

Comparative risk assessment of clinical and radiation risk across a cohort of patient and individualized risk optimization

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Purpose

Informed by a recent mathematical framework, we formulated an imaging strategy to balance interpretative performance-based clinical risk (i.e., false positive and false negative rates) and radiation risk as a risk-versus-risk assessment. The model was applied to a population of one million cases simulating a clinical liver cancer scenario. Moreover, a model was developed to predict individualized risk-versus-risk optimization.

Methods

The proposed model defined a Total Risk (TR) as the linear combination of radiation risk and clinical risk defined as functions of the radiation burden, the disease prevalence disease, the false positive rate, the expected life-expectancy loss for an incorrect diagnosis, and the radiologist interpretative performance (i.e., AUC). The mathematical framework was applied to a simulated dataset of 1,000,000 CT studies investigating localized stage liver cancer assuming a typical false positive rate of 5% and optimal imaging conditions (AUC=0.75). Demographic information was simulated according with literature and census data including male and female for different patient races (white, black, Asian, and Hispanic). Following BEIR-VII report, organ-specific radiation doses were used to calculate the radiation Risk Index per each patient. The model was then extended to predict the optimal scanner output associated with the TR for specific patients.

Results

Across all races and sexes, median radiation risk ranged between 0.008 and 0.012 number of deaths per 100 patients; median clinical risk ranged between 0.042 and 0.076; and medial total risk ranged between 0.010 and 0.088 deaths per 100 patients. The mathematical model was then generalized to estimate individualized optimal imaging condition minimizing TR.

Conclusion

A mathematical framework to describe total risk in CT was robustly tested in a simulated dataset of 1,000,000 CT studies. The results highlighted the dominance of clinical risk at typical CT examination dose levels. The generalization of the mathematical model allowed the prediction of individualized risk optimization.

Innovation/Impact

The proposed comprehensive risk-versus-risk assessment is essential in the effective justification of radiological procedures and in the design of optimal clinical protocols. Framing imaging optimization as a risk-versus-risk question, calculating both clinical and radiation risk using comparable units, allows a quantitative and complete depiction of total risks in CT.

Key results

For typical clinical operation CTDI_{vol} values (<50 mGy), the data clearly showed how clinical risk plays a more dominant factor in the overall procedure evaluation whereas radiation risk is a secondary consideration and is further a longer-term effect than more immediate clinical risk consideration. The model generalization enables individualized optimization based on the theoretical scanner output, namely CTDI_{vol}, that can result in the minimum patient total risk considering both interpretative performance-based clinical risk and radiation risk. Figure 1 (top) reports the median values of radiation, clinical, and total risk for each ethnic group and sex considered in the study; Figure 1 (bottom) shows an example of the application of the theoretical model to a 66-year-old white female (waist diameter = 36.8cm) undergoing a CT exam for the investigation of liver cancer.

race	sex	Number of patients	median radiation risk (deaths per 100 patients)	median clinical risk (deaths per 100 patients)	median total risk (deaths per 100 patients)
white	male	335,847	0.010	0.047	0.059
	female	373,467	0.008	0.051	0.059
black	male	493,86	0.011	0.042	0.054
	female	61,750	0.010	0.058	0.066
Asian	male	26,140	0.009	0.066	0.075
	female	31,062	0.008	0.076	0.088
Hispanic	male	58,375	0.012	0.047	0.059
	female	63,973	0.010	0.050	0.010
total		1,000,000			

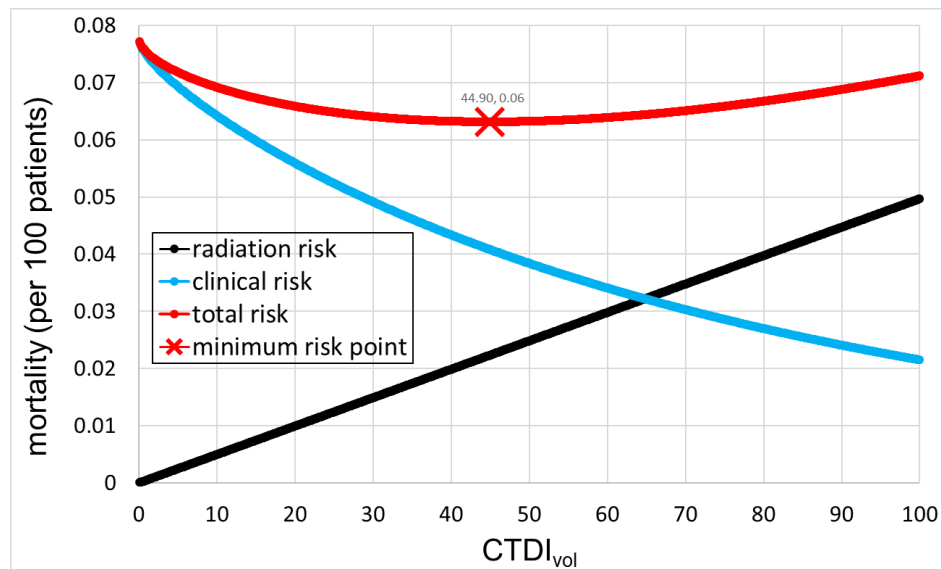


Figure 1. Table reporting the median values of radiation, clinical, and total risk for each ethnic group and sex considered in the study (top); and plot for a specific patient reporting Radiation risk (black), Clinical risk (blue), and Total risk (red) assuming $0.1 < \text{CTDI}_{\text{vol}} < 100 \text{ mGy}$ and related AUC calculated based on known relationships between CT image quality and radiation output. The red mark represents the optimal risk point.