Comparison and validation of noise magnitude estimation methods from patient CT images

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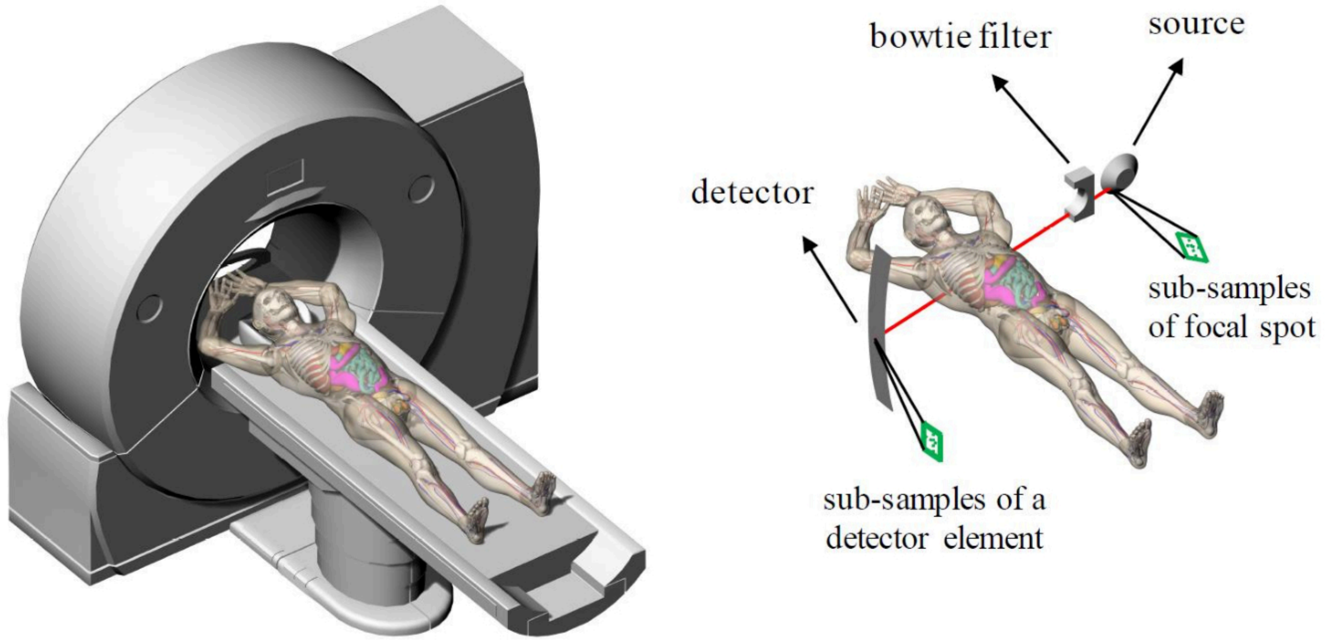
Purpose

The estimation of image quality in CT is crucial for technology assessment, procedure optimization, and overall benefit evaluation, with noise magnitude playing a key role. Several methods have been proposed to estimate noise surrogates. The most accurate approach is to assess ensemble noise by scanning a patient multiple times and sampling each pixel noise within the ensemble of images, an ethically undoable repeated imaging process. Such impasse can be surmounted using Virtual Imaging Trials (VITs) that use computer-based simulations to mimic clinically realistic scenarios. In this study, we evaluated two different noise magnitude estimation methods by comparing them with the ensemble noise measured in a VIT population.

Methods

The study included a set of 47 XCAT-phantom repeated chest exams acquired virtually using a scanner-specific simulator (DukeSim) modeling a commercial scanner geometry, reconstructed with FBP and IR algorithms.



DukeSim virtual simulator modelling a commercial scanner geometry.

The noise magnitudes were calculated in soft tissues (GNI) and in the air surrounding the patient (AIRn), applying [-300,100] HU and HU<-900 thresholds, respectively. Furthermore, for each pixel in GNI threshold, the ensemble noise magnitudes in soft tissues (En) were calculated across images. Noise magnitude from different methods were compared in terms of percentage difference with the correspondent En median values.

Example of one image considered in the study reconstructed with FBP (a). Noise was calculated in red areas applying (b) GNI threshold and (c) AIR threshold.

Results

As summarized in the following table, the noise calculated in soft tissues overestimates the ensemble noise with both FBP and IR technique whereas the noise calculated in the air surrounding the patient underestimates En.

metric	median En	median GNI (% difference with En)	median AIRn (% difference with En)
FBP	30.6 HU	40.1 HU (+31%)	25.1 HU (-18%)
IR	19.5 HU	25.1 HU (+29%)	18.8 HU (-4%)

Conclusions

GNI:
- represents spatial noise in tissue
- overestimates ensemble noise in tissue
- overestimation is relatively constant
- enables calibration to estimate tissue noise

Estimation of spatial or ensemble noise in tissue *in vivo* enables optimization and improvement of consistency across CT imaging.

AIRn:
- does not represent spatial noise in tissue
- underestimates ensemble noise in tissue
- underestimation is reconstruction-dependent

To what extent spatial noise vs ensemble noise need to be the primary metric informing protocol optimization requires additional research.

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