Toward Developing a Practical Approach for Evaluating CT Scanner Tube Current Modulation Performance

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

INTRODUCTION

Annual evaluation of CT scanner Tube Current Modulation (TCM) performance is required by the latest New York City Article 175 regulations since May 2019, but many manufacturers do not provide protocols for assessing TCM performance of their systems. This study evaluates TCM performance of two GE and two Siemens scanners based on the method recommended by AAPM TG233 [1]. The results of this comparison study will provide insights into CT scanner TCM function of different manufacturers and models, and are also useful to assess the feasibility of implementing the AAPM TG233 method in clinical setting.

AIM

The aim of this study was to evaluate CT scanner TCM performance using the method recommended by AAPM TG233 and to compare the resulting metrics of scanners of various manufacturers and models.

METHOD

- Two GE and two Siemens scanners were selected for evaluation: GE Light Speed VCT, GE Discovery CT750, Siemens Definition AS, and Siemens Biograph.

- 32cm $CTDI_{vol}$ phantom was placed flat on the patient table to introduce thickness variability as the phantom travels in/out of bore. Clinical routine abdomen protocols on each scanners were used, and both AP and lateral localizers were acquired for scan prescription (Figure 1). The phantom was scanned in both table travelling directions.

- For each slice, tube current value (mA) was extracted from DICOM header using MATLAB, and the phantom effective diameter was calculated.

- The slopes (α) and the linear correlation relation coefficients ($R_{mA\_eff}^2$) of $\ln(mA_{eff})$ vs. phantom effective diameter were determined for each image set.

RESULTS

- The resulting average α- and $R_{mA\_eff}^2$-values differed significantly between GE scanners and Siemens scanners (Figure 2 and Table 1); Siemens scanners have considerably higher α-values.

- A disparity between the scanner TCM response was observed as the phantom size decreases/increase during scan. When scanning in the direction of decreasing phantom size, α-value increased significantly for Siemens scanners (an average difference of 38.8%) as compared to when scanning in the direction of increasing size. On the other hand, the α-value remained relatively unchanged for GE scanners (an average difference of 7.0%).

- The directionality of the table movement also had some effects on scanners' TCM response. When the table was traveling out of the bore, α-value differed by an average of 5.2% for GE scanners comparing to when the table was traveling inward. The difference in α-value was more significant for Siemens scanners (12.1%).
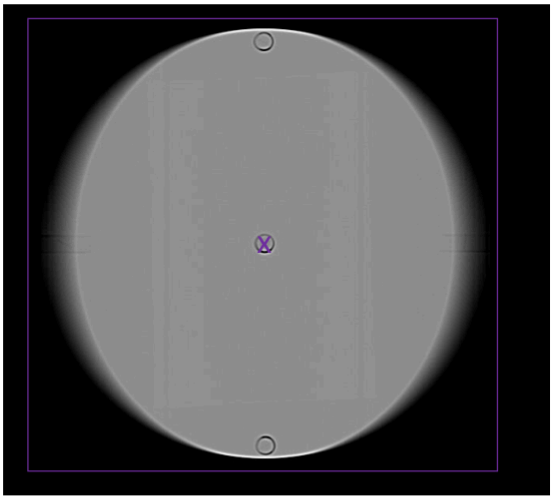

Figure 1. The scout image of the 32cm $CTDI_{vol}$ phantom was used to prescribe each scan, with the center of the scan prescription lining up with the center rod.
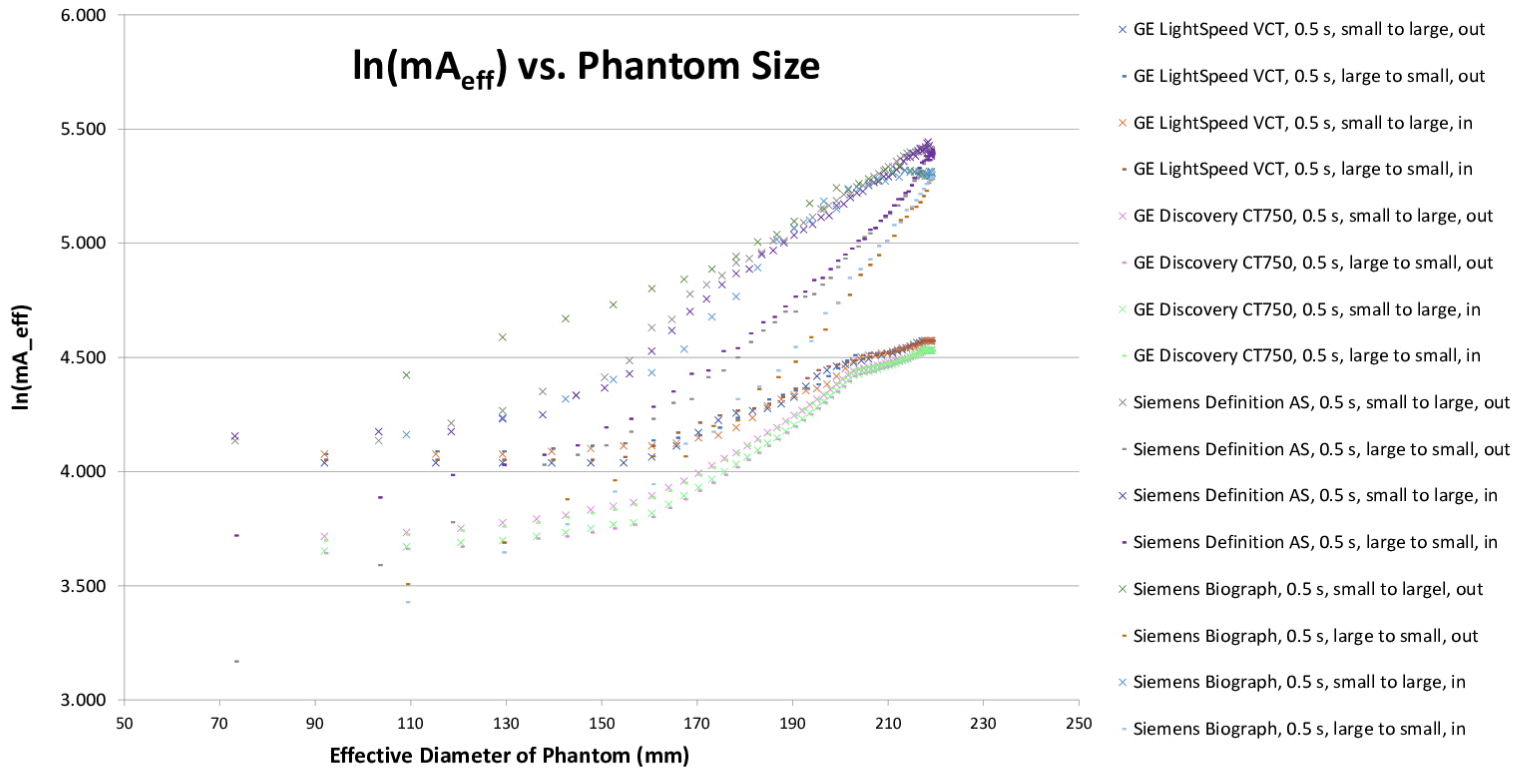

Figure 2. Comparison of the $\ln(mA_{eff})$ vs. effective diameter of phantom plot for GE and Siemens systems for different scanning orientations.

	Table Direction	Phantom Scan Direction	α	$R_{mA\_eff}^2$
GE LightSpeed VCT	out of the bore	small to large	0.0060	0.8917
		large to small	0.0055	0.8833
	into the bore	small to large	0.0056	0.8628
		large to small	0.0058	0.9083
		Average:	*0.0057*	*0.8865*
GE Discovery CT750	out of the bore	small to large	0.0086	0.9386
		large to small	0.0097	0.9281
	into the bore	small to large	0.0095	0.9304
		large to small	0.0088	0.9385
		Average:	*0.0092*	*0.9339*
Siemens Definition AS	out of the bore	small to large	0.0117	0.9546
		large to small	0.0160	0.9681
	into the bore	small to large	0.0119	0.9388
		large to small	0.0139	0.9302
		Average:	*0.0134*	*0.9479*
Siemens Biograph	out of the bore	small to large	0.0087	0.9760
		large to small	0.0180	0.9477
	into the bore	small to large	0.0127	0.9532
		large to small	0.0189	0.9639
		Average:	*0.0146*	*0.9602*

Table 1. Comparison of slope (α) and linear correlation relation coefficient ($R_{mA\_eff}^2$) values for GE and Siemens systems.

CONCLUSIONS

The results suggest that α-value can vary significantly depending on the manufacturer and the model of the scanners, as well as some scan settings, such as the phantom scanning direction (i.e. from the smaller section of phantom to the larger section, or vise versa) and the patient table moving direction. Hence, if the metric is to be used for monitoring CT TCM performance over time, one must be mindful to always use the same scanning parameter.

The study also discovered that the Siemens scanners TCM data result in higher $R_{mA\_eff}^2$-values, which suggest that the log-linear model recommended by TG233 better describes the TCM response of Siemens scanners as compared to that of the GE scanners.

This study confirms that α-value is a viable metric for characterizing scanner TCM response. Future directions for this research include evaluation of TCM behavior of other CT models, investigation of how other scan settings can impact TCM response (e.g. noise level setting), as well as inclusion of image noise evaluation as part of the TCM performance assessment.

REFERENCES

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