# Commissioning, Performance and QA Tests for Real-Time Motion Tracking and Correction with MLC and Jaws

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## INTRODUCTION

In 2019, Accuray introduced a first commercial motion compensation system for tumor motion management in radiotherapy, Synchrony on Radixact.[1] The system utilizes a 90˚-offset-mounted 2D kV x-ray imaging component to monitor either implanted fiducials or lung tumor, together with external surrogates (LED markers) when tumor motion is caused by respiration, to instruct binary MLC and jaws for motion correction during helical tomotherapy delivery.[2] The system offers 3 tracking modes: fiducial with non-respiratory (FNR), fiducial with respiratory (FR), and fiducial-free with respiratory (FFR) tumor motion. The first clinical Synchrony on Radixact system was installed at Froedtert & Medical College of Wisconsin in the summer of 2019.[3]

## AIM

Prior to the clinical use of the system, commissioning and quality assurance (QA) tests were performed in order to verify the mechanical and dosimetric performance of the system. These tests include measuring the extra dose from the tumor motion monitoring kV radiograph images, investigating the effect of jaw and MLC motions on the characteristics of the treatment beams and the efficacy of jaw and MLC tracking which is subject to the spatial and temporal resolution of the target localization and system lag times.

## METHOD

The kV imaging dose, quantified by weighted CTDI, was measured with a pencil chamber inserted in a center and 4 peripheral locations in a CTDI phantom, placed at the machine isocenter with its longitudinal axis aligned to IEC Y. At each chamber location, multiple kV radiograph images were acquired with static couch.

Tracking plans were generated on fiducials or high-contrast-block embedded 3D phantoms and delivered with them placed on certain motion platforms driven by various motion traces. Such 3D phantoms and motion platforms combinations (PMC) include (1) a TomoPhantom or (2) a Sun Nuclear ArcCheck placed on a CIRS motion platform, with the CIRS motion platform rotated 30˚ around IEC Z to mimic 2D motion, and (3) a Delta4 Phantom+ sitting on a HexaMotion phantom.

Tracking geometry accuracy was obtained by evaluating the difference between the predicted and instructed target positions with PMC1, and quantified as the root means square (RMS) of the difference. Ion chamber (1D) and film (2D) measurements with motion correction were compared to those with no correction or no motion at all with PMC1. The measured dose using 3D dosimeters with PMC2 and 3, and delivered dose reconstructed on daily MVCT images (PreciseArt), were compared with the planned dose. For measurement to plan dose comparison, gamma analysis with 3% dose difference, 2 mm distance, and 10% dose threshold was carried out to quantify the dose agreement.

Synchrony plans generated on a Sun Nuclear Daily QA3 device were delivered with manual offsets to verify daily output constancy and tracking functionality.

## RESULTS

The imaging dose was measured to be 0.084 mGy/image for the 120 kVp 1.6 mAs protocol. It is substantially smaller than the imaging dose for a regular IGRT.

The RMS values for the difference between the predicted and instructed target positions obtained with PMC1 were 0.84, 1.13 and 0.48 mm for FNR, FR and FFR, respectively. The predicted and instructed target positions are shown in Fig1 for a FFR delivery.

The ion chamber measurement ratios of Synchrony and non-Synchrony for both 1 and 2.5 cm jaws were obtained with Synchrony plans delivered with various motion traces. It was found that the Synchrony and non-Synchrony difference could be up to 4.3% with extreme large motion amplitude (±20 mm), otherwise the differences were within 1.0% for typical motion.

Comparison of films irradiated with Synchrony (motion corrected) and non-Synchrony (with and without motion) showed that, the broadening of the radiation field in the IEC Y direction caused by motion can be compensated with Synchrony, and in respiratory cases, the phase or amplitude difference between the target and the surrogate doesn't affect the compensation with Synchrony (Fig 2).

For both ArcCheck and Delta4 measurements, while slightly lower than 90% passing rates may be obtained for FNR cases, gamma passing rates for FR and FFR cases were both above 95%, when measured doses were compared to those of planned.

The delivered doses from phantom plans were reconstructed on daily images with an adaptive radiotherapy tool and compared with the planned doses. The difference of daily and fractional mean doses for various structures were found to be within 1% (Fig.3).

The Sun Nuclear Daily QA3 device were manually offset by -5 mm in both lateral and longitudinal directions after IGRT and left static during Synchrony plan deliveries. The target was detected at the expected position within 2 mm (Fig.4), and the recorded daily dose constancy was 0.991±0.003.

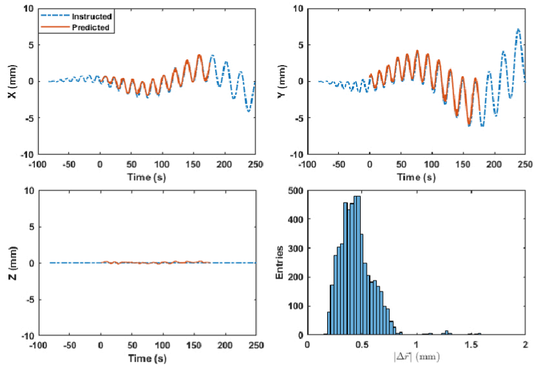


*Fig1. Predicted and instructed target positions (IEC X,Y and Z) as well as the 3D difference for a FFR Synchrony plan delivery.*

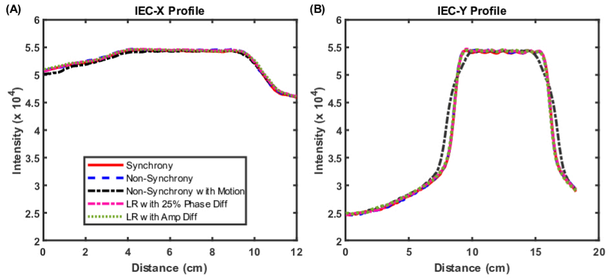


*Fig2. Comparison of IEC X (A) and IEC Y (B) profiles measured with films in the following deliveries: Synchrony with ±10 mm target motion, non-Synchrony, non-Synchrony with ±10 mm target motion, Synchrony with ±10 mm target motion but the surrogate with a phase shift of 25%, Synchrony ±10 mm target motion but the surrogate with ±15 mm motion. Big motions were in Y direction.*

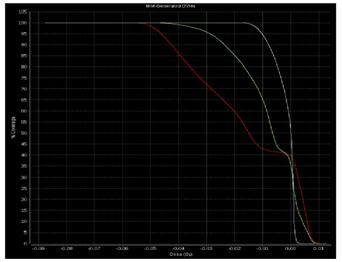

*Fig3. The difference of daily and fractional doses of various structures for a Synchrony phantom plan delivery.*

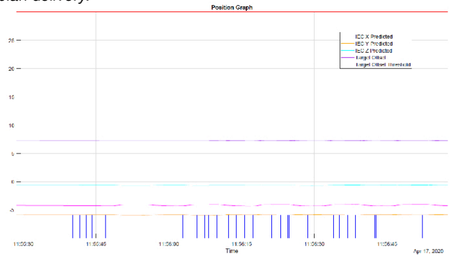


*Fig4. The detected target positions for the delivery of a Synchrony plan generated on a Sun Nuclear Daily QA3 device.*

## CONCLUSIONS

Key components and capabilities of tumor tracking with Synchrony on Radixact have been evaluated.[4]

- Additional dose from Radiograph has been verified to be small.
- Target can be detected accurately.
- Dose compensation is effective.
- QA procedures have been established.

We gained Synchrony treatment experience with Synchrony on Radixact while commissioning and testing the system. We have been working closely with Accuray with feedback provided and the system has been improved with a few upgrades!

The system has been used in clinic.

## ACKNOWLEDGEMENTS

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## 1.REFERENCES

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