JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

Performance Characterization of a Clinical 1.5 T MR-Linac

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INTRODUCTION

MR-Linac radiotherapy has been implemented in a number of cancer centres worldwide over the past number of years [1]. That being said, this is a relatively new technology that continues to develop. This work provides useful feedback to the medical physics community on the initial quality control results and downtime statistics of a clinical 1.5 T MR-Linac over its initial first year of use.

AIM

To report on our institutions experience with a clinical 1.5 T MR-Linac in its first year of use, in terms of quality control performance, unscheduled down time statistics and most frequent faults.

METHODS

- Daily, weekly, and monthly quality control (QC) tests were established for both the linac and MRI of our 1.5 T MR-Linac treatment machine (Elekta AB,Stockholm,Sweden).
- Machine QC results were recorded/plotted using our machine quality assurance database (QATrack+, v0.3.0.16, Ottawa, ON), an open source software application used for our fleet of linacs. The data presented is over the past 1 year.
- The following were used: MR IC Profiler (Sun Nuclear, Melbourne,Fl), Exradin A1SL ion chamber (Standard Imaging, Middleton,WI), reference dosimetry water tank (in house), energy check device (in house), MR to MV coincidence phantom (Elekta,Stockholm,Sweden), and Quasar MRID distortion phantom (ModusQA,London,ON)
- Unscheduled downtime was software activated by the treatment unit therapists. Faults were recorded manually in an IT electronic spreadsheet with date and time stamp.

RESULTS

- The output constancy using the IC Profiler CAX detector was 1.001 ± 0.002 at gantry = 0 measured weekly.
- Monthly energy measurements of TPR20/10 were 0.699 ± 0.001.
- The MR to MV transform stability was within 0.1 mm measured daily over the past 1 year.
- Gradient non-linearity absolute distortion vector was on average 0.61 mm ± 0.15 mm. This is an average value over all distances out to 22.5 cm from the isocentre, measured monthly (see Figure 3).
- Main B field absolute distortion vector was on average 0.65 mm ± 0.02 mm. This is an average out to 22.5 cm from the isocentre, measured monthly.
- Flatness/Symmetry, as measured by the IC Profiler weekly, varied by on average, less than 0.2% over the course of the year.
- Unscheduled downtime for the MR-Linac was 5.5%. This was mainly due to a magnetron change, modulator tank replacement, or a cooling issue (Figure 1).
- Machine fault statistics are shown in Figure 2.

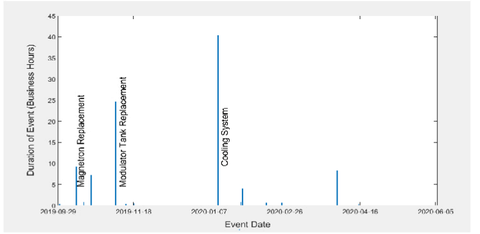

Figure 1: Duration of unscheduled downtime events (business hours) for the MR-Linac over its initial 10 months (Aug 2019 – June 2020). The MR-Linac unscheduled downtime was 5.5 %. Also shown are the causes for the 3 longest durations. It was mainly transit time for parts that caused the long durations, not time for diagnosis or repair. The frequency and durations of downtime have reduced as of late compared to earlier on.

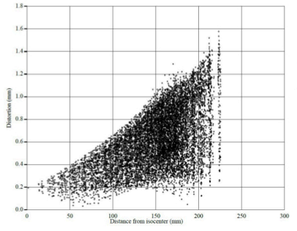

Figure 3: Sample monthly gradient distortion as a function of distance from the isocenter. Greater than 95% of all points shown have a distortion within 1 mm. This has been stable over time.

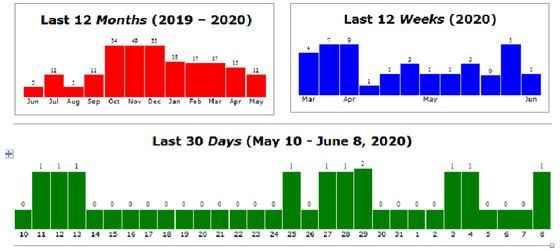

Figure 2: Linac machine faults. This gives an indication of the number of faults over various time periods. This data includes (in addition to unscheduled downtime) all machine related faults. Most of these faults were "patient on bed" interlock trips during treatment that were cleared quite readily and did not result in downtime. The details of each fault are recorded in a data base at our institution.

Interprofessional Team

Radiation Oncologists
CSRT MR-Linac
MRIT(T)s
MRIT(T)(MR)s
Medical Physics
MRI Scientists

CONCLUSIONS

The radiation beam characteristics and MRI quality control tests have been robust to date. Having rapid access to machine parts would help to decrease downtime.

ACKNOWLEDGEMENTS

We gratefully acknowledge the collation of downtime statistics by Mr Scott MacKenzie and the use of the IT ticketing software (provided by our IT group) that was used to capture the machine fault details. Machine faults were captured by our MR-Linac therapists: Shawn Binda, Danny Yu, Anne Carty, Susana Sabaratram, Helen Su, Christina Silverson, Thanh Truong , and Katie Wong.

REFERENCES

1 Raaymakers B W et al. First patients treated with a 1.5 T MRI-Linac: Clinical proof of concept of a high-precision, high-field MRI guided radiotherapy treatment. Phys Med Biol. 2017 Nov 14; 62(23):L41-L50.

CONTACT INFORMATION

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