



Clinical decision making in CT: risk assessment comparison across 12 risk metrics in patient populations

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Purpose

The Medical Physics 3.0 initiative aims to enhance direct physicist involvement in clinical decision making to improve patient care. In this involvement, it is crucial to achieve effective and patient-specific radiation risk assessment.

CT risk characterization presents a variety of potential metrics; some are related to the device output (CTDI), used in the absence of better alternatives, whereas others include organ risk-, age-, and sex-factors (Effective Dose, Risk Index).

It is unclear how different metrics can accurately reflect the radiological risk. This study compared how twelve metrics characterize radiation risk across CT patient populations to inform effective clinical decision making in radiology.

Methods

This IRB-approved study included 1394 adult CT examinations (Table 1).

Organ doses were calculated using Monte Carlo methods. Table 2 summarizes the twelve risk metrics involved in the study.

A linear regression was applied to assess each metric's dependency to RI, assumed to be the closest surrogate of patient risk. The results were characterized in terms of a Risk Sensitivity Index ($RSI = \frac{Slope}{RI/metric}$) and a Risk Differentiability Index ($RDI = \frac{RMSE}{Slope}$) as representatives of the relative sensitivity of a metric and its ability to differentiate radiation burden across clinical CT examinations.

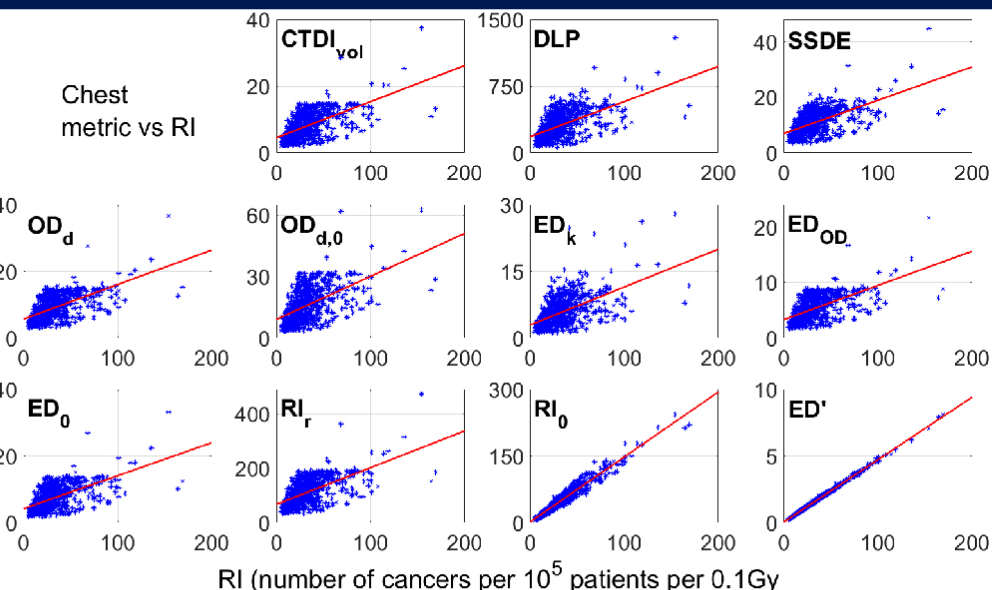
| Protocol | Number of exams | Slice thickness (mm) | Detector configuration (mm) | kV | Pitch | NI |
|--------------------|-----------------|----------------------|-----------------------------|----------|------------------|------|
| Chest | 659 | 2.5 | 40 | 120; 140 | 1.53 | 19.2 |
| Abdomen and Pelvis | 735 | 2.5 | 40 | 120; 140 | 0.52; 0.98; 1.38 | 28.0 |

Table 1. Summary of examinations included in the study sorted by clinical protocols and scan parameters. The angular automatic tube current modulation (ATCM) descriptor is noise index (NI).

| Index | Risk Surrogate | Definition | Unit |
|---------------------|--|--|--|
| CTDI _{vol} | Volume CTDI | CT device output in terms of dose in a specified phantom placed at the iso-center | mGy |
| DLP | Dose Length Product | CT device output in terms of the product of CTDI _{vol} and the exposed length | mGy x cm |
| SSDE | Size-specific Dose Estimate | CT device output in terms of the product of CTDI _{vol} and a patient-size adjustment factor | mGy |
| OD _D | Defining Organ Dose | Dose to an organ which is sensitive enough to be used as a radiation burden primary indicator for a specific anatomical region (lungs in chest and stomach in abdominopelvic studies) | mGy |
| ED _k | DLP based Effective Dose | Pre-calculated Effective Dose for a reference phantom based on CT output | mSv |
| ED _{OD} | Organ Dose-based Effective Dose | Effective Dose calculated based on actual organ doses of the patient for the exact applied imaging condition incorporating organ sensitivities | mSv |
| RI | Risk Index | Radiation Risk Index calculated based on actual organ doses of the patient for the exact applied imaging condition incorporating organ sensitivities | Number of cancers per 10 ⁵ patients per 100 mGy |
| RI _{rp} | Risk Index for a Reference Patient | Risk Index for 20 y. o. reference patient undergoing the same exam | Number of cancers per 10 ⁵ patients per 100 mGy |
| OD _{D,0} | Defining Organ Dose from Reference Phantom | Defining Organ Dose calculated rescaling the organ doses for a reference phantom undergoing a standard exam (CTDI _{vol} = 6.01 mGy) | mGy |
| ED ₀ | Organ Dose-based Effective Dose from Reference Phantom | Organ Dose-based Effective dose calculated rescaling the organ doses for a reference phantom undergoing a standard exam (CTDI _{vol} = 6.01 mGy) | mSv |
| RI ₀ | Risk Index from Reference Phantom | Radiation Risk Index calculated rescaling the organ doses for a reference phantom undergoing a standard exam (CTDI _{vol} = 6.01 mGy) | Number of cancers per 10 ⁵ patients per 100 mGy |
| ED' | Risk-adjusted Effective Dose Effective Dose Prime * | Effective dose calculated based on actual organ doses of the patient for the exact applied imaging condition incorporating organ sensitivities and corrected with a factor that takes into account age- and sex-specific risk: $ED' = \frac{RI}{RI_{rp}} \times ED_{OD}$ | mSv' |

Table 2. Risk surrogates in this study. * The symbol ' is used to designate a difference between characterization of ED and its unit mSv from other method used for the quantity.

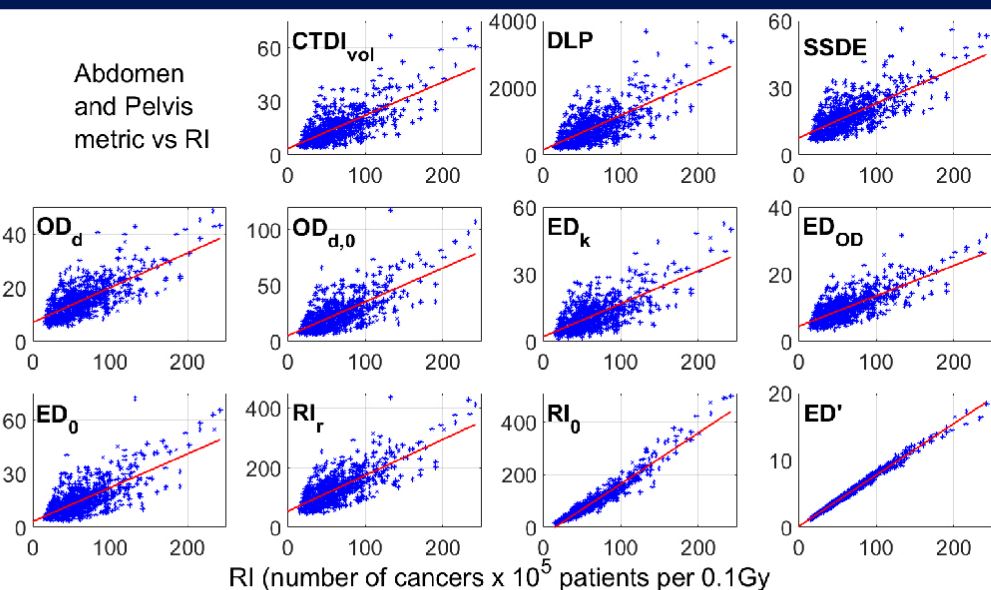
Results



Linear regression of each metric to RI for the Chest protocol. Y axes units are reported in Table 2.

| metric | Chest | | | Abdomen and Pelvis | | |
|---------------------|----------------|------|---|--------------------|------|---|
| | R ² | RSI | RDI (cancers per 1000 patients per 100 mGy) | R ² | RSI | RDI (cancers per 1000 patients per 100 mGy) |
| ED' | 1.00 | 0.98 | 0.01 | 0.99 | 0.97 | 0.03 |
| RI ₀ | 0.94 | 0.97 | 0.05 | 0.94 | 1.29 | 0.09 |
| OD _D | 0.36 | 0.38 | 0.30 | 0.51 | 0.54 | 0.35 |
| RI _{rp} | 0.35 | 0.40 | 0.30 | 0.55 | 0.59 | 0.32 |
| CTDI _{vol} | 0.34 | 0.45 | 0.30 | 0.49 | 0.77 | 0.36 |
| ED _{OD} | 0.34 | 0.39 | 0.31 | 0.55 | 0.57 | 0.32 |
| SSDE | 0.34 | 0.37 | 0.31 | 0.50 | 0.57 | 0.35 |
| ED ₀ | 0.34 | 0.44 | 0.31 | 0.50 | 0.79 | 0.35 |
| DLP | 0.32 | 0.43 | 0.32 | 0.49 | 0.81 | 0.36 |
| ED _k | 0.30 | 0.49 | 0.34 | 0.49 | 0.82 | 0.39 |
| OD _{D,0} | 0.30 | 0.44 | 0.34 | 0.50 | 0.79 | 0.35 |

Green color shows the best values whereas red shows the poorest agreement with the RI risk prediction.



Linear regression of each metric to RI for the Abdomen and Pelvis protocol. Y axes units are reported in Table 2.

Conclusions

Different risk surrogates lead to different characterization of population risk.

ICRP-motivated, new defined ED'

- incorporates organ sensitivities
- accounts for age- and sex-specific risks
- exhibits close characterization and differentiability of population risk (RSI = 0.98 in Chest CT; RSI = 0.97 in Abdominopelvic CT)

Care should be exercised in drawing risk predictions from unrepresentative risk metrics applied to a population

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