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Feasibility of Patient-Specific Quality Assurance (PSQA) for Real-Time Robotic Stereotactic Body Radiotherapy (SBRT) Based on Patient Breathing Traces

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Abstract
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Nie Wei [1] , Qianyi Xu [1] , Ashish Chawla [2] , Yevgeniy Vinogradskiy [3] , Kiet Huynh [1] , Tamara LaCouture [4] , Gregory Kubicek [5] , Jiajin Fan [2]

1. Advanced Radiation and Oncology and Proton Therapy, Inova Schar Cancer Institute, Fairfax, USA 2. Advanced Radiation Oncology and Proton Therapy, Inova Schar Cancer Institute, Fairfax, USA 3. Radiation Oncology, Thomas Jefferson University, Philadelphia, USA 4. Radiation Oncology, Jefferson Health, Sewell, USA 5. Radiation Oncology, MD Anderson at Cooper University Hospital, Camden, USA

Corresponding author: Nie Wei, wei.nie@inova.org

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Abstract

Objectives:

The CyberKnife Synchrony system is used to track targets and delivers lung and liver SBRT in moving anatomy. A patient specific quality assurance (PSQA) has not been performed on the CyberKnife Synchrony system. The purpose of this work was to use a motion phantom driven by patient breathing traces and a high-resolution detector array to 1) design a PSQA process for the CyberKnife Synchrony system and 2) to quantify the dosimetric accuracy of the CyberKnife Synchrony tracking system.

Methods:

The CyberKnife Synchrony system was evaluated using a motion platform (MODUSQA) and a SRS MapCHECK phantom. MODUSQA motion platform. The motion platform was capable of moving in the superior-inferior (SI) direction according to a realistic patient breathing signal. Two self-adhesive cater wheels were inserted underneath the moving platform to introduce lateral motion (± 2 mm) and pitch angles (4.0° ± 0.6° and 1.2° ± 0.1° separately). The patient breathing signals extracted from Synchrony logfiles were scaled to the maximum motion range and fed into the platform. The high-resolution detector array (SRS MapCHECK) housed by the StereoPhan was placed within a Styrofoam holder on the platform. A CT scan with 1.25 mm slice thickness was performed and imported into the Precision TPS to generate a phantom plan. Four fiducials in the detector array were extracted for Synchrony tracking.

A total of 10 CyberKnife lung/liver patient QA plans were delivered to the SRS MapCHECK on the motion platform under the Synchrony tracking mode. The motion platform provided a plate with synchronized motion in AP, where the Synchrony LED was placed for real-time tracking. When the added pitch angle was < 1.5°, the robot angle correction was turned on, otherwise it was turned off (boundary check was on) during delivery. The delivered dose was compared to the QA plan dose calculated after overlaying the patient plans with the phantom plan. All the results in the study were benchmarked by the PSQA results based on the static SRS MapCHECK phantom.

Results:

For static SRS MapCHECK phantom, the corresponding mean passing rates were 99.7% ± 0.8% for 3% 1mm and 99.6% ± 0.4% for 2% 1mm. For Synchrony PSQA, the averaged delivery time was 19 ± 4 minutes. During Gamma analysis, no extra shifts and rotational correction were applied to the results. For smaller pitch angles (1.2° ± 0.1°), the mean passing rates were 99.5% ± 1.3% and 97.9% ± 3.5%, for 3% 1mm and 2% 1mm respectively. Large discrepancy in the passing rates was observed for different pitch angles due to limited capability of angle correction by the robot. For larger pitch angles (4.0° ± 0.6°), the mean passing rates were 92.7% ± 12.7% and 88.8% ± 15.6%, for 3% 1mm and 2% 1mm respectively. When comparing the results from the static phantom, no significant statistic difference was observed for smaller pitch angles ($p = 0.22$ for 3% 1mm and $p = 0.08$ for 2% 1mm), whereas a larger statistic difference was observed for larger pitch angles ($p = 0.06$ for 3% 1mm, and 0.03 for 2% 1mm).

Conclusion(s):

The significance of this work is that it is the first study to benchmark PSQA for the CyberKnife Synchrony system using realistically moving phantoms. With reasonable delivery time, we found it is feasible to perform PSQA with a realistic breathing pattern for Synchrony patients with superior Gamma passing rates. Special attention needed to be paid to robotic angle corrections since the passing rates dropped after the correction was turned off, though still met TG 218 recommendations.