Purpose: The CyberKnife™ compensates translational target motion by moving the beams synchronously. While the system was found to operate with sub-millimeter accuracy in phantoms, determining the clinical accuracy is challenging. Measuring the delivered dose distribution inside a patient is impractical. Hence an analysis of treatment data is typically used to estimate residual errors.

Methods: We implant 3-5 fiducials for target tracking and treat liver tumors in 3-5 fractions with 45Gy at 80% to the PTV (CTV+3mm). Patients are aligned based on X-ray images in expiration breath hold. During delivery, X-ray images are acquired every 60-90s, and the translational and rotational misalignment is computed. We grouped this data into 10 respiratory phases. The mean misalignment for each phase was used to simulate the translation and rotation of the target with respect to the alignment center. The resulting dose distribution was computed and compared to the planned dose. Additionally, the quality of motion prediction was evaluated.

Results: We analyzed 5 cases with a total of 17 fractions. The maximal target motion per fraction ranged from 9.2mm to 25.7mm (3D trajectory). The mean error for each patient ranged from -0.76/-0.01/-0.32mm to 0.35/0.17/0.10mm (Translation IS/LR/AP) and -0.94/-0.82/-2.07 degrees to 0.24/1.95/2.36 degrees (Rotation roll/pitch/yaw). The dose simulation showed point dose difference for each patient ranging from -0.10Gy to -0.76Gy (Mean) and -1.13Gy to -5.05Gy (Max). The resulting reduction in coverage ranged from 0.37% to 4.19% (PTV) and -0.43% to +0.94% (CTV). Finally, the mean prediction error over all fractions was 0.33mm.

Conclusions: We demonstrated that while maximum point dose differences can be considerable, the coverage of the CTV is maintained even in the presence of substantial respiratory motion. The results indicate that the standard 3mm system uncertainty margin can account for errors due to rotation and deformation during robotic radiosurgery for tumors in the liver.