Real-Time Target Tracking in Pancreatic SBRT: Characterizing the Clinical Impact

Corresponding author: Bernard Jones

1. Radiation Oncology, University of Colorado School of Medicine, Denver, USA 2. Radiation Oncology, University of Colorado Sc, Aurora, USA 3. Radiation Oncology, University of Colorado School of Medicine, Aurora, USA 4. Radiation Oncology, University of Colorado School of Medicine, Aurora, USA 5. Radiation Oncology, University of Colorado School of Medicine, Aurora, USA

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Abstract

Objectives: Abdominal motion can increase the risk of toxicity and hinder dose-escalation in Stereotactic Body Radiotherapy (SBRT) of pancreatic tumors. Real-time imaging and tracking is an emerging technique to increase the accuracy of delivery. We report on a large, retrospective cohort of pancreatic patients treated with real-time, fiducial-based kV image guidance. The purpose of our study was to determine the clinical and dosimetric impact of real-time target tracking in pancreatic SBRT by answering three key clinical questions: what is the impact of real-time target tracking on 1) clinical workflow, 2) treatment accuracy, and 3) tumor dose? To answer these questions, we retrospectively analyzed data collected during pancreatic SBRT with real-time target tracking.

Methods: 68 patients were treated with pancreatic SBRT under real-time kV image guidance. kV images were acquired during treatment to visualize the location of implanted fiducial markers. Corrections were made to the position if the markers were observed >3 mm from the expected reference position. To understand impact on treatment accuracy and clinical workflow, we retrospectively analyzed all treatment interruptions and corrections made based on this imaging. To assess the dosimetric impact of the real-time imaging, an artificial neural network dosimetric model was trained with prior clinical plans to calculate the impact of real-time imaging interventions on tumor dose.

Results: Real-time imaging resulted in 0.81 pauses per fraction of treatment. 60% of the treatment pauses were due to having to adjust the gating thresholds and 40% were due to having to re-localize the target. The average time per pause was 1.9 ± 1.8 minutes. Treatment pauses that required patient re-alignment due to real-time tumor tracking occurred during 32% of all fractions. The median shifts for patient re-alignment were 0.8 mm (AP), 4.0 mm (SI), and 1.2 mm (LR). The median radial (3D) shift was 5.2 mm. 41% of all patients had at least one shift throughout the course of treatment with magnitude >5 mm, and 16% of all fractions had at least one treatment pause that required an alignment >5 mm. 45% of shifts resulted in dosimetric differences to the tumor; of these, the median point dose difference was 23% ± 22% of prescription dose (max 94%). The number of pauses per fraction was significantly higher in patients treated with respiratory gating (vs. abdominal compression) and in patients with greater treatment time.

Conclusions: In this study, we demonstrated the feasibility of fiducial-based real-time target tracking for pancreatic SBRT treatment, and quantified the benefits of this imaging to increase the accuracy of pancreatic SBRT. This dataset represents, to our knowledge, the largest
experience treating these tumors with fiducial marker-guided in-treatment kV imaging. Our data indicate that real-time tumor tracking leads to patient re-alignment in 32% of cases and results in significant dosimetric benefit to target coverage. The increased accuracy of real-time target tracking may potentially enable safe dose escalation in pancreatic SBRT.