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Potential Effect of Rotational Variations on Live Tumor Tracking, and a Method for Improvement

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Abstract
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Abstract

Objective: Impact of rotational variations on live tracking accuracy is assessed. A method using standard user-interface features is proposed to optimize tracking accuracy.

Methods: Live motion tracking in the CyberKnife version 11.1.3 console software has the rotational RoboCouch controls locked by default, and the maximum tracked roll and pitch are +/- 1.5 degrees; and +/- 3 degrees for yaw. Potential effects of tumor rotations in excess of 1.5 degrees are investigated, and a process to optimize usage of the full rotational range is proposed.

From simple trigonometry we know that the tangent of 1.5 degrees is approximately 1/40; which implies that a rotation of 1.5 degrees can result in targeting differences larger than 1mm to any object more than 40mm from the centroid of tracking. Therefore a simple procedure is proposed to center the rotations across the peak and valley of the breathing cycle.

After the peak and valley of the patient's breathing are acquired via onboard stereoscopic x-ray imaging, the console software automatically writes the average shift in the x, y, z couch controls, and automatically displays the roll, pitch, and yaw rotational averages, but the rotational couch controls are locked. The proposed method is to temporarily switch to Manual Mode and hand-type the rotational averages into the couch controls, so that a single click of the move-couch button can correct both the average shift and the average rotation. Then the mode can be switched back to Automatic, to capture a centered peak and valley of the breathing. As long as the shifts and rotations are consistent, one iteration may be sufficient, or the method can be repeated.

The accuracy of the rotation estimate depends on how well the fiducial constellation in the live images agrees with the DRRs, i.e., the size of the "rigid body errors. Therefore, when rigid body errors are high, it might not be worthwhile to attempt rotational corrections, and when rigid body errors are low, it may be worth the effort to be more persistent on trying to center the rotations across the peak and valley of breathing.

By fusing normal inhale to normal exhale CT scans in the treatment plan, the maximal rotations from peak to valley of the breathing cycle can be anticipated in advance, and if they are likely to exceed 1 degree it is wise to fuse with shifts only, and to account for all rotational deviations of tumor and adjacent critical structures in the contours, in case it is not possible to track rotations during treatment. When the plan is designed this manner, it makes decision-making at the console easier, so that if the rotational excursion exceeds +/- 1.5 degrees, or if centering is difficult, at least it is known that the treatment plan was designed to accommodate the uncertainty.

Results: The proposed method does not require any additional x-ray images to be taken, only that the mode be temporarily switched to Manual, that the roll, pitch, and yaw be manually transcribed into the couch controls, and that the mode then be switched back to Automatic. Fusion of normal inhale to normal exhale scans can be used to accommodate rotations in the planned contours in the treatment plan, in case rotations exceed the +/- 1.5 degree limitation during treatment. For most patients, however, it is hoped that this method can enable the treatment accuracy to be improved.

Conclusion: Even when rotational corrections need to be turned off, Synchrony still tracks the tumor shifts continually while the radiation beam is on, which is an improvement over many other treatment delivery systems. With the proposed method, it is hoped that rotational corrections can also be tracked for more patients to further improve live targeting accuracy.