INTRODUCTION
The Synchrotron system allows for target tracking and motion compensation during treatment delivery on the Tomotherapy Radixact system. Montefiore Medical Center installed its clinical Synchrotron system in September 2019. Target motion in the sup/in direction is compensated for via jaw tracking. Motion in the axial directions is compensated for via MLC offset in which the binary MLCs that are open are shifted, depending on the magnitude of the shift in the projection gantry angle.

AIM
Before clinical implementation, evaluation of the system performance was undertaken. Sinusoidal periodic motions were evaluated to separately evaluate the efficacy of jaw-based motion correction, MLC-based motion correction and the two combined.

METHOD
This study evaluates the accuracy of the Synchrotron motion correction for the “respiratory” and “respiratory with fiducials” tracking modes using a Delphi phantom and Hexamilton stage. EB73 film was also used to allow for increased resolution and comparison to Delphi values. For both respiratory models these LED’s act as an external surrogate allowing a motion model to be created. This model is constantly updated as kV images are acquired before and during the treatment.

Custom inserts were designed, and then 3D printed, that allow for target tracking using both a dense silicon rubber plug and triangular fiducial arrangement. The planned dose was delivered to a stationary phantom and a moving phantom both with and without motion correction enabled.

The dose delivery changes were evaluated using the gamma index (2%, 2 mm, 10% threshold) for the Delphi and film placed in horizontal and vertical orientations. 10 motions in the sup/in direction (y direction) only are compensated for with jaw positioning corrections. Motion in the axial plane (x-z direction) only are compensated for with MLC correction. Each type of motion was evaluated separately, and combined motions in both the y and z planes were evaluated with varying breathing periods.

RESULTS
For treatment deliveries with uncorrected motion the gamma pass rates clearly show the need for target motion compensation. With increasing phantom motion the delivered dose distribution became increasingly distorted, reflected in low gamma pass rates. For the “respiratory” tracking in mode Delphi data shows an increase in pass rates of 4.4% for 2.5 mm y direction motion, 16.6% for 5 mm motion and an average increase of 74% for motions ±7.5 mm. For x-a motions a benefit was found when the motion exceeded the MLC leaf width of 6 mm at isocenter, with an average increase in pass rate of 9.8%. Analysis of film data shows similar improvement.

For “respiratory with fiducials” tracking mode Delphi data shows an increase in pass rates of 1.9% for 2.5 mm y direction motion, 12.4% for 5 mm motion and an average increase of 68.1% for motions ±7.5 mm. For x-a motions an average increase in pass rate of 14.0% was found.

For 3D motions with different respiratory periods there was a greater improvement for plans with a faster respiratory period. Measured pass rates using the Delphi phantom were above 98% for all corrected plans. Even with a more generous 5%/5 mm criteria, all motions in the direction ±6.0 mm resulted in a failing gamma analysis (<90% of points passing).

CONCLUSIONS
These results clearly show the benefit of jaw tracking using Synchrotron and to a lesser extend the benefit of MLC tracking. The results show a larger deviation in delivered dose distributions for target motion in the y direction only when compared to motion in the x-z plane only. Due to the helical nature of the Radixact delivery, dose deposition is less sensitive to target motion in the x-z plane.

The ability of the system to continuously deliver radiation to the exact target position, without the need to pause with the patients breathing cycle, is a clear advantage and improvement upon existing techniques.

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