Characterization of MLC Latency for Non-Invasive Intrafractional Tumour-Tracked Radiotherapy (NifteRT) on Alberta linac-MR

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PURPOSE/BACKGROUND

- **The development of MRI-guided multileaf collimator (MLC) tracking using hybrid linac-MR radiotherapy systems has proven potential to reduce margins for mobile tumours.[1]**
- **One such tracking technique is Non-Invasive Intrafractional Tumour-Tracked Radiotherapy (NifteRT), which is a multistep technique using Alberta linac-MR to track tumours in real time (Figure 1).[2]**
- **Precise MLC control and characterization of the system latency, or lag between the MLC and the target, is required in NifteRT to conform to the target in real time.**
- **This system latency can be further divided into the mechanical latency, image processing latency, and the image acquisition latency.**
- **The mechanical latency describes the time lag between the set position of a target or tumour, and the reached MLC position.**
- **Previous studies have explored this on the Elekta Unity linac-MR system, where the mechanical latency without prediction was found to be 141ms.[3]**
- **Characterization of this latency under different clinical conditions, such as at various gantry angles and leaf velocities, has yet to be explored.**

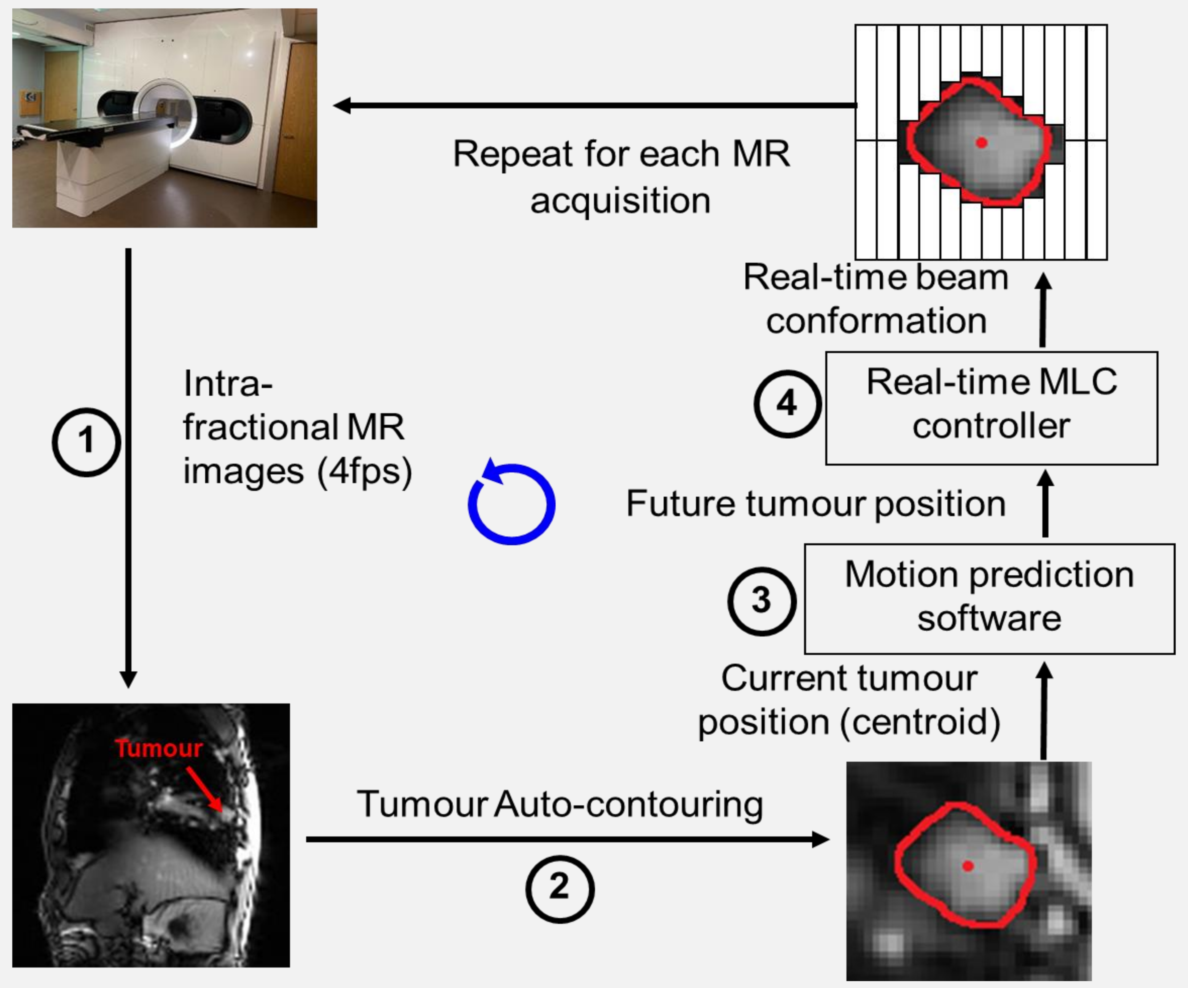


Figure 1: NifteRT flowchart as performed on the Alberta linac-MR. Modified from Yun et al. [2]

- **<u>HYPOTHESIS:</u> The mechanical latency will be higher at gantry angles 90 and 270 degrees due to gravitational effects whereas the mechanical latency will be consistent and lower at gantry angles 0 and 180 degrees.**

METHODS

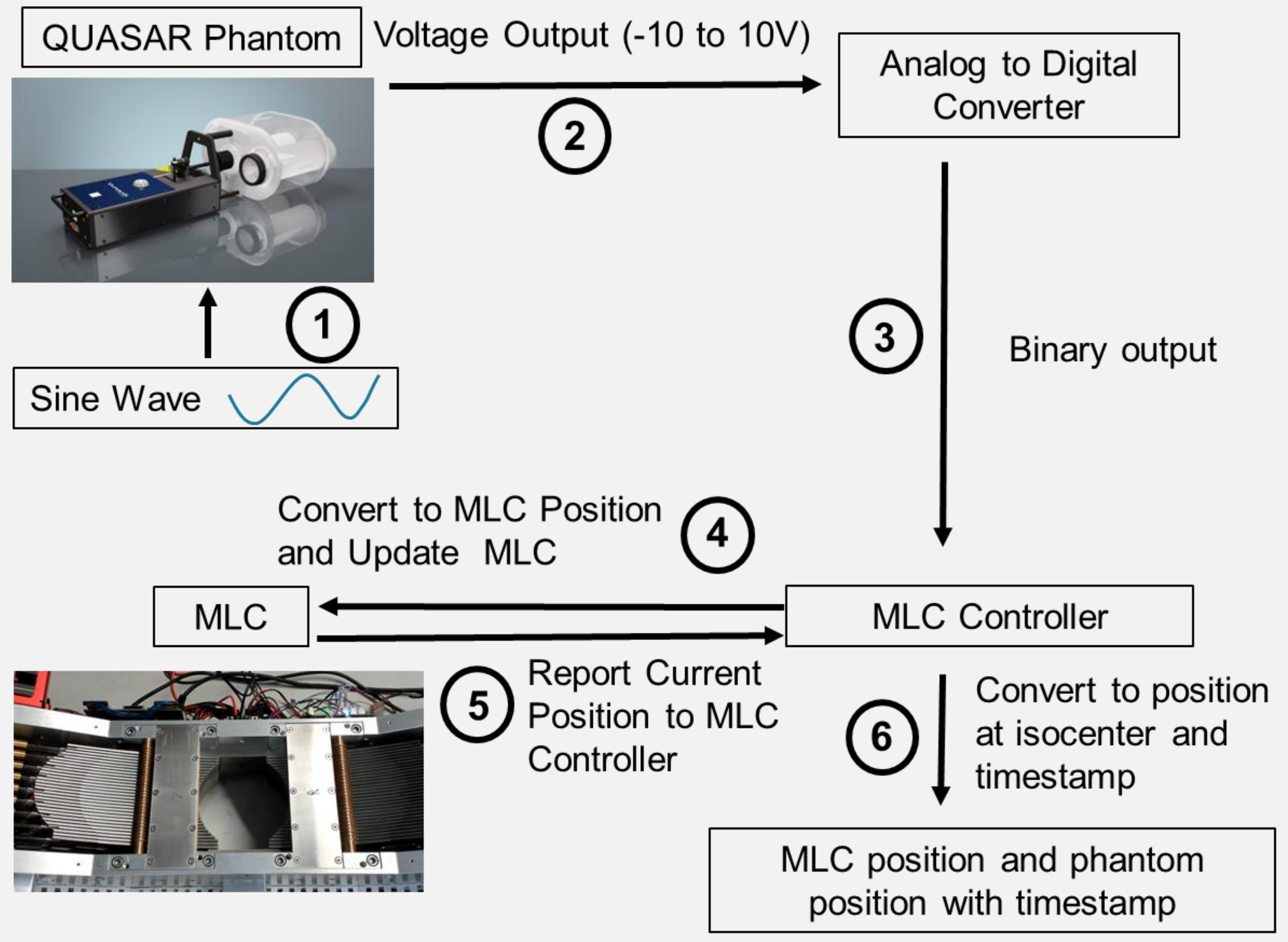


Figure 2: Flowchart from the QUASAR phantom to the MLC motion, performed using the Alberta linac-MR MLC.

- **A QUASAR MRI^{4D} motion phantom is programed to emulate 1-D sinusoidal tumour motion using two different equations:**

Basic sine motion: $$\mathrm{P}(t) = A\sin(\omega t) \quad (1)$$

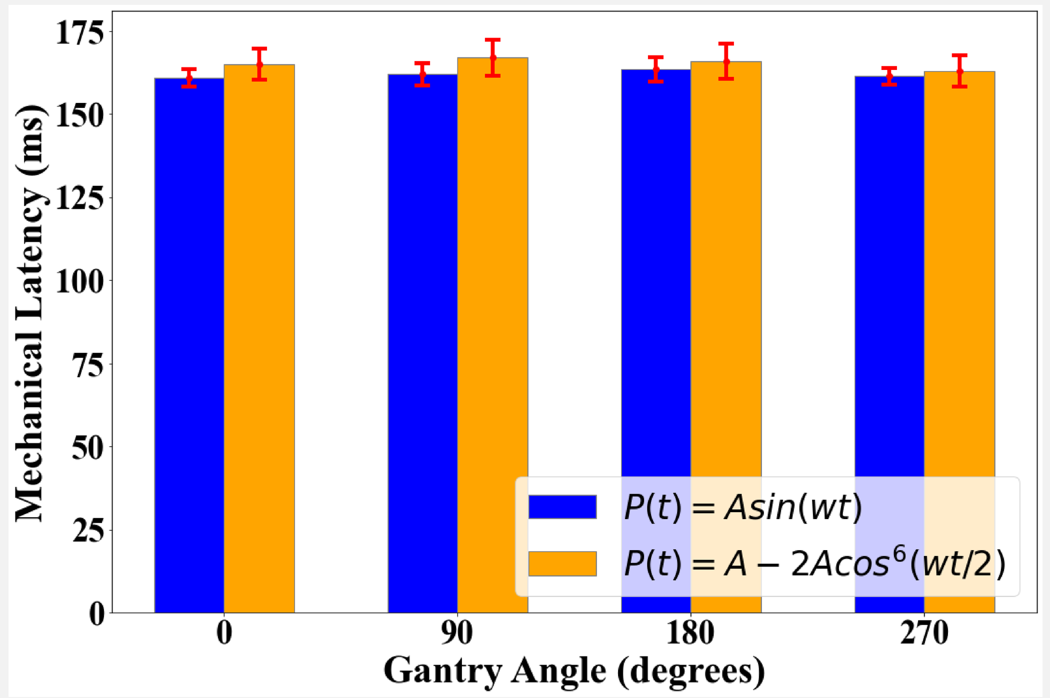
Breathing pattern: $$\mathrm{P}(t) = A - 2A\cos^6\left(\frac{\omega t}{2}\right) \quad (2)$$

- **The 1-D positional data from the phantom is used as a positioning source for the MLC (Figure 1).**
- **Every 50ms the MLC position is updated using an in-house developed MLC controller which communicates directly with both the phantom and the MLC.**
- **Both the MLC and phantom positions are timestamped and saved for comparison.**
- **The data is fitted to the sinusoidal equations and the latency between the MLC and phantom's positions is calculated.**
- **The reached position of the MLC leaves are provided by the previous version of the MLC used in the Alberta linac-MR, which is mounted on a gantry that can rotate 360 degrees.**

RESULTS/DISCUSSION

- **Figure 3 depicts the observed motion patterns of the MLC and phantom for both the basic sine motion and breathing pattern at gantry angle 0.**
- **The basic sine wave and breathing pattern have similar latencies at gantry angle 0 with 161ms and 165ms, respectively. This is slightly higher than the 141ms latency found in previous studies with the Elekta Unity linac-MR.[3]**
- **Figure 4 compares the latency at gantry angles 0, 90, 180, and 270 for both motion patterns.**
- **There is no significant difference in latency between the four gantry angles.**
- **Slightly higher error and latency are found for the breathing pattern when compared to the basic sine motion indicating higher latencies and error could be present in breathing patterns with more complexity or higher acceleration.**

Figure 4: A comparison of the mechanical latency at various gantry angles using basic sine motion and a breathing pattern



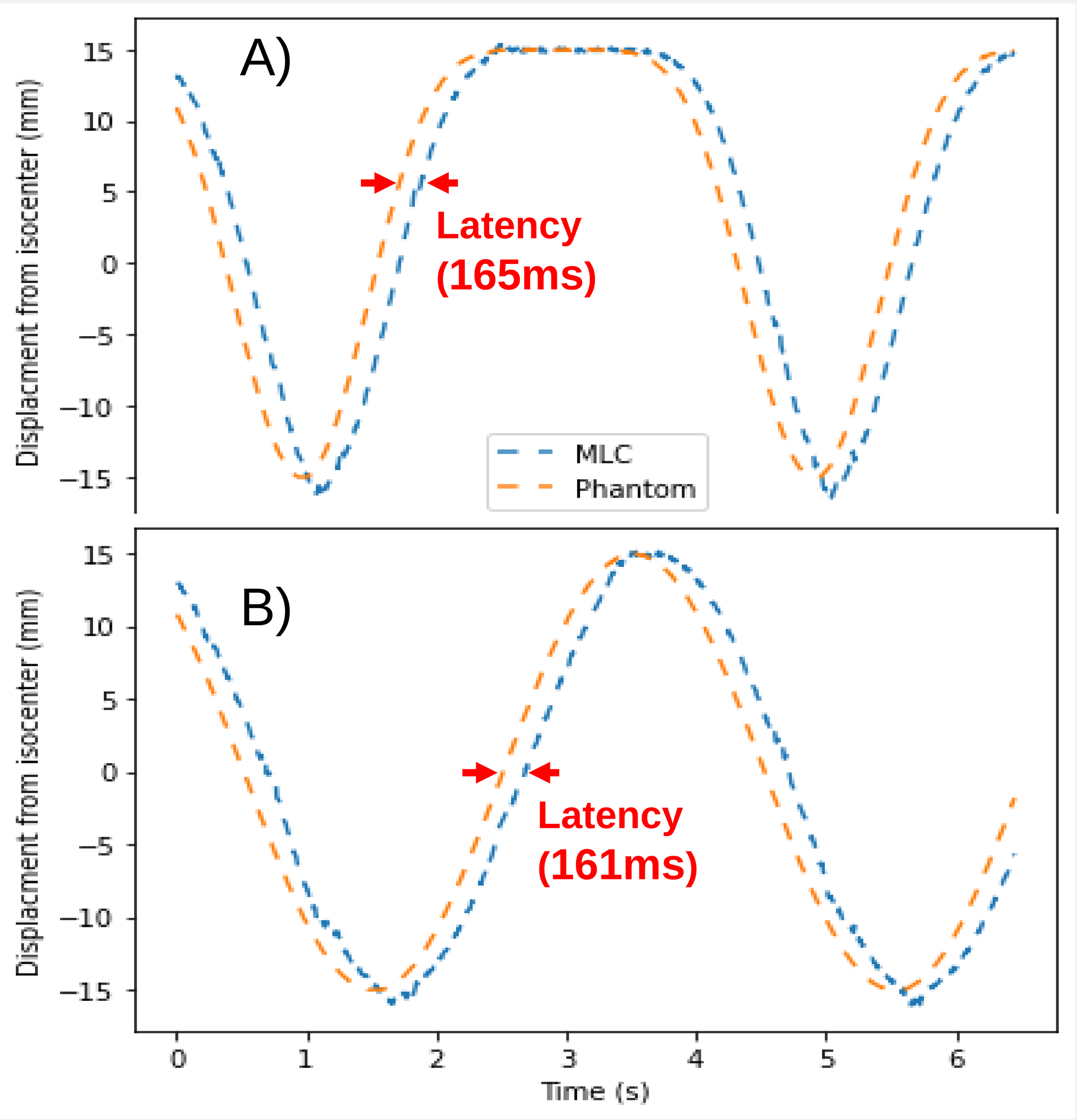


Figure 3: Displacement over time of the Alberta linac-MR MLC and the QUASAR motion phantom with the calculated latencies at gantry angle 0 for A) breathing pattern and B) basic sine motion.

CONCLUSIONS

- **A method was developed to determine the mechanical latency on the Alberta linac-MR using an in-house built MLC controller.**
- **This latency was between 160-170ms for all gantry angles with the basic sine motion having slightly lower latency than the more complex breathing pattern.**
- **The mechanical latency is higher than previous studies which can be partially explained due to the shorter control system cycle of 40ms on the Elekta Unity compared to 50ms on the Alberta linac-MR.**

FUTURE WORK

- **Incorporation of a motion prediction algorithm would allow for the determination of the latency when the MLC is following the target's predicted position.**
- **An external camera used check the positions and latency of the MLC and phantom would confirm the internal latency calculations.**
- **Latency measurements using MRI as the positioning source on the Alberta linac-MR would allow for the determination of the image acquisition and image processing latencies.**

REFERENCES

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