Dosimetric analysis on AI based virtual log file patient-specific QA

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Purpose: AI-based virtual log file patient-specific QA (PSQA) consists of predicting linear accelerator parameters at delivery for a new treatment plan, based on an AI model trained using delivery-based log files from prior patients. This tool has the potential to enhance current IMRT QA workflows and enable a pre-treatment analysis for online-adaptive RT. We perform a dosimetric comparison of PSQA using AI-based virtual log files versus delivery-based log files directly from the 1st fraction treatment.

Methods: We utilized a Monte Carlo dose calculation algorithm (SciMoCa) to compare calculated dose distributions from (1) secondary dose calculation of the Eclipse treatment plan, (2) AI-based virtual log files, and (3) delivery-based log files recorded during 1st fraction treatment delivery on a Varian TrueBeam linear accelerator. Fifty IMRT/VMAT plans from various sites (**Table 1**), including single-target SRS, multi-target SRS, spine, H&N, lung, GI, GU, breast, GYN, and sarcoma, were included in the analysis. We quantified the differences in PTV D99%, D95%, D1%, Dmean, D50%, and V100%. To evaluate effects on normal tissue, we quantified the differences in ring structures surrounding the PTV at distances of 0-3 mm, 3-6 mm, and 6-9 mm; dose indices for ring structures included Dmean, D99%, D50%, and D1%.

Table 1 Plan characteristics for the 50 IMRT/VMAT plans from various sites.

Site	Technique(s)	Range of PTV volume (cm^3)		Site	Technique(s)	Range of PTV volume (cm^3)
Single-target SRS	VMAT	7.2 - 51.1		GI	VMAT	24.9 - 3206.8
Multi-target SRS	VMAT	1.5 - 17.6		GU	IMRT/VMAT	40.8 - 879.1
Spine	VMAT	9.2 - 136.9		Breast	IMRT/VMAT	140.8 - 1777.9
HN	VMAT	9.6 - 321.6		GYN	VMAT	300.1 - 1947.5
Lung	VMAT	32.9 - 239.2		Sarcoma	IMRT/VMAT	354.5 - 996.2

*Large PTV volume has been reported in simultaneous integrated boost (SIB) and sequential boost plans.

Results: The differences between the doses calculated with AI-based virtual log files and delivery-based log files directly from 1st fraction treatment were minimal, with most differences being within 1% (**Figure 1**). The maximum observed differences were on the order of 5% for the PTV D100%, which was observed for a multi-target SRS plan. When comparing the dose indices differences of AI-based virtual log files versus secondary dose calculations and the differences of delivery-based log files directly from 1st fraction treatment versus secondary dose calculations, most differences were within 2% (**Figure 2**). The maximum observed differences were on the order of 6% for PTV D100% in the multi-target SRS plan for secondary dose calculation vs. delivery-based log files. The linear relationship showed a significant correlation between the differences comparing AI-based virtual log files versus secondary dose calculations and the differences comparing delivery-based log files versus secondary dose calculations (slope = 0.53, $r^2 = 0.17$, p-value <0.001, **Figure 3**).

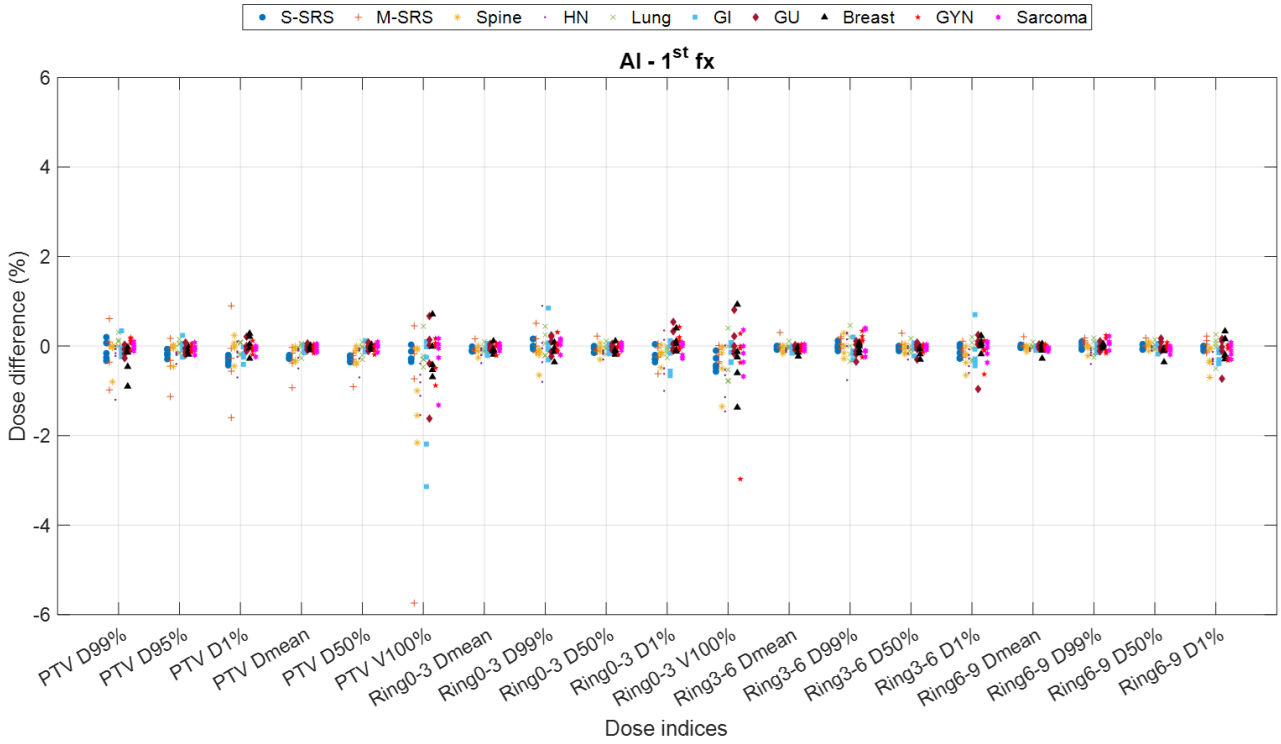

Figure 1 Dose indices differences between doses calculated with AI-based virtual log files and delivery-based log files recorded during the 1st fraction of treatment.

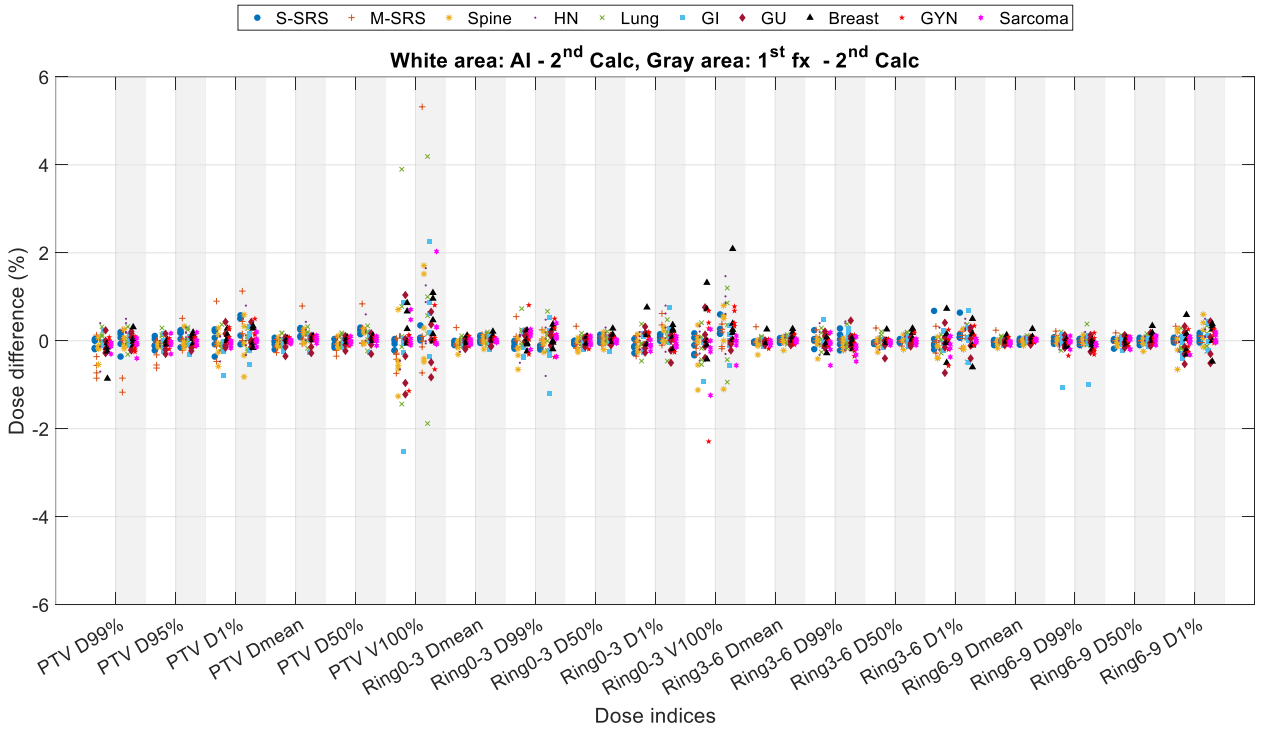

Figure 2 Dose indices differences of AI-based virtual log files versus secondary dose calculations and the differences of delivery-based log files from 1st fraction treatment versus secondary dose calculations.

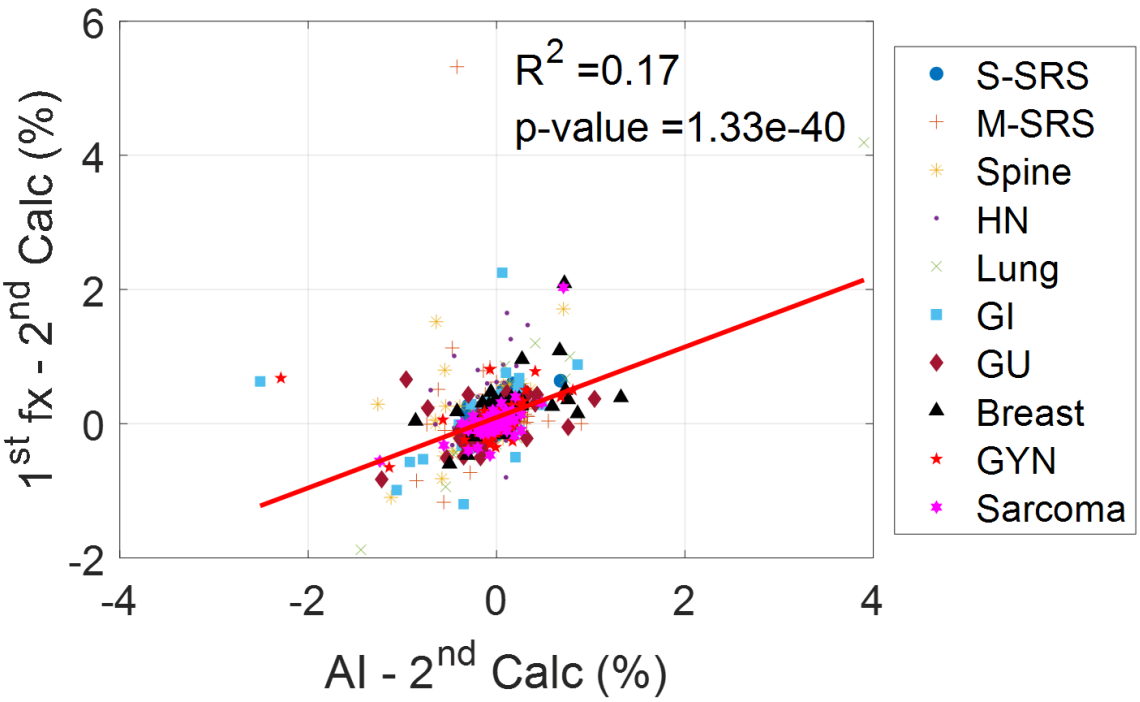

Figure 3 Linear relationship between the differences of AI-based virtual log files versus secondary dose calculations and the differences of delivery-based log files directly from 1st fraction treatment versus secondary dose calculations.

Conclusions: AI-based virtual log files can be used to predict the dosimetric results of delivery-based log files and have the potential to become a "delivery-free" pre-treatment analysis to enhance PSQA. We believe it is the first study to dosimetrically compare secondary dose calculations, AI-based virtual log files, and delivery-based log files (recorded during 1st fraction treatment). The dosimetric analysis results supported the idea that the AI-based virtual log files could be a pre-treatment PSQA option.

Relevance to CIRMS: We consider this study to be relevant to the mission of CIRMS on therapeutic uses of ionizing radiation, as patient-specific QA (PSQA) is the standard process to verify the quality and safety of IMRT and VMAT radiotherapy. The first author aims to become an academic/clinical medical physicist and currently works in the radiation therapy physics residency program.