Enhancing quality assurance in hybrid DCAT plans: The impact of reduced maximum dose rate

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Introduction

Recent innovations in the area have seen the introduction of **hybrid-DCAT/VMAT** (Dynamic Conformal Arc Therapy / Volumetric Modulated Arc Therapy) plans, which incorporate **variable dose rates** to potentially enhance treatment efficacy and safety.[1,2] These plans mix:

- precision of traditional **DCAT**
- flexibility of **VMAT**

aiming to optimize the distribution of radiation doses while minimizing exposure to surrounding healthy tissues.[3] Parallel, the Integral Quality Monitor **IQM** system has emerged as a crucial tool for precise dose measurement, providing real-time feedback on dose delivery accuracy.[4] Our investigation assesses the accuracy of dose delivery under varying conditions, particularly looking at how the adjustment of the linac's maximum dose rate affects the congruence between planned and delivered doses. We hypothesize that controlling the dose rate can significantly influence the dose delivery seen with the IQM systems.

Material and Methods

For each of these novel plans featuring variable dose rates where gantry movement reversals were observed (7 in total), we reduced the maximum dose rate from 600 MU/min to 200 MU/min and measured the dose delivery using the Integral Quality Monitor IQM (Figure 1). Below, you can see the differences between the planned and measured IQM signals (segment-by-segment) for an exemplary plan at both maximum dose rates.

Field-by-Field Evaluation of Measurement Results:

Field ID	Session #	Beam Energy [MV]	Gantry Angle Span [°]	Field MU/ Fraction	Ref. Type	Final Cumu. Dev [%]	Segment-weighted Pass Rate [%] Cumu. Watch	Cumu. Action	SbS Watch	SbS Action	Field Result
01001	1	6	170.0-10.0	214	C	-0.4	100	100	100	100	Pass
01001	1	6	170.0-10.0	214	C	-0.3	95	100	70	78	Action

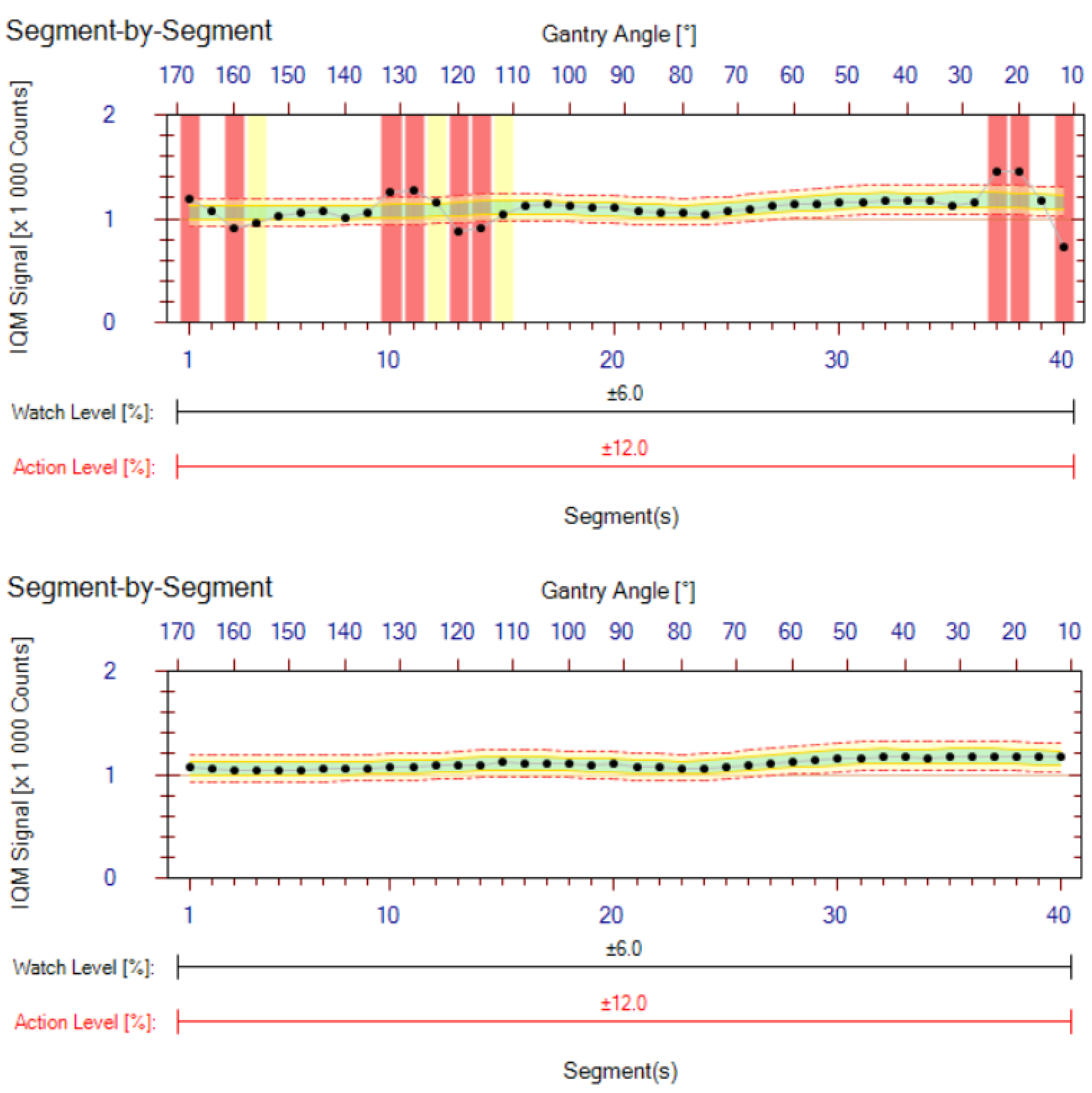

*Figure 1: IQM measurements of a new DCAT Plan (**Top**) with variable dose rates at a maximum of 600 MU/min (**Mid**) and 200 MU/min (**Bottom**) – Generated by the IQM Report Tool*

The impact of this reduction was systematically evaluated by monitoring various linac hardware parameters during the measurements, seeking potential causes for the segment-wise over- and under-regulation.

Results

A total of 338 linac parameters were analyzed for each plan at both maximum dose rates of 600 and 200 MU/min. The parameters included: **Gantry angle (a), Gantry speed (b), delivered MU (c), dose rate (d), Leaf 46 Y1 Speed (e), Leaf 46 Y1 Position (f), Leaf 47 Y1 Speed (g), and 2R Error (g)**.

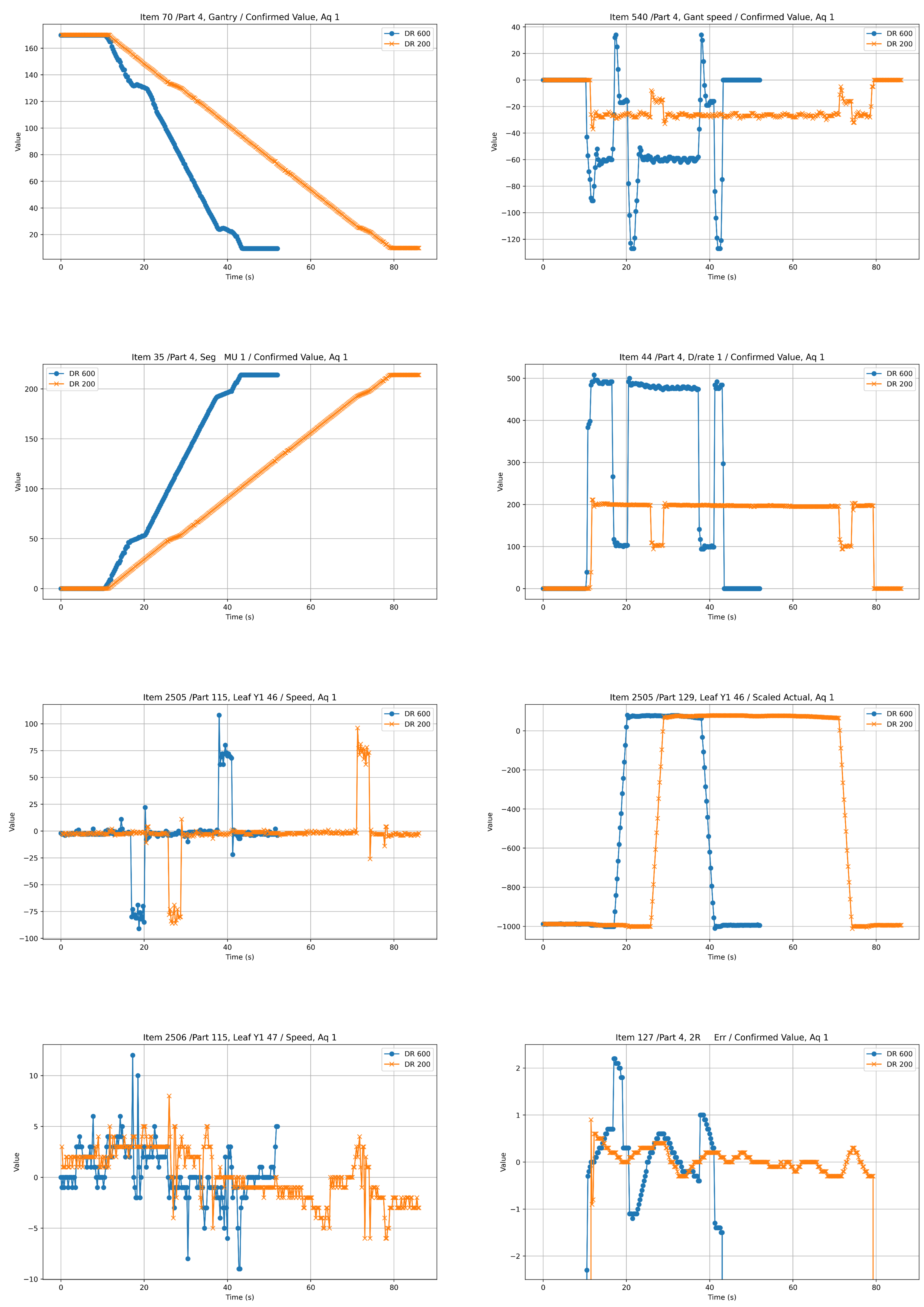

*Figure 2: Monitoring of various Linac parameters during the measurement of the same plan as in Figure 1 with both max. dose rate values. Gantry angle (**a**), Gantry speed (**b**), delivered MUs (**c**), dose rate (**d**), Leaf 46 Y1 Speed (**e**), Leaf 46 Y1 Position (**f**), Leaf 47 Y1 Speed (**g**), and 2R Error (**h**)*

Conclusion

Examining the selected parameters, particularly gantry speed and leaf speed, it is evident that the additional flexibility of a variable dose rate places the linac under stress. During the time bins where the dose rate changes, other mechanical parameters reach their technical limits, compelling the linac to adjust in order to deliver the monitor units accurately for each segment. This regulation process appears to lead to the observed over- and under-regulation in the IQM measurements. However, it must be noted that the cumulative dose signal remains within the prescribed tolerances.

Outlook

- **Identify Key Factors**: Pinpoint mechanical and software parameters that directly contribute to the observed fluctuations in dose delivery accuracy
- **Analyze Interdependencies**: Understand how changes in one parameter affect others, potentially leading to the over- and under-regulation noted in the IQM measurements
- **Strengthen System Reliability**: Implement improvements to enhance the reliability and efficiency of dose delivery, particularly under complex treatment scenarios.

References

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