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Radiochromic Film Based Dosimetry of Novel Rectal Electronic Brachytherapy Applicator

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INTRODUCTION

The 50 kVp X-ray tube technique was clinically implemented by Jean Papillon, both as curative modality for early stage or as a pre-operative modality on T2, and T3 rectal adenocarcinomas. Technique survived to this date using the "end-on" geometry, where the radiation is emitted through the end of a rectoscope-like applicator.

Such "end-on" geometry may require applicator bending to accommodate for the target position and this process with knee-down prone position is very uncomfortable for patients.

Such discomfort might result in unwilling patient movement during treatment, which in result might lead to a treatment miss.

AIM

We recently finished development of a "side-on" geometry based rectal applicator that will also allow for patient treatment in supine position.

In this work we present results of radiochromic film based dose measurements of the new applicator employing the 50 kVp (Xoft) electronic-brachytherapy source.

METHOD

To perform output measurements, following the AAPM TG-61 reference dosimetry protocol (1), we measured first the HVLs for the new applicator using a calibrated parallel-plate Exradin A20 ionization chamber, and the very same ionization chamber was used to measure air-kerma in the air at 3 cm distance from the source. Calibration EBT3 film pieces were irradiated in air at 3 cm distance from the source (at the same position corresponding to the effective measurement point of the ionization chamber) and calibration curves were created in terms of air-kerma in air (K_{air}) air for Xoft 50 kVp source beam quality.

Film pieces were scanned using an Epson Expression 10000 XL scanner in transmission mode, and the green color channel was used for dose analysis. Scanning resolution was 127 dpi (0.2 mm/pixel) and the ROI size was 10 x 10 pixels (2 mm x 2 mm). As a response function we used normalized pixel value [$PV_{norm} = (PV_{unexposed}/PV_{exposed}) - 1$], the quantity that linearizes dose response, in which $PV_{unexposed}$ and $PV_{exposed}$ represent averaged (over sampling ROI) pixel values of an unexposed and exposed film pieces, respectively (2). It is important that the "unexposed" film piece originates from the same film lot-number (preferably from the same sheet) and to be always scanned together with the exposed film pieces.

Subsequently, pieces of EBT3 film were placed in front of the 3 cm diameter collimator opening of the applicator prototype placed within special phantom designed to mimic clinical situations. As the scatter is incorporated into the measured film response, such measured (K_{air}) phantom was converted into dose to water by multiplying it by the $(\mu_{en}/\rho)^{air}_{wat}$ for a given beam quality (3) determined by measured HVL, following the AAPM TG-61 protocol.

RESULTS

The new applicator design retains cylindrical shape but has an opening on the side, close to the tip of the cylinder, which can have variable collimator size openings (1, 1.5, 2, 2.5, and 3 cm diameter). Beam quality of the new applicator assembly was measured to be 0.4 mm Al. This source is stepping through a plastic sheath, which has to assure reproducible source motion within the applicator. Figure 1 summarizes results of our dose measurements around novel 50 kVp rectal applicator. We found that the most uniform dose distribution is obtained by stepping the source over 13 dwell positions, 0.5 cm apart, with first 10 positions set at 20 seconds and the last 3 positions (towards the tip of the applicator) set at 25 seconds. Boost at the end was needed due to non-radial dose distribution in the close vicinity of the source. The dose variation was 5% in both longitudinal and transversal direction (with respect to source motion axis). The output with such plan was measured to be 7 Gy/min.

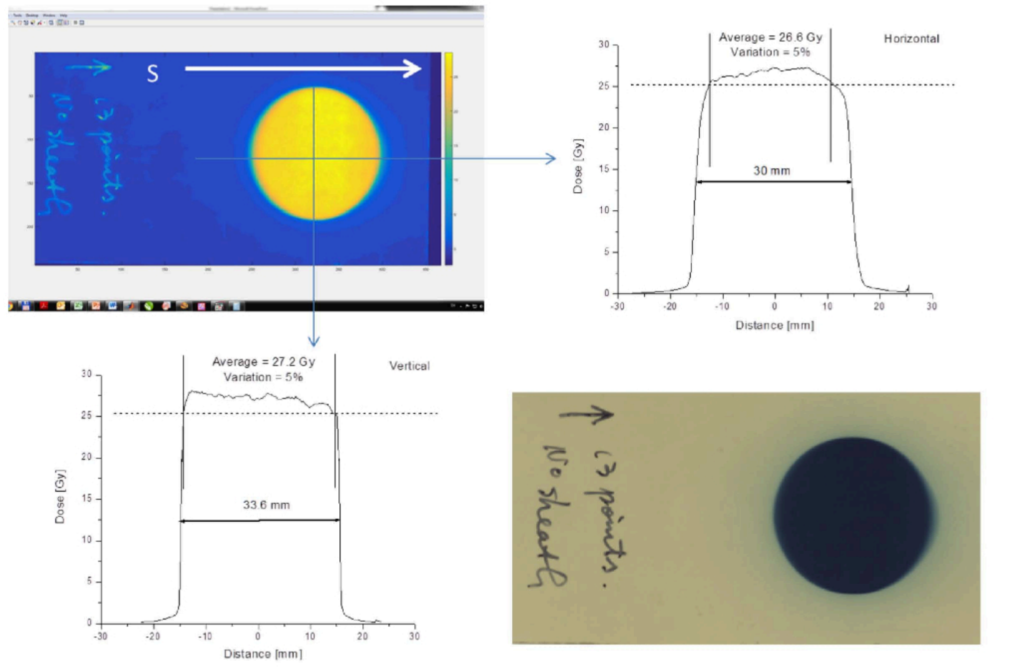

Figure 1: Results of dose distribution measurements around novel 50 kVp rectal applicator: 2D dose distribution (up-left); horizontal dose profile (up-right); vertical dose profile (bottom-left); measurement film piece (bottom right).

CONCLUSIONS

The results from the film measurements confirm that the side-on applicator developed could be used clinically for rectal cancer treatments.

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