CHARACTERIZING THE RESPONSE OF A CONICAL, SCINTILLATION-BASED DETECTOR FOR MACHINE AND PATIENT-SPECIFIC QUALITY ASSURANCE APPLICATIONS IN PHOTON RADIOTHERAPY

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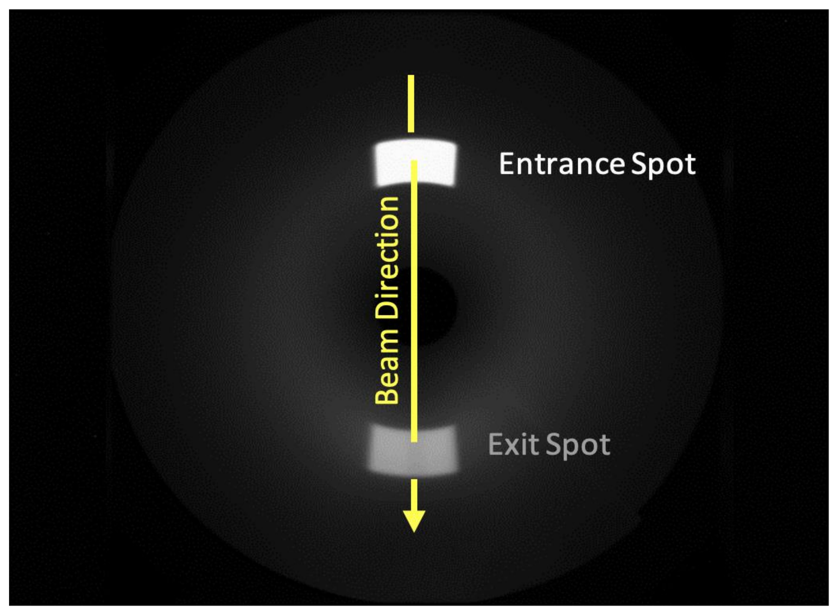
PURPOSE

To evaluate the potential application of a conical, scintillation-based detector for machine and patient-specific QA by assessing signal dependence on irradiation conditions and device acquisition parameters. The XRV-124 scintillation detector (Logos Systems International) has advantages that may apply to this application including high spatial resolution, 3D measurement capabilities, independence from the treatment machine, and avoidance of excess collision risk. QA applications such as patient-specific IMRT and SBRT QA feature a broad range of energies, dose rates, and aperture sizes. To be used in this context, the signal response and behavior of the device as a function of these factors must be thoroughly understood.

METHODS

Extensive characterization of the device concerning a broad range of energies, dose rates, and aperture sizes is required to extend the use of a scintillation detector typically used for geometric targeting accuracy. For this purpose, we used a conventional c-arm linac to irradiate the device with square fields of varying size (1x1cm, 3x3cm, and 5x5cm), longitudinal position, gantry angle (45° increments), energy (6MV, 6MV FFF, 10MV FFF), and dose rate (100-2000MU/min). Vendor-provided software was used to analyze both the entrance and exit scintillation spots observed for each irradiation to determine the effect of these variables on the device response. The dependence of device response on acquisition settings such as gain and frame rate was also analyzed. For each unique measurement, 3 replicates were performed. The mean, standard deviation, and coefficient of variation of these replicates was analyzed to gain an understanding of device precision and variability of results.

The vendor-provided software is capable of integrating the normalized scintillator intensity of each beam over time, accounting for different camera gain and frame rate settings. To generate this value, the software uses the camera parameters used during beam capture, and corrects the reading relative to a reference frame rate (fps) and reference gain (dB). This work evaluated the original normalization equation by comparing the measured coefficient of variation of raw data to that of the corrected data, and further characterized the normalized readings as a function of dose rate.

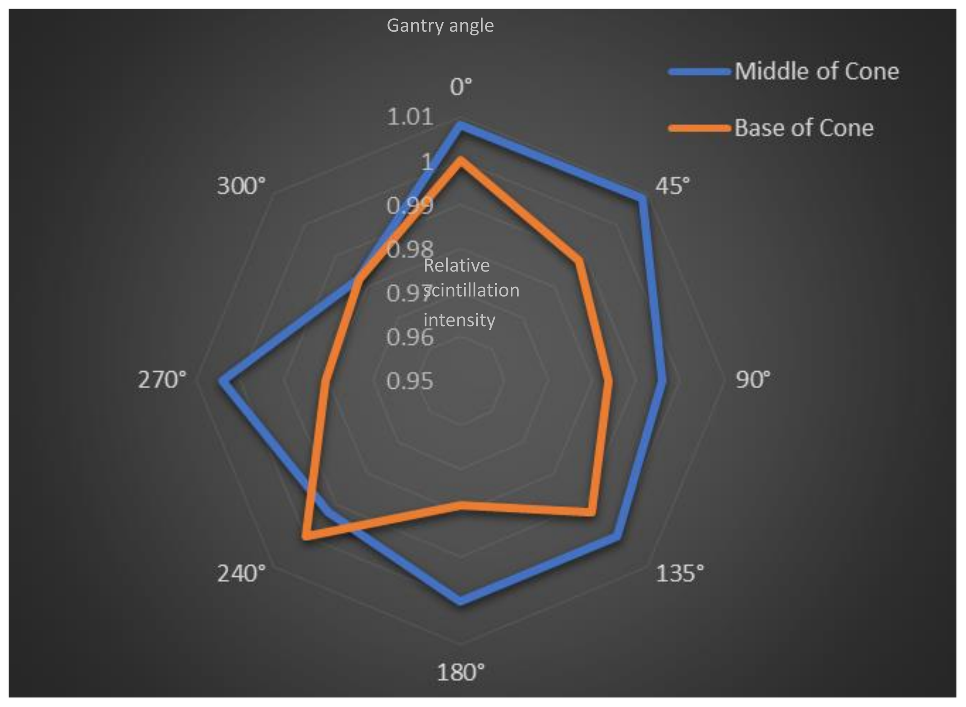


Scintillating device at left with CCD camera opposite the cone. At right, an image frame during irradiation showing entrance and exit spots, viewed along central axis of the cone from the base.

RESULTS

Across all replicate measurements, the coefficient of variation was observed to be 1.3%, indicating good precision of the device from one measurement to the next over several hours of use.

Differences in scintillation intensity with varying incident gantry angles were small (0.8%) although larger systematic differences were observed based on longitudinal position of the device (1.1%).



Relative scintillation intensity as a function of longitudinal position and gantry angle.

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RESULTS CONTINUED

As can be seen in the figure below, after renormalization by the proposed original equation (Equation 1), the scintillation intensity still demonstrated a considerable dependence on dose rate. We therefore implemented an additional correction factor to remove this dependence (Equation 2) in an effort to allow direct comparison of measurements acquired with different dose rates. This refined normalization equation considerably decreased the coefficient of variation for measurements that differed in dose rate but were otherwise acquired with identical parameters.

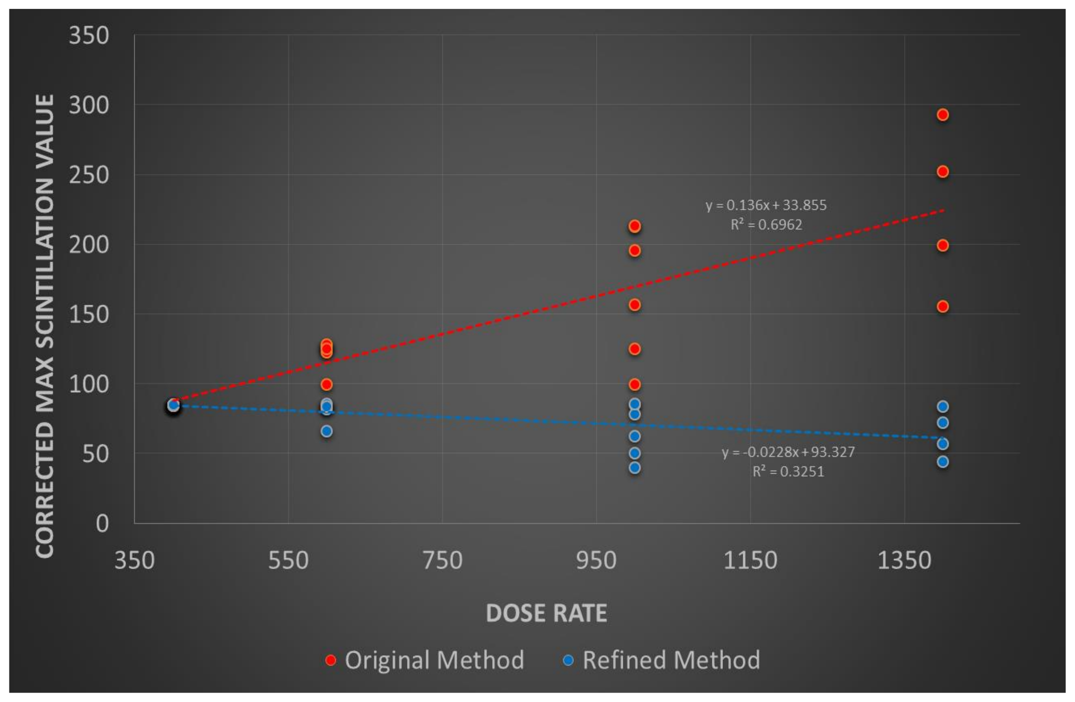
$$Normalized\ Signal = Gray\ Value \times \frac{Frame\ Rate\ Multiplier}{Gain\ Ratio\ Divisor};\ \text{where:} \qquad (1)$$

$$Frame\ Rate\ Multiplier = \frac{Measurement\ Frame\ Rate}{Reference\ Frame\ Rate};\ \text{and,}$$

$$Gain\ Ratio\ Divisor = 10^{\frac{Measurement\ Gain - Reference\ Gain}{20}}$$

$$Normalized\ Signal = Gray\ Value \times \frac{Frame\ Rate\ Multiplier}{Gain\ Ratio\ Divisor \times Dose\ Rate\ Divisor};\ \text{where:} \qquad (2)$$

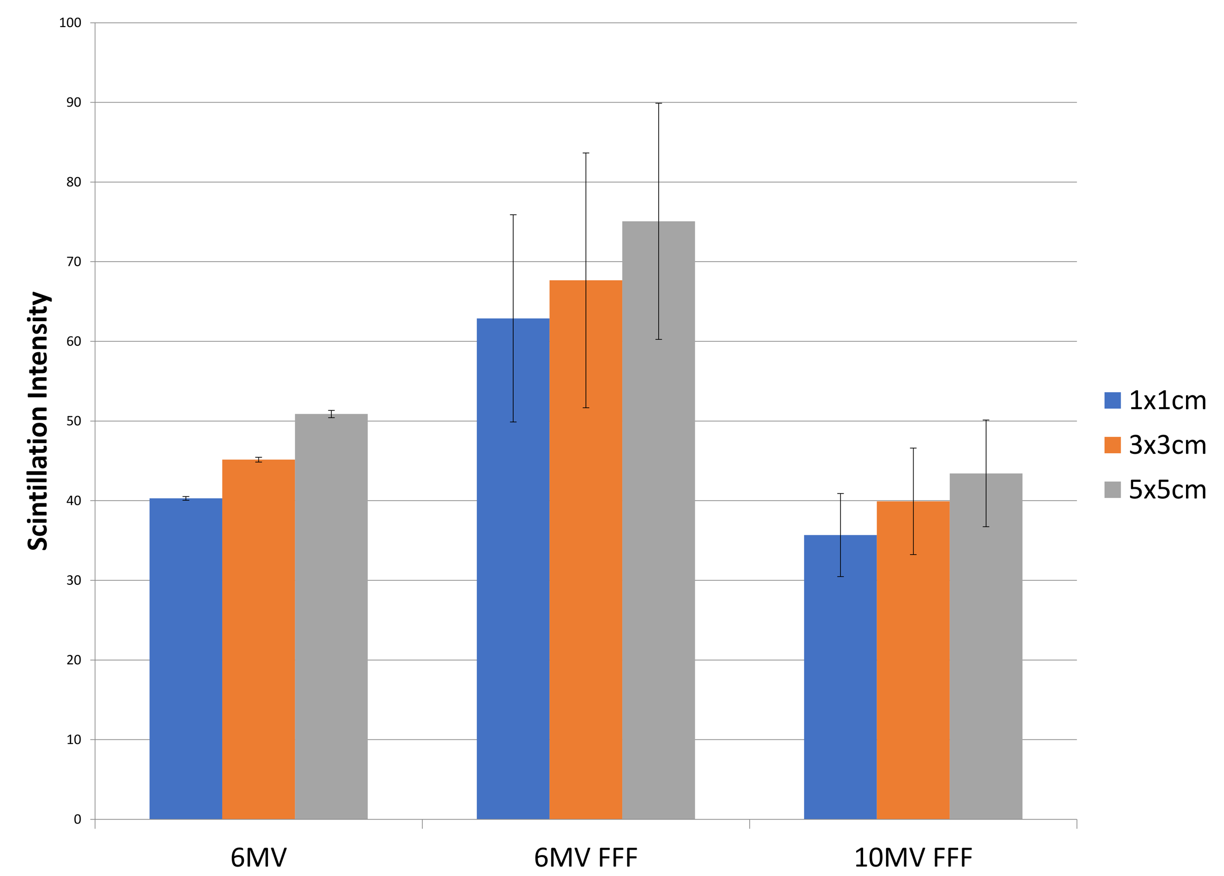
$$Dose\ Rate\ Divisor = \frac{Measurement\ Dose\ Rate}{Reference\ Dose\ Rate}.$$



		Correction Method	
Field Size	**Beam Energy**	**Original**	**Refined**
1x1cm	**6MV**	19.20%	0.56%
	6MV FFF	42.14%	20.68%
	10MV FFF	41.61%	14.62%
3x3cm	**6MV**	17.67%	0.67%
	6MV FFF	41.44%	23.65%
	10MV FFF	46.42%	16.76%
5x5cm	**6MV**	20.46%	0.91%
	6MV FFF	42.32%	19.74%
	10MV FFF	43.55%	15.43%

At left, plot of scintillation values as a function of dose rate. One series having the dose rate normalization in the correction factor (blue data series), the other not (red data series). At right, a table displaying coefficients of variation for beam data of various field sizes and energy for series with and without this dose rate correction.

The figure below displays the corrected maximum scintillation intensity for three different beam energies at three field sizes. In measurements, the 6MV beam exhibited the smallest standard deviation. For each beam energy, signal intensity increased as a function of field size



Scintillation intensity as a function of energy and field size with error bars of +/- one standard deviation.

CONCLUSIONS

Our characterization of a conical, scintillation-based detector demonstrates the signal response depends on irradiation and acquisition parameters including field size, irradiation position and angle, gain, frame rate, and dose rate. The original normalization equation was expanded to consider dose rate effects on signal in addition to frame rate and gain. Understanding the influence of these factors on the device is imperative for its application to a broader range of QA applications such as patient-specific intensity modulated QA.