Dual Energy Subtraction Imaging to Improve Tumor Visibility at Oblique Angles

Impact: Dual energy (DE) subtraction imaging can be applied to oblique angle planar imaging to increase tumor visibility for image-guided radiotherapy (IGRT) of lung cancer patients.

Introduction: In the treatment of lung cancer, daily kilovoltage (kV) on-board imaging is used to assist with patient positioning. Using image registration software, the therapists overlay planar kV images on planning digitally reconstructed radiographs (DRRs). The images are aligned based on visual cues that include both bony (ribs, vertebra) and soft tissue (carina, tumor) landmarks. While these individual structures can be easily highlighted on DRRs, as shown in the 120 kVp exposure in Figure 1 and 2, soft tissue landmarks may be obstructed and difficult to visualize on kV images. One solution to this problem that can be incorporated within the existing On-Board Imager (OBI, Varian Medical Systems, Palo Alto, CA) framework is the use of dual energy (DE) subtraction imaging [1].

DE subtraction involves obtaining sequential images at a “high” energy (i.e. 120 kVp) and a “low” energy (i.e 60 kVp). By performing a weighted logarithmic subtraction, bone can effectively be removed from the resultant image [2]. DE imaging has been shown to increase soft tissue visibility and lesion detection in diagnostic radiology [3]. However, most diagnostic x-ray DE imaging is performed in anterior-posterior view; in clinical radiotherapy oblique angles are important as they correspond to the angle of the treatment beams. This study demonstrates the potential clinical efficacy of DE methods in imaging tumors at various angles of gantry rotation.

Methods: Paired high and low energy exposures were obtained about a simulated tumor (2.3 cm in diameter) located in the middle left mediastinal shadow in an Alderson Lung/Chest anthropomorphic phantom (Radiology Support Devices, Long Beach, CA). Image sets were obtained every 10° for a full (360°) rotation using the OBI. The OBI mAs settings were optimized to best suppress the bone overlaying the simulated tumors. DE images were then created using weighted logarithmic subtraction, and simulated tumor visibility in the DE image sets was measured using the Contrast-to-Noise Ratio (CNR) and compared with single exposure images similar to clinical imaging protocols.

Results: In order to quantify the improvement in simulated tumor visibility, the ratio of the CNR from the DE image relative to a single image (standard protocol) was considered. As seen in Figures 1 and 2, DE imaging can greatly reduce anatomical clutter obstructing the view of the tumor. At 20° the CNR is improved by a ratio of 1.25 and at 170° CNR is improved by a ratio 1.54. Figure 3 illustrates the improvement in CNR versus gantry rotation. CNR values were improved by an average ratio of 1.66 over all gantry angles. It is interesting to note how the
CNR varies based on the overlapping anatomical structure in an individual projection. In cases where the simulated tumor overlaps the heart, or the dense spine, as expected, only limited improvement is observed in the CNR. However, in cases where the simulated tumor overlaps the ribs, significant improvement both quantitatively (Figure 3) and qualitatively (Figures 1 and 2) is observed.

**Conclusions:** This study illustrates the improvement in a simulated tumor visibility using DE imaging at oblique gantry angles. It also highlights the features of the OBI that make it unique compared to standalone DE imaging systems – the ability to rotate around the patient. Incorporating DE imaging into the clinical practice will allow for verification of tumor position at oblique gantry angles, and may facilitate the development of markerless motion tracking techniques.

**References:**

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**Figure 2:** Simulated tumor in 120 kVp image versus the DE bone suppression image. Tumor visibility is improved following DE subtraction.

**Figure 3:** Improvement in CNR ratio of DE subtraction imaging versus single exposure. Improvement was highly dependent upon the material obstructing the tumor, and thus gantry rotation. Labeled regions delineate between angles in line with heart and spine, which showed modest CNR improvement, and those obstructed by rib, which showed higher CNR improvement.