A photon scatter imaging system to guide radiation therapy of lung cancer

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Objective/Aim/Hypothesis:
Breathing motion is a fundamental challenge in external beam radiation therapy of lung tumors because the tumor location is not well-defined during treatment. To ensure that the tumor receives full radiation dose despite this motion, current clinical practice dictates that the target volume is defined to encompass the full extent of the tumor movement. As a result, healthy tissue surrounding the tumor is irradiated during the breathing cycle. Because the 4DCT may not capture the full range of motion, there is also the possibility that the tumor may stray from within the 4DCT-defined target volume. We hypothesize that a novel scatter imaging system can monitor and track the tumor position in real-time during lung stereotactic body radiation therapy (SBRT).

Design/Approach/Methods:
To characterize the scatter imaging technique, an analytical method was developed to simulate scatter images. The scatter images resulting from irradiation of a 3 cm-diameter lung tumor were simulated. Using a pinhole camera and a flat panel detector, scatter images were collected during the irradiation of two lung-tumor phantoms: a stationary, anthropomorphic phantom and a dynamic phantom that incorporates respiratory motion. The phantom tumor positions were identified on the collected scatter images and compared to the known positions. Finally, a crane-mounted prototype camera was constructed and used to collect scatter images during the treatment of eight (8) patients undergoing lung SBRT.

Results:
Using the developed analytical method, a lung tumor is clearly identifiable in the scatter images simulated from multiple detector positions. Using an open-field irradiation and an integration time of 300 ms, the dynamic phantom lung-tumor position was identified on the scatter images with a root-mean-squared error (RMSE) of 0.9 mm. When multileaf collimator modulation was incorporated into the delivered radiation field, the tracking accuracy was reduced to RMSE = 2.8 mm. Over 6,000 scatter images were collected during the irradiation of eight (8) lung cancer patients. Although the lung tumor and chest wall are discernable from lung tissue in some scatter image frames, the large isocenter-to-imager distance (50-110 cm) resulted in > 2 cm spatial resolution and > 5x lower photon counts than collected during preliminary phantom experiments.

Conclusion:
The scatter imaging technique was characterized through simulations. Preliminary experiments with phantoms demonstrate the potential for submillimeter tracking of lung tumor motion during radiation treatments, but beam modulation decreases accuracy. We present the first patient scatter images collected during radiation therapy. To further improve the quality of these promising images, we are developing strategies to increase the spatial resolution and low photon counts, issues which must be addressed to realize scatter image-guided, real-time lung tumor tracking.