Accuracy of noise magnitude measurements from patient CT images: a virtual imaging study

Francesco Ria, Hananiel Setiawan, Ehsan Abadi, Ehsan Samei

Purpose

Noise magnitude is a main CT image quality indicator. *In vivo* measurements emerged as a patient-specific methodology to assess and qualify CT noise, yet methods to do so vary. Current noise measurement methods in soft tissues and air surrounding the patient use distinct image segmentations, HU thresholds, and region-of-interests, resulting in noise estimation variations. In this study, we compared two noise magnitude calculation methods against the gold standard ensemble noise in two cohorts of virtually-generated patient images across 36 imaging conditions.

Methods

1800 image datasets were generated using a virtual trial platform based on anthropomorphic phantoms (XCAT) and a validated, scanner-specific CT simulator (DukeSim). XCAT phantoms were repeatedly imaged 50 times using Chest and Abdominopelvic protocols, three dose levels, and three reconstruction kernels, using both FBP and IR algorithms. Noise magnitudes were calculated in the air surrounding the patient (An) and soft tissues (GNI) by applying HU<-900 and -300<HU<100 thresholds, respectively. Per each imaging condition, An and GNI were compared to the ensemble noise calculated in soft tissue (En) and to the ensemble noise calculated in the liver and in the lungs (On) for abdominopelvic and chest studies, respectively.

Results

Across the three kernels and dose levels, An largely underestimated En and On for both FBP (median differences: -46% and -49%) and IR (median differences: -49% and -51%); whereas the GNI showed closer values to the En and On for FBP (median differences: 4% and 3%) and IR (median differences: -3% and -8%).

Conclusion

Applying virtual imaging techniques enabled an unbiased comparison of different noise magnitude calculation methods in large and realistic populations simulating clinical conditions. The noise measured in the air surrounding the patient cannot represent noise magnitude in soft tissues. The results affirmed the validation of soft tissue-based noise measurements as a close surrogate to inform protocol design and technology assessment.

Innovation/Impact

Virtual Imaging Trials enable the objective and unbiased comparison of different noise magnitude estimation methods *in vivo*. Such comparisons are essential because, currently, different methods can provide different noise values even when applied to the same image condition, negatively affecting protocol design, technology assessment, as well as implementation and evaluation of optimization actions. In particular, the comparison with the gold standard ensemble noise, both in soft tissue and in an organ representative of the scanned anatomical region, can inform the establishment of adjustment or calibration factors to better represent clinical results.

Key results

Because noise magnitude is measured as a surrogate of overall image quality, it is essential to establish consistent and robust methodologies to estimate it. Figure 1 reports the differences between noise measured in the air surrounding the patients and in soft tissues with ensemble noise measured in soft tissues and in a representative organ for each imaging condition. Noise measured in the air surrounding the patient largely underestimates the gold standard ensemble noise methods. Therefore, care should be exercised in designing optimization actions or assessing technology performances using methods that measure image quality in diagnostic image areas that are not clinically relevant.

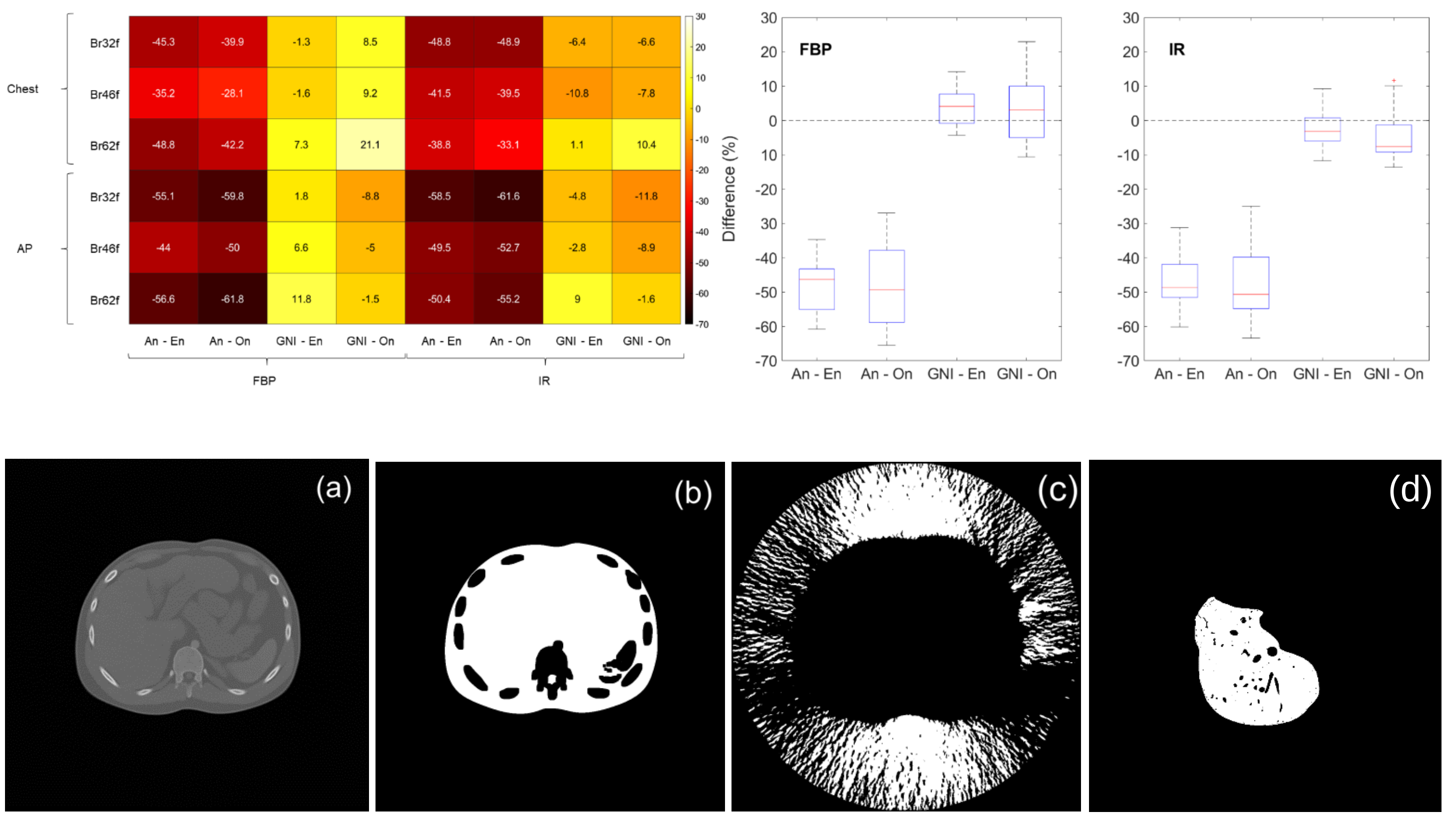

Figure 1. Percentage differences between An and GNI with both En and On for each imaging condition in chest and abdominopelvic patients (heatmap, top left). Percentage difference boxplots aggregated for FBP and IR reconstruction algorithms (top right); values close to zero show the best agreement with gold-standard ensemble noise. Example of one Abdominopelvic image (WW: 2500; WL: 250) considered in the study reconstructed with FBP (bottom, a); when GNI threshold is applied (bottom, b); when An threshold is applied (bottom, c); and example of segmented liver for the calculation of ensemble organ noise (bottom, d).