cm²). The Xoft Skin Applicators are conically shaped with circular treatment diameters of 10, 20, 35, and 50 mm. Each applicator has a specially designed aluminum flattening filter which acts to soften the low energy x-rays from the beam to mitigate the radial inverse square distribution on a flat surface. Previously methods (1) and AAPM Task groups (2) have examined the backscatter with an embedded flattening filter which acts to both filter the low energy x-rays over small target areas (< 20 cm²). The Xoft Skin Applicator and source (figure 2) was designed to be used at an SSD of 2.5 cm, at 100 cm, the signal did not include the effects of inverse square. The first and second HVL for this system are 1.4 mm and 2.5 mm. A VSSD of 22 mm was measured. As this data was compared relatively, the dose units are arbitrary. However, it is important that all apparatus be calibrated, some small modifications were made to the flattening filter design which could soften or harden the beam. The depth doses measured with the A-16 and RK matched within 1%, whereas the data doses measured with SFD (in water) and PTW in Solid Water required corrections.

Materials and Methods: A 35 mm surface applicator assembly and Axcent 50 kVp controller and source were used to produce low energy x-rays (Xoft, Inc., Sunnyvale, CA). The manufacturer recommends the use of a 0.5 mm polyacrylic end cap at the end of the conical section of the surface applicator (figure 2), this end cap was used for all measurements. Prior to each measurement the temperature-pressure corrected dose rate of each source was measured using the inherent well-chamber and electrometer provided with the Xoft system. Each measurement was then corrected for variation of that dose rate from the nominal dose rate (100,000 U). The Xoft Axcent system has a 30 second ramp up period which delivers dose equal to 2 seconds of full dose. All measurements were corrected for this end-effect.

The relative depth and profile dose characteristics of the 35 mm diameter cone were measured at room temperature in water and Solid Water (Kodak EDR2, GAFChromic EBT) film, ionization chamber (A16, RK, Marcus) and semiconductor diode (SFD). Correction factors for backscatter response and solid water density are derived by comparison. Beam profile metrics for parallel beam transmission with (PTW) field width, flatness and asymmetry were computed. A virtual SSD was computed using in-air diode measurements.

Results: HVL: The first and second HVL for this system were measured at 1.4 mm and 2.5 mm (H= 0.56), where the manufacturer suggested ranges are: 1.45 ± 0.15 mm AI and 2.5 ± 0.17 mm Al.

VSSD: As shown in figure 4, a VSSD of 22 mm was measured, differing from the nominal 25 mm SSD. A VSSD could be useful for predicting dose rate or output factors if this applicator required an air gap.

Film Calibration curves: As shown in figure 5(a) and (b) the calibration curves for EDR2 and GAF EBT are noted, along with the exponential or polynomial fits. As with the dose rates, a VSSD of 22 mm is useful for predicting dose rate or output factors if this applicator required an air gap.

Depth Doses: The depth doses normalized to 2 mm depth are shown in figure 5. The depth doses for this applicator is a 35 mm HVL in water of 8.0 mm and 2nd HVL of 9.6 mm. It is important to note that after this applicator was investigated, some small modifications were made to the flattening filter design which could soften or harden the beam. The depth doses measured with the A-16 and RK matched within 1%, whereas the data doses measured with SFD (in water) and PTW in Solid Water required corrections.

SFD Dose correction: The raw SFD data underestimates the dose at depth and at a depth based correction is required, similar to that noted by Li(2). A comparison of the correction modeled in EGS4 by Li is shown in figure 6 for similar energies (a 50 kVp endo rectal therapy unit). The measurement based correction differs significantly from that noted by Li, and can be attributed to the differences in the size of diodes used (0.6 mm diameter vs. 2.5 mm diameter).

Introduction to Surface profiles at 2mm deep for SFD diode, RK chamber, A16 chambers, EDR2 and EBT film are shown in figure 7. The profile metrics for each are noted in table 1. The PTWs, ranging from 0.4 to 5.0 mm, were measured with References (1) and AAPM Task groups (2) to provide a baseline series of results for each detector, and 3) suggest planned dose distributions.

Discussion: As clearly noted in TG-61, water based measurements of low energy x-rays are difficult to perform. A 1.2 mm gap in the applicator media would introduce a 2% error in the asymmetry. The choice of detector will also influence the results, as the chamber size correlates with the PTW. However, very small detectors (such as the SFD) which can more precisely measure the penumbra show depth responses and angular variance. The ease of use of film and solid water, it is appropriate calibrated and density corrected provide high spatial resolution, but are limited in the range of use. It would be difficult to use the film in a clinical setting, below 10%, may be not be routine clinical use. However, the data given in the two types of film, besides having a highly linear response at this energy, GAF EBT will also eliminate processor artifact.

The method proposed by TG-61 to measure HVL is not possible with this system. The wide angular aperture of the cone and short SSD, will result in a room full of scattered x-rays that overwhelmed the signal from the aperture. All this system is designed to be used at an SSD of 2.5 cm, at 100 cm, the signal would be reduced by 3 orders of magnitude. Even at 25 cm, the signal will be reduced by a factor of 100, the off-axis x-rays can be effectively blocked by a 25 cm x 25 cm sheet of 2 mm lead.

Conclusion: The Xoft skin applicator provides depth doses similar to other 50 kVp superficial systems. The dose profiles are similar to short SSD applicators. Film measurements in Solid Water, when appropriately calibrated and adjusted for density, can be useful to use metrology for verifying the relative dose distributions at this energy. An adjustment to the TG-61 specified method for measuring the HVL must be made. As compared to film, the choice of detector provides the clinical physicist with options for measuring energy and beam characteristics of the Xoft Surface Applicators.

References:


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