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Developing a simple commissioning protocol for Leipzig brachytherapy surface applicators using only radiochromic film

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ABSTRACT

Purpose: To develop a simple protocol for dose verification of Leipzig surface HDR applicators using Gafchromic EBT3 film.
Methods: Although radiochromic film is considered to display an energy independent response to high energy photons, calibration measurements were taken using both a 6X linear accelerator beam and an Iridium-192 HDR source. Surface applicator calibration measurements were made with films at two depths in solid water, 3mm at multiple dose points, and 5cm at a single dose point of 1Gy. Applicator film dose was calculated pixel-wise, averaged over a 1cm diameter ROI, and compared to average treatment planning dose over a similar contour.
Results: When fit to the same calibration dataset, the rational function and polynomial fits represented essentially equivalent curves. However, the Iridium-192 and 6X calibrations diverged strongly with increasing dose. At a pixel value of 15000, the iridium curve reached 885cGy, while the 6X curve computed 710cGy. Using the 6X rational function calibration, the average film difference from TG-43 dose, at 3mm depth, was -4.96%+/-4.44% (standard deviation). The 7Gy dose point and 40mm cone showed distinctly better agreement than the others. Film measurements at 5cm depth showed greater differences from TPS dose, with an average of -10.3%.
Conclusion: Further investigation is necessary to develop a film dosimetry protocol which responds accurately and linearly to surface applicator dose.

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INTRODUCTION

Previously published methods of Leipzig surface brachytherapy applicator commissioning measure dose with a custom positioning jig and Exradin A20 ionization chamber, which is primarily designed for kV X-ray dosimetry [1]. The goal of this study is to develop a dose measurement protocol which can be implemented using only detectors and software packages commonly available in the radiotherapy clinic, in order to make Leipzig applicator commissioning a more generally accessible process. Calibration curves generated with a brachytherapy source, as opposed to with a 6X photon beam, may eliminate some sources of systematic error, such as potential minor energy dependence, and so were a primary focus of protocol development. Calibration curves developed using a polynomial fit, as used clinically at our institution, and those developed with a rational function fit, as recommended by the manufacturer, were also compared.

METHODS AND MATERIALS

The 6X calibration irradiations were performed with a 10x10cm field size at 100SSD and under 10cm solid water with backscatter. Iridium-192 calibration irradiations were performed with four dwell positions in a Freiburg flap applicator above a solid water phantom. The assembly was scanned in a CT simulator and expected dose at a reference point centered between the dwell positions was calculated with the TG-43 algorithm. Film was scanned after 24 hours and red channel pixel value to dose calibrations were generated by fitting a 6th-order polynomial and a rational function of the form y=a+b/(x-c) to each dataset. Iridium calibration red channel values were measured as the average value over a 1mm diameter ROI centered between the four dose hotspots visible on the measurement film. Leipzig measurements were also performed using solid water, with the film under a 3mm sheet, to verify 30, 35, 40, and 45mm applicators. Four dose points were measured: 1, 3, 5, and 7Gy. Additionally, surface applicator dose was measured in a solid water phantom at 5cm depth, for all applicator sizes, at a dose point of 1Gy. This was intended to reveal whether sharp spatial dose gradients near to the source, or air gaps forming between thin solid water slices, were contributing to dose uncertainty. EBT3 Gafchromic film was used for all calibrations and measurements.

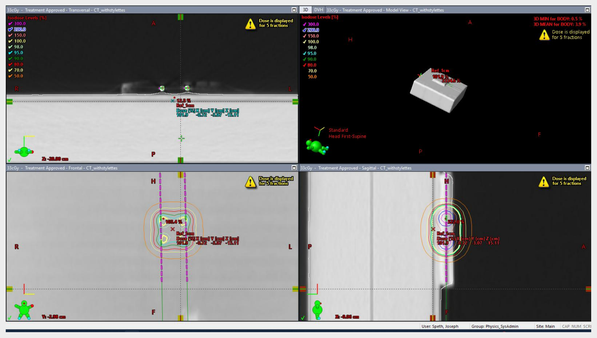

Figure 1. Freiburg Flap Film Calibration Geometry

RESULTS

Figure 2 shows, over a relevant segment of the fitting range, the equivalence of rational and polynomial function fits to calibration data, and the unexpectedly large nonequivalence of Iridium and 6X calibration datasets. The Iridium calibration measurements may be skewed by the difference in volume averaging between the film active layer*readout region area and the effective volume represented by the dose reference point value in the treatment planning system (TPS) dose matrix.

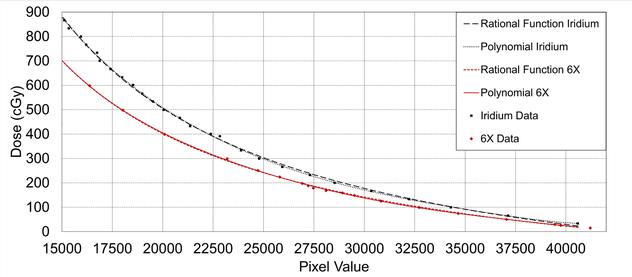

Figure 2. Comparison of Calibration Curves

Figure 3 shows the discrepancies in average dose between film measurement at 3mm depth and equivalently sized TPS region of interest over the central 1cm diameter of the surface applicator field, for all dose points and applicator cone sizes. Film dose was computed pixel-wise using the 6X rational function calibration, which agreed more closely with the expected dose than the Ir-192 calibration. The average percent difference was -4.96%+/-4.44% (standard deviation).

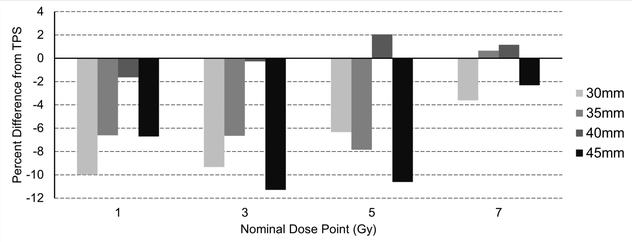

Figure 3. Surface Applicator TPS Dose Comparison to 6X Calibrated Film Dose

Table 1. Measured vs TPS Dose at 5cm Depth

Applicator Size (mm)	Measured Dose (cGy)	TPS Dose (cGy)	Percent Difference
30	88.83225669	100.89	-11.95137606
35	92.35592313	100.83	-8.404321006
40	84.45049872	100.76	-16.186484
45	95.72801044	100.61	-4.852389981

Table 1 shows the discrepancies in average dose between film measurement at 5cm depth and equivalently sized TPS region of interest over the central 1cm diameter of the surface applicator field, for all applicator cone sizes at one dose point. Film dose was again computed pixel-wise using the 6X rational function calibration. The average percent difference was -10.3%+/-4.85% (standard deviation).

DISCUSSION

As shown in Figure 2, the choice of fitting function was not seen to have a major effect on the film calibrations. The Iridium and 6X calibration datasets did significantly and unexpectedly diverge over the calibrated range. This is unlikely to be solely due to film energy dependence. Any energy dependence of film response should be of a much smaller magnitude than the difference we observed between calibrations, and the 6X curve gave better agreement with the TPS when used to convert the surface applicator film data to dose. It is also unlikely to be due to random noise in the calibration measurements, as the individual datapoints visibly align well with their respective fitted curves. There is likely still some systematic error in our Iridium calibration protocol, which may have to do with setup uncertainty in high dose gradient regions near the source, or digitization error involving the TPS dose matrix voxel dimensions

Film measurements at 3mm depth were converted to dose with the 6X rational function curve and displayed in Figure 3. Dose values calculated with this curve tended to be lower than TPS values. Some individual measurements displayed >10% differences, which was considered unacceptable for surface applicator dose commissioning. Measurements at 5cm depth showed much worse agreement with TPS, both in terms of maximum and average percent differences. This indicates that issues that are minimized at greater depths, such as setup errors and high dose gradients near the source, were a smaller contribution to surface applicator measurement error than issues that are magnified at greater depths, such as potential non-water equivalence of our solid water at brachytherapy photon energies.

CONCLUSIONS

More work will be necessary to develop a fully satisfactory protocol by which Leipzig-style brachytherapy surface applicators may be commissioned using radiochromic film to verify dose output. It seems likely that calibration curves made using a flattened 6X linac beam have advantages in convenience and robustness over those made using the relevant brachytherapy source. If measurements are made in a solid water phantom, measurements made at several millimeters depth may correspond better to TPS dose calculations than those made at several centimeters depth.

REFERENCES

1. Iftimia, I., McKee, A.B. and Halvorsen, P.H. (2016), Varian HDR surface applicators — commissioning and clinical implementation. Journal of Applied Clinical Medical Physics, 17: 231-248. https://doi.org/10.1120/jacmp.v17i2.6033

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