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

F. Ria, W. Fu, J. Hoye, P. Segars, A Kapadia, E. Samei

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 metrics, many of which used as radiation risk surrogates; some are related to the device output (CTDI), whereas others include patient organ risk-, age-, and gender-factors (Effective Dose, Risk Index). It is unclear how different metrics can accurately reflect the radiological risk. This study compared how twelve metrics characterize risk across CT patient populations to inform effective clinical decision making in radiology.

Methods

This IRB-approved study included 1394 adult CT examinations (abdominopelvic and chest). Organ doses were calculated using Monte Carlo methods. The following risk surrogate metrics were calculated: $CTDI_{vol}$, DLP, SSDE, DLP-based Effective Dose (ED_k), organ-dose-based ED (ED_{OD}), dose to defining organ (stomach- and lungs-OD_D), organ-dose-based Risk Index (RI), and 20 y.o. patient Risk Index (RI_r). Furthermore, $OD_{D,0}$, ED_0, and RI_0 were calculated for a reference patient (ICRP 110). Lastly, an adjusted ED (ED') was computed as the product of RI/RI_r and ED_{OD}. A linear regression was applied to assess each metric's dependency to RI, assumed to be the closest patient risk surrogate. The normalized-slope (nS) and a Minimum Risk Detectability Index (MRDI=RMSE/slope) were calculated for each fit.

Results

The analysis reported significant differences between the metrics. ED' showed the best concordance with RI in terms of nS and MRDI. Across all metrics and protocols, nS ranged between 0.37(SSDE) to 1.29(RI_0); MRDI ranged between 39.11(ED_k) to 1.10(ED') cancers per 10^5 patients per 0.1Gy.

Conclusion

Radiation risk characterization in CT populations is strongly affected by the index used to describe it. When involved in clinical decisions, medical physicists should exercise care in ascribing an implicit risk to factors that do not closely reflect risk.

Innovation/Impact

The study explored how twelve different radiation risk surrogate metrics characterized radiation burden across two sets of clinical CT examinations. The data clearly showed how different risk metrics can lead to different characterization of population risk. RI was assumed to be the closest surrogate of actual patient risk, which was why it was chosen as the normalization reference against which to compare other radiation burden indexes. All metrics, except ED' and RI_0, showed MRDI greater or equal to 30 number of cancers per 10^5 patients per 0.1Gy, indicating poor sensitivity in risk characterization (Table 1). Normalized-slope is also a metric of sensitivity, but in terms of population risk depiction. Values closed to the unit indicate that the metric describes population risk closer to RI, whereas nS values greater or smaller than 1 indicate risk overestimation or underestimation.

Care should be exercised in drawing risk predictions from unrepresentative risk metrics applied to a population. Risk overestimation or underestimation can negatively affect justification and optimization of CT procedures. Furthermore, to fulfill Medical Physics 3.0 goal to enhance direct medical physicist involvement in clinical decision making, there is the need to standardize risk metrology and to extend it to include age- and gender-specific assessment, as reported in this study. Particularly, ED' was introduced as a new metric that can expand the traditional definition of Effective Dose (ED_k and ED_{OD}) to also include age and gender factors. ED' exhibited a close characterization of population risk (nS = 0.98 in Chest exams; nS = 0.97 in Abdominopelvic exams), showing also the best sensitivity (MRDI = 1.10 and MRDI = 3.49 number of cancers per 10^5 patients per 0.1Gy for Chest and Abdominopelvic exams respectively).

Table 1. Normalized-slope and MRDI across all metrics and protocols. Green color shows the best values, whereas red shows the poorest agreement with the RI risk prediction.

	Chest		Abdominopelvic	
metric	**Normalized-slope**	**MRDI** (number of cancer per 10^5 patients per 0.1Gy)	**Normalized-slope**	**MRDI** (number of cancer per 10^5 patients per 0.1Gy)
ED'	0.98	1.10	0.97	3.49
RI_0	0.97	5.49	1.29	9.27
OD_D	0.38	29.80	0.54	34.81
RI_r	0.40	30.21	0.59	31.77
$CTDI_{vol}$	0.45	30.51	0.77	35.98
ED_{OD}	0.39	30.52	0.57	32.19
SSDE	0.37	30.61	0.57	35.03
ED_0	0.44	30.96	0.79	35.00
DLP	0.43	32.25	0.81	35.82
ED_k	0.49	33.67	0.82	39.11
$OD_{D,0}$	0.44	33.69	0.79	35.17

Note: OD_D was calculated for lungs in Chest and for stomach in Abdominopelvic exams.