Matching convolution kernels and iterative reconstruction for quantitative accuracy and noise power spectrum in dual-layer and dual-source spectral CT

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INTRODUCTION

Dual-energy computed tomography (DECT) offers improved image quality and quantitative capabilities for a variety of diagnostic applications.[1] The use of iterative reconstruction algorithms in these CT systems can also greatly reduce noise in the virtual images without compromising resolution.[2] However, variation in dual energy technology, filter kernels, and iterative algorithms between vendors can complicate attempts to standardize clinical imaging protocols.[3,4]

AIM

The aim of this project was to identify comparable reconstruction techniques in two advanced DECT scanners by examining noise properties and quantitative accuracy of material decomposition.

METHOD

- The CT American College of Radiology phantom was scanned with an abdominal protocol on a dual-layer (DL) (Philips iQon, Best, The Netherlands) and dual-source (DS) (Siemens SOMATOM Force, Erlangen, Germany) scanner.
- The noise power spectrum (NPS) and modulation transfer function (MTF) were computed according to Friedman et al.[5]
- Multiple filter kernels, iterative reconstruction levels, and dose levels were compared.
- The effective atomic number (Z_{eff}), and density (ρ) of the material insert module (Module 1) of the phantom were derived and compared for various reconstruction techniques.
- Noise coarseness and magnitude were quantified from the NPS as the central (median) frequency and integral of the curve, respectively.

RESULTS

- Parameters used in the protocols for each DECT scanner are listed in Table 1.
- An example NPS calculation is shown in Figure 1.
- Figure 2 depicts NPS curves for the DL and DS systems, with three different filter kernels for the latter.
  - The Force Br44 filter most closely matched the iQon B filter in terms of central frequency and noise magnitude.
- Figure 3 depicts NPS curves for the DL and DS systems at varying iterative levels when using comparable kernels.
  - Iterative reconstruction induced similar noise reduction and center frequency shifts in both systems, quantified by noise magnitude ratio (NMR) and central frequency ratio (CFR)
  - Iterative vs. filtered back projection reconstruction:
    - DL: NMR = **0.75, 0.58;** CFR = **0.91, 0.82** for **iDose 2 and 4**, respectively
    - DS: NMR = **0.84, 0.58**; CFR = **0.92, 0.83** for **ADMIRE 1 and 3**, respectively.
  - Comparing default iterative settings (iDose 4, ADMIRE 3):
    - DS had slightly sharper noise texture (center frequency = 0.025 mm greater).
    - DS had reduced noise magnitude (**NMR = 0.90–0.93**) over DL.
- Z_{eff} and ρ were accurate within 6% for both scanners.
- Iterative reconstruction and Qr filters did not alter estimates of Z_{eff} or ρ.

Table 1: The scanning parameters for Philips iQon and Siemens SOMATOM Force. For the SOMATOM FORCE scanner, tube voltages and mAs for both tubes were listed. "Sn150" denotes 150 kVp with added tin filtration in the second tube. The mAs was varied in both scanners to result in three different but matched CTDIvol values.

Parameters	iQon	Somatom Force
Protocol	Adult abdomen	Adult abdomen
Scan Type	Helical	Helical (dual-source)
kVp	120	90/Sn150
mAs	111, 166, 221	200/125, 300/188, 400/250
$CTDI_{vol}$	10, 15, 20	10, 15, 20
Scan FOV (cm)	50	50
Reconstructed FOV (cm)	25	25
Voxel size (mm^3)	0.49 x 0.49 x 4.00	0.49 x 0.49 x 4.00
Filter	B	Br44
Reconstruction	iDose 0, 2, 4	ADMIRE 0, 1, 3

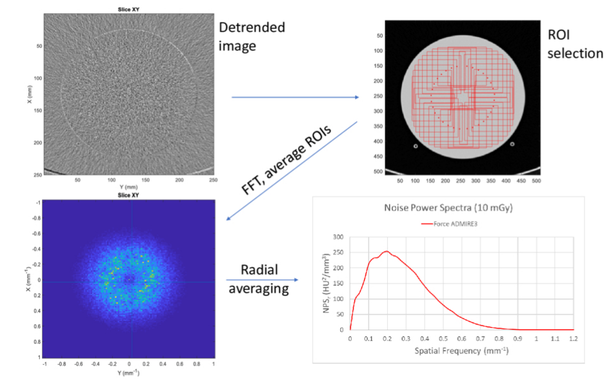

Figure 1: Workflow of NPS calculation, as described by Friedman et al.[5]

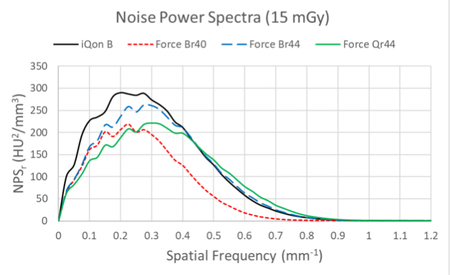

Figure 2: Noise power spectra generated from DL (iQon) and DS (Force) CT images with filtered back-projection reconstruction and various filter kernels at CTDI of 15 mGy. The curves demonstrate greatest similarity between the Force Br44 kernel and iQon B kernel. The Qr44 kernel reduces noise magnitude and shifts the center frequency higher when compared with Br44.

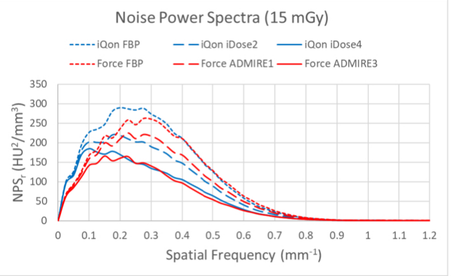

Figure 3: Noise power spectra generated from DL (iQon) and DS (Force) CT images, using comparable filter kernels with multiple iterative reconstruction levels. The curves show similar changing patterns of NPS: both scanners' algorithms reduce noise magnitude while shifting the NPS center frequency lower.

CONCLUSIONS

When using matched reconstruction techniques, DL and DS scanners achieve comparable levels of noise magnitude and texture at the default iterative reconstruction level. Quantitation of Z_{eff} and ρ in tissue-equivalent material is accurate and comparable in DL and DS scanners and is unaffected by filter kernel selection or iterative reconstruction. Iterative methods do, however, reduce noise magnitude and increase noise coarseness.

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