Total risk index: a mathematical model for decision making based on clinical and radiation risk assessment in CT

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Purpose

Radiological risk is a combination of radiation and clinical risk (likelihood of not delivering a proper diagnosis), which together may be characterized as a total risk index (TRI). While many strategies have been developed to ascertain radiation risk, there has been a paucity of studies assessing the clinical risk. This knowledge gap makes impossible to determine the total radiological procedure risk and, thus, to perform a comprehensive optimization. The purpose of this study was to develop a mathematical model to ascertain TRI and to identify the minimum TRI (mTRI) in a clinical CT population.

Materials and Methods

This IRB approved study included 21 adults abdomen exams performed on a dual-source single energy CT at two different dose levels (84 CT series). Virtual liver lesions were inserted into projection data to simulate localized stage liver cancer (LSLC). The detectability index (d') was calculated in each series and converted to percentage of correct observer answers (AUC) in a two-alternative forced-choice model. The AUC was converted into the loss of 5-year relative survival rate (SEER, NCI), considering an upper bound on patient's risk for a misdiagnosis of LSLC (false positive + false negative). Concerning radiation risk, organ doses were estimated using a Monte Carlo method and the Risk Index was calculated and converted in 5-year relative survival rate for cancer. Finally, the two risks were weighted equally into a combined TRI curve per each patient as a function of $CTDI_{vol}$. The analytical minimum of each TRI curve provided the patient mTRI.

Results

The mTRI for LSLC patients that underwent an abdominal CT exhibited a rapid rise at low radiation dose due to enhanced clinical risk of under-dosed examinations. Increasing dose offered less risk with mortality per 100 patients between 2.1 and 6.5 (mean 4.5) at CTDIvol=5mGy, between 1.1 and 5.9 (mean 3.5) at CTDIvol=10mGy and between 0.5 and 5.4 (mean 3.0) at CTDIvol=20 mGy.

Conclusion

The clinical risk seems to play a more dominant factor in designing optimum CT protocols. The TRI may provide an objective and quantifiable metric of the interplay of radiation and clinical risks during the optimization of the CT technique for individual patients.

Clinical Relevance statement

CT risk-based optimization can be made possible by first quantifying both radiation and clinical risk using comparable units, then calculating an overall risk, and finally minimizing the total risk.