

Comparing CT Scan Organ and Effective Dose Estimates from Radiation Dose Index Monitoring Systems (RDIMs) across Institutions Using a Reference Set of Patient Datasets

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ABSTRACT

Purpose: Radiation Dose Index Monitoring Systems (RDIMs) can report and track estimated organ and effective doses from CT scans. However, the methods to estimate these doses are not standardized. The purpose of this initial study was to assess the feasibility of performing direct comparisons of organ and effective dose estimates from several RDIMs using a reference set of patient datasets.

Methods: Under IRB approval, seven deidentified reference datasets were created and shared across sites: 4 routine thoracic scans and 3 routine abdomen/pelvis CT scans. For each exam, the dataset included: (a) Planning CT Radiograph; (b) Cross sectional CT image data; (c) Radiation Dose Structured Report (RDSR) and (d) Patient Protocol Page. Four sites used their RDIM to produce organ and effective dose estimates for each case. Estimates were compared by calculating the mean value of each organ and effective dose across RDIMs and then the average absolute percent difference (AAPD) across estimates. This was repeated for each estimated organ and effective dose for each patient.

Results: Estimates were provided from two different RDIMs (three sites had the same RDIM product). Mean effective dose estimates across datasets ranged from 6.88 to 12.14 mSv and AAPD of effective doses ranged from 0.1 to 22.9%. The AAPD for key organ dose estimates were: (a) 9.5 to 25.7% for breast and lung doses in thoracic scans; and; (b) 2.5 to 13.9% for colon and stomach doses in abdomen/pelvis scans. For the three sites using the same RDIM product, AAPDs were < 3% for key organ dose estimates and < 4% for effective dose estimates, respectively.

Conclusion: This study demonstrated the feasibility of performing direct comparisons of organ and effective dose estimates using a reference set of patient datasets. Future work will investigate sources of observed differences in RDIM results and possible mitigation strategies.

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INTRODUCTION

- Radiation Dose Index Monitoring Systems (RDIMs) track and report CT scanner output radiation dose indices (CTDI_{vol}, DLP, SSDE).
- Many RDIMs now also report **estimated organ and effective doses for each CT scan**.
- While scanner output indices are standardized, methods to estimate organ and effective doses are not.
- The purpose of this initial study was to **investigate the feasibility of performing direct comparisons of organ and effective dose estimates** from several RDIMs using a reference set of patient datasets.

METHODS AND MATERIALS - 1

1. Reference Patient Datasets (Same for all Sites)

For this initial study, 7 reference datasets were curated and deidentified. They included:

- (a) 4 routine, single phase thoracic scans:
2 adult female, 2 adult male
- (b) 3 routine single phase abdomen/pelvis CT scans
2 adult female, 1 adult male

For each dataset, the following were collected and deidentified:

- Planning CT Radiograph
- Cross sectional CT image data
- Radiation Dose Structured Report (RDSR)
- Patient Protocol Page

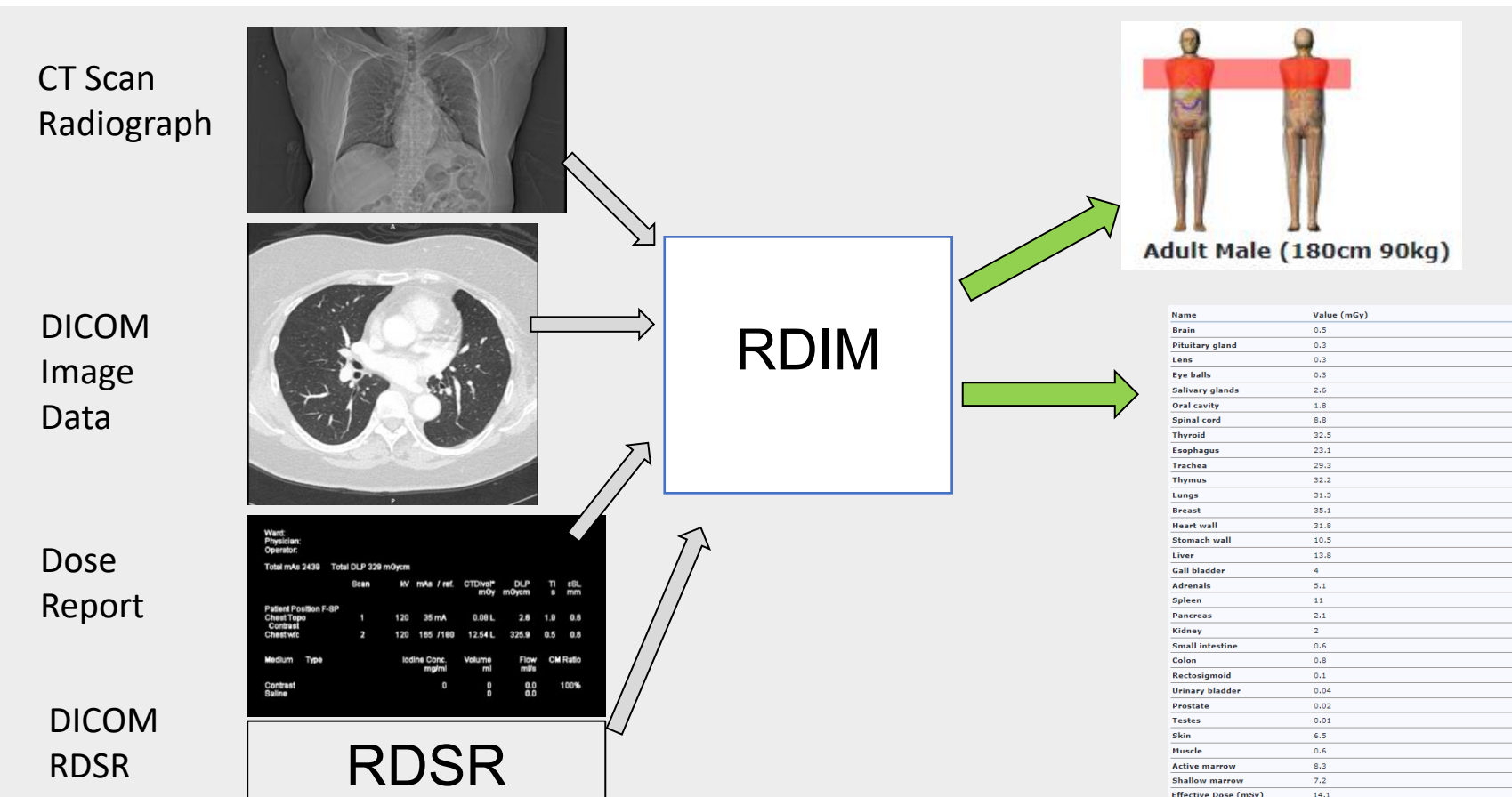


Figure 1. Diagram of workflow – Deidentified CT Scan Radiograph, DICOM image data, Dose report and DICOM RDSR are input to RDIM. RDIM then determines patient model to use in estimating organ and effective doses, which are reported out for each case.

METHODS AND MATERIALS - 2

2. Comparing Estimated Organ and Effective Doses

Each site worked with RDIM vendor to produce organ and effective dose estimates for each case.

Estimates were compared by calculating:

- Mean, standard deviation and standard error (Std Dev/Mean) for each dose estimate for **each** organ for **each** patient **across** RDIMs
- Similarly for effective dose for **each** patient **across** RDIMs

Also calculated the average absolute percent difference (AAPD) across estimates.

$$AAPD = \text{Average} (|(Dose_1 - Dose_2)| / (\text{Average}(Dose_1, Dose_2)))$$

Repeated for **each** estimated organ and effective dose for each patient.

RESULTS - 1

Pt.	Anatomic Region	Sex	BMI	CTDIvol (mGy)	SSDE (mGy)
1	Routine Chest	F	27.2	12.5	16
2	Routine Chest	F	19.2	6.7	10
3	Routine Chest	M	29.3	18.1	16
4	Routine Chest	M	24.0	12.6	16
5	Routine Abd/Pel	F	29.6	10.2	14
6	Routine Abd/Pel	F	41.6	17.6	19
7	Routine Abd/Pel	M	19.2	7.0	10

Table 1 – Scan type, Sex, BMI, CTDIvol (mGy) and SSDE (mGy) for each patient

Organ	Organ Dose RDIM 1 (mGy/mSv)	Organ Dose RDIM 2 (mGy/mSv)
Active marrow	5.87	5.75
Breast	15.67	19.87
Colon	1.16	0.63
Esophagus	15.15	12.66
Liver	13.79	13.16
Lungs	17.17	20.58
Ovaries	0.10	0.16
Stomach wall	11.73	10.42
Thyroid	25.68	1.48
Urinary bladder	0.07	0.07
Uterus	0.09	0.15
Effective Dose (mSv)	9.25	9.25

Table 2 – Organ (mGy) and Effective (mSv) Doses for **same case** (Pt. 1- Routine Chest, Female, BMI=27.2,) **from two different RDIMs**. Breast, lung and thyroid doses (highlighted in yellow) **all differed by at least 20% between RDIM estimates**. Note that **effective dose** (highlighted in green) **has < 1% difference** despite organ dose differences.

RESULTS - 2

ROUTINE CHEST (N=4)

	Pt. 1: Female, BMI 27.2		Pt. 2: Female, BMI 19.2		Pt. 3: Male, BMI 29.3		Pt. 4: Male, BMI 24.0	
Organ	Avg Organ Dose (mGy)	AAPD	Avg Organ Dose (mGy)	AAPD	Avg Organ Dose (mGy)	AAPD	Avg Organ Dose (mGy)	AAPD
Thyroid	13.55	61.6%	4.77	33.7%	7.74	54.4%	6.08	51.6%
Esophagus	13.89	8.5%	8.63	8.6%	17.19	11.5%	12.89	2.8%
Breast	17.76	12.7%	9.59	17.9%	NR	NR	NR	NR
Lungs	18.87	9.5%	11.59	14.7%	25.06	25.7%	18.13	10.9%
Liver	13.46	2.2%	11.02	3.5%	22.18	21.5%	16.43	5.0%
Stomach wall	11.05	5.6%	10.95	2.7%	21.11	22.9%	15.97	5.3%
Colon	0.88	25.1%	5.39	52.6%	3.53	32.4%	7.10	52.0%
Ovaries	0.13	22.7%	0.62	16.7%	NR	NR	NR	NR
Uterus	0.12	28.1%	0.43	17.3%	NR	NR	NR	NR
Urinary bladder	0.07	8.3%	3.32	148.6%	0.16	15.3%	0.26	36.2%
Testes	NR	NR	NR	NR	0.02	5.7%	0.04	23.9%
Active marrow	5.80	0.9%	4.66	3.2%	8.13	27.1%	6.59	5.9%
Effective Dose (mSv)	9.24	0.1%	7.04	2.6%	12.14	6.8%	9.63	10.0%

Table 3 – Average Organ and Effective (mSv) Doses as well as AAPD values for each patient in Table 1 with **Routine Chest** scan. **Green highlights** indicate AAPD values < 20%; **Yellow highlights** indicate AAPD values > 20%. Table is organized by organs in approximately superior to inferior direction. **Organs highlighted in blue box would be those be expected to be fully irradiated** during a routine chest scan. NOTE: One RDIM did not report breast dose for males.

RESULTS - SUMMARY

Across these 7 reference datasets:

- Mean effective dose estimates ranged from 6.9 to 12.1 mSv
- AAPD of Effective Doses ranged from 0.1% to 22.9%**
- Organ Doses ranged from 0.07 to 25.1 mGy
- AAPD of organ doses ranged from < 1% to 148 %**

- Agreement is reasonable among fully irradiated organs**, typically 10-20% (sometimes higher)
- Agreement frequently less among partially irradiated organs**

- Organ doses tend to be lower, so differences may be larger %
- We also identified some issues related to determining scan start and stop location (which introduced some variation)

- Extremely small sample (feasibility study), so can't read too much into these numbers

LESSONS LEARNED

- Each site needed to work with RDIM Vendor to create a test server for these analyses.
 - Most sites already have one for pre-production versions
- Initially, saw diff's across sites even w/ same RDIM vendor.
 - Further investigation revealed differences in scan location (start location, end location, scan length).
 - Some of this was a difference in a default parameter regarding scan length (set default scan length based on type of scan performed vs. option to obtain information from patient scan data – RDSR, Image data, etc.).
- Other differences most likely due to:
 - Different assumptions about scan length/location
 - Different phantom size models between vendors (or S/W versions)

CONCLUSIONS/FUTURE WORK

- Successful pilot study that generated initial results.
- Demonstrated the **feasibility** of performing **direct comparisons** of organ and effective dose estimates from RDIMs using a reference set of patient datasets.
- FUTURE WORK** – expand scope:
 - Increase number of cases (including range of patient sizes)
 - Additional RDIM systems

ROUTINE ABD/PEL (N=3)

	Pt. 5, Female, BMI 29.6		Pt. 6: Female, BMI 41.6		Pt. 7: Male, BMI 19.2	
Organ	Avg Organ Dose (mGy)	AAPD	Avg Organ Dose (mGy)	AAPD	Avg Organ Dose (mGy)	AAPD
Thyroid	0.19	7.6%	0.42	6.4%	0.09	5.6%
Esophagus	4.15	59.0%	5.32	60.1%	3.38	13.7%
Breast	3.69	63.1%	7.14	67.5%	NR	NR
Lungs	4.92	95.6%	6.73	89.7%	3.21	29.9%
Liver	12.84	17.9%	16.29	15.3%	10.81	7.3%
Stomach wall	13.31	13.6%	17.06	11.6%	11.03	9.6%
Colon	13.58	2.5%	17.29	4.0%	10.96	4.9%
Ovaries	10.73	12.9%	13.05	17.4%	NR	NR
Uterus	10.46	23.2%	12.72	26.3%	NR	NR
Urinary bladder	5.56	65.3%	6.44	63.5%	10.35	17.3%
Testes	NR	NR	NR	NR	13.23	3.4%
Active marrow	6.41	18.0%	8.19	20.4%	5.09	5.9%
Effective Dose (mSv)	8.27	21.5%	10.85	22.9%	6.88	4.1%

Table 4 – Average Organ and Effective (mSv) Doses as well as AAPD values for each patient in Table 1 with **Routine Abd/Pel** scan. **Green highlights** indicated AAPD values < 20%; **Yellow highlights** indicated AAPM values > 20%. Table is organized by organs in approximately superior to inferior direction. **Organs highlighted in blue box would be those be expected to be fully irradiated** during a routine abd/pel scan