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Optimization of the Design of Portal Imaging Systems Incorporating Thick, Segmented Scintillating Detectors Employed for Megavoltage Cone-beam CT through a Novel Hybrid Modeling Technique

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SST15-06

Langechuan Liu
Larry E Antonuk , PhD
Hao Jiang
Youcef El-Mohri , PhD
Qihua Zhao , PhD

PURPOSE
Active matrix flat-panel imagers (AMFPIs) incorporating thick, segmented scintillators have demonstrated order-of-magnitude improvements in DQE at radiotherapy energies compared to systems based on conventional phosphor screens. Such improved DQE values facilitate megavoltage cone-beam CT (MV CBCT) at clinically practical doses – providing distinct advantages over kV CBCT performed using additional on-board imaging equipment. However, the MV CBCT performance of such AMFPIs is highly dependent on the design parameters of the scintillators. In this presentation, a theoretical examination of imaging performance as a function of these parameters is reported.
METHOD AND MATERIALS
The imaging performance of various scintillator designs was examined through a hybrid approach involving Monte Carlo simulation of radiation transport and determination of optical point spread functions. For each design, a full tomographic scan of a contrast phantom incorporating various soft-tissue inserts was simulated at a total dose of 3 cGy. This novel technique was validated through comparisons of theoretical predictions of contrast, noise and contrast-to-noise ratio (CNR) with measurement results obtained from a 1.13 cm thick, 1016 µm pitch BGO prototype.
RESULTS
Theoretical values for contrast, noise and CNR were found to be in close agreement with measurements for the BGO prototype, strongly supporting the validity of the modeling technique. For various other scintillator designs, results for CNR demonstrate improvement by a factor of ~2.2 when the scintillator thickness is increased from 1.13 to 6 cm, and an improvement by a factor of ~2.6 when the pitch is increased from 508 to 1016 µm. Finally, optimization of design based on a trade-off between thickness and pitch, along with evaluation of the corresponding spatial resolution performance, is discussed.
CONCLUSION
A new technique to model both radiation and optical effects was validated and employed to accurately evaluate the MV CBCT performance of MV-AMFPIs incorporating various segmented scintillator designs. It appears that significant improvement in the imaging performance of such AMFPIs can be achieved through optimization of scintillator design parameters.
CLINICAL RELEVANCE/APPLICATION
Enhanced performance of MV-AMFPIs with segmented scintillators should greatly facilitate soft tissue visualization in external beam radiotherapy through MV CBCT imaging at clinically practical doses.