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Comparison of Organ and Effective Dose Estimates for CT Exams Obtained From Two Commercially Available Radiation Dose Monitoring Software (RDMS) Systems

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INTRODUCTION

As reporting CT dose has become an accreditation standard (and state law in California), a number of RDMS systems have become available. While at a minimum, systems are used to report dose metrics (CTDIvol, DLP), most also report organ and effective dose (ED). While the former (CTDIvol and DLP) are "pass-through" values and originate from the CT scanner and scanner-generated dose report, reported organ dose and ED are calculated values and depend on utilized CT dose simulation methods and patient models. Patients and physicians increasingly request ED values which are simple to understand and have widely available comparison data to other imaging modalities and background radiation. Therefore, these values are frequently reported in the patient's record and reportedly are even being used in determining medical necessity. However, the methods used to estimate organ dose and even effective dose by the RDMS are not always clear, nor is it clear what benchmarking these systems have used to obtain these values. In this work, we compare organ dose and ED from two commercially available radiation dose monitoring software (RDMS) systems to quantify the expected difference between the estimates in terms of both organ and effective doses.

AIM

Radiation Dose Monitoring Software (RDMS) systems are being used to assist in reporting CT doses required by accreditation standards. These systems also provide organ and effective dose estimates. The purpose of this work was to directly compare the organ and effective dose estimates obtained from two RDMS systems for a set of reference CT exams.

METHOD

Two widely used RDMS systems, Radimetrics (Bayer Healthcare) and DoseMonitor (PACSHealth), were utilized in this study. For a total of 48 adult and pediatric CT exams of various sizes and from three different exam types (16 routine head, 16 chest and 16 abdomen/pelvis), identical image data and dose reports were provided to these commercially available RDMS systems. For each patient, water equivalent diameter (Dw), organ dose and effective dose (ED) estimates were extracted from each RDMS system and percent differences with DoseMonitor as the reference were calculated. For each exam type, maximum, mean and standard deviation of percent differences between estimates were reported for ED, organ dose and Dw.
For head exams, brain and eye lens doses were compared between the two systems. For chest exams, compared organ doses were lung and breasts dose, while for abd/pel exams, liver, colon, stomach and testes/ovaries doses were compared.
Table I illustrates the patients' range of sizes as described by weight, height, and age for each exam type.

Table I:

Exam Type	Height (m)	Weight (kg)	Age (years)
Head (N=16; 8 Peds, 8 adult)	0.5 – 1.9	5.6 – 110	5 weeks – 82
Chest (N=16; 8 Peds, 8 adult)	0.69 – 1.88	7.3 – 106	32 weeks – 84
Abd/Pel (N=16; 8 Peds, 8 adult)	0.83 – 1.88	12.4 - 155	28 weeks – 70

RESULTS

For head CT exams, Radimetrics provided consistently higher estimates of ED and organ dose than DoseMonitor. A similar trend is seen in both abd/pel and chest exams, with its prevalence being lower in chest than abd/Pel exams. As compared to abd/pel and chest exams, ED and organ doses differences were larger in head exams (yellow cells indicate differences > +/- 25%; red cells indicate differences > +/- 50%).
WED is also overestimated by Radimetrics as compared to DoseMonitor across most patients. Currently DoseMnitor is not reporting WED for head exams.

A systematic relationship between dose percent differences and patient size could not be determined, suggesting significant differences between Radimetrics and DoseMonitor, in both their patient models and their Monte Carlo CT simulation approach.
For each exam type mean, standard deviation, minimum, and maximum of calculated % differences are shown in table II through table IV.

Table II	Adult								Peds								Stats			
Head	**Pt1**	**Pt2**	**Pt3**	**Pt4**	**Pt5**	**Pt6**	**Pt7**	**Pt8**	**Pt9**	**Pt10**	**Pt11**	**Pt12**	**Pt13**	**Pt14**	**Pt15**	**Pt16**	**Ave**	**STD**	**Min**	**Max**
% Diff ED	22	61	56	55	74	56	64	56	32	32	68	29	6	-2	51	10	42	23	-2	74
% Diff Brain	27	37	24	30	41	23	41	24	21	27	38	28	23	21	40	23	29	7	21	41
% Diff Eyes	37	38	26	23	41	26	29	26	26	37	37	25	26	19	39	23	30	7	19	41

Table III	Adult									Peds							Stats			
Abd/Pel	**Pt1**	**Pt2**	**Pt3**	**Pt4**	**Pt5**	**Pt6**	**Pt7**	**Pt8**	**Pt9**	**Pt10**	**Pt11**	**Pt12**	**Pt13**	**Pt14**	**Pt15**	**Pt16**	**Ave**	**STD**	**Min**	**Max**
% Diff WED	59	26	37	23	8	14	18	15	62	47	38	50	61	60	50	-9	35	22	-9	62
% Diff ED	16	16	34	21	33	23	29	6	28	14	23	11	-11	0	4	19	17	12	-11	34
% Diff Colon	-7	-14	-12	-9	4	1	11	-7	2	-5	4	6	-31	-28	-15	9	-6	12	-31	11
% Diff Stomach	11	13	19	21	21	-5	33	-9	23	18	32	22	0	-5	5	29	14	13	-9	33
% Diff Liver	11	11	23	17	24	0	29	5	18	14	32	20	-3	-5	4	26	14	12	-5	32
% Diff Testes/ovaries	23	8	16	12	34	34	36	20	22	11	9	26	-9	9	10	23	18	12	-9	36

Table IV	Adult								Peds								Stats			
Chest	**Pt1**	**Pt2**	**Pt3**	**Pt4**	**Pt5**	**Pt6**	**Pt7**	**Pt8**	**Pt9**	**Pt10**	**Pt11**	**Pt12**	**Pt13**	**Pt14**	**Pt15**	**Pt16**	**Ave**	**STD**	**Min**	**Max**
% Diff WED	-1	14	9	23	39	40	17	12	63	57	62	63	43	54	29	13	34	22	-1	63
% Diff ED	5	-18	-26	-3	2	-12	-46	7	39	-18	38	39	-4	-7	-20	19	0	25	-46	39
% Diff Lung	17	7	7	23	24	11	-8	18	27	5	16	27	7	18	15	18	14	9	-8	27
% Diff Breast	24	NA	NA	17	17	NA	NA	20	41	NA	36	41	23	NA	NA	27	27	10	17	41

CONCLUSIONS

When provided the **same input data**, two RDMS produced **substantially different values in effective dose, organ dose and water equivalent diameter values**. While differences in calculated values were not entirely unexpected, the magnitude was surprising, especially for Dw. Although there are few standards or guidelines for calculation of organ dose and effective dose, AAPM reports 204 and 220 describe calculation of Dw in detail; hence a better agreement between these two RDMS systems were expected. We consider differences in reported ED to be too large to reliably communicate dose and risk to patients and clinicians. Further work needs to be conducted to standardize and validate dose calculation across the industry before dose estimates can be credibly used.

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