Energy Selection to Reduce Size-Dependent HU Bias In Photon Counting CT :

Monoenergetic Imaging of Iodine and Calcification

Afrouz Ataei, PhD; Victor Moy; Mark P. Supanich, PhD

Department of Diagnostic Radiology & Nuclear Medicine, Rush University Medical Center, Chicago, IL

afrouz_ataei@rush.edu

mark_supanich@rush.edu

2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

RUSH

Introduction

Photon-counting CT (PCCT) records individual X-ray photons and sorts them into energy bins, enabling simultaneous multi-energy acquisition and routine reconstruction of virtual monoenergetic images (VMIs) from 40–190 keV in a single scan[1,2]. VMIs are increasingly used for quantitative tasks such as iodine contrast assessment and calcification characterization, where the reported Hounsfield unit (HU) is treated as a stable, energy-specific quantity[3].

Low-keV VMIs boost iodine and soft-tissue contrast, while higher-keV VMIs suppress beam-hardening and metal/calcium blooming. However, VMI HU accuracy is known to depend on patient size and material density: prior work has shown PCCT can underestimate 40 keV HU for dense materials in large-habitus phantoms[2,4]. Because attenuation, beam-hardening, and scatter all scale with object size, residual size-dependent HU bias may persist even with PCCT and vary systematically with the selected energy.

Purpose

To quantify the energy-dependent effect of phantom size on monoenergetic HU for high-density materials relevant to contrast and calcification assessment in PCCT, and to identify VMI energies that minimize size-related HU bias for quantitative tasks.

Materials & Method

Scanner & phantom: A high-density insert module in a multi-energy phantom (Gammex) was scanned on a Siemens NAEOTOM Alpha PCCT.

Sizes: Two habitus configurations, 20 cm (small) and 40 cm (large), to bracket clinical patient size.

VMIs: Reconstructed from 40–190 keV using Quantum Iterative Reconstruction (QIR3).

Materials: Iodine (4 & 5 mg/mL), iodine+blood, gadolinium, calcium/calcification surrogates ($CaCO_3$, cortical & inner bone, calcium), water, and background.

Analysis: Mean HU measured with consistent ROIs at each energy. Size dependence quantified as $\Delta HU_{size} = HU_{40cm} - HU_{20cm}$ versus energy.

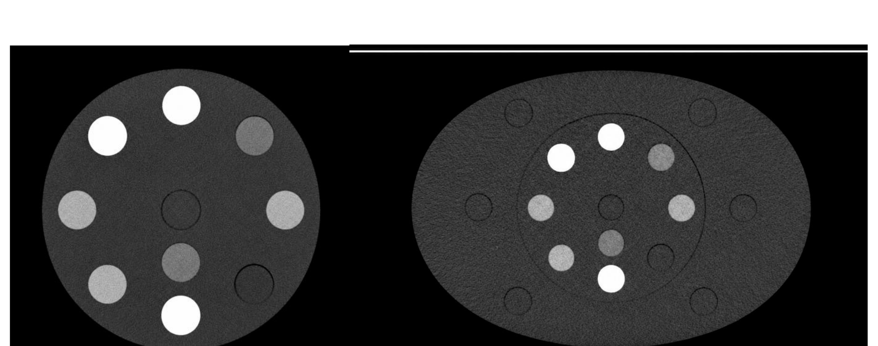

Figure 1. CT images showing the arrangement of the rods in 20 cm and 40 cm phantoms.

Results

Phantom-size dependence of monoenergetic HU was strongly energy dependent and, for several materials, changed sign across the VMI range.

Low keV (40 keV): ΔHU_{size} was positive and largest for gadolinium (+43 HU) and cortical bone (+37 HU), with smaller positive bias for iodine (+20 HU) and water (+13 HU).

High keV (190 keV): bias decreased and became negative for gadolinium (−16 HU), iodine (−9 HU) and water (−9 HU); background bias was small (−3 HU).

(A) (B)

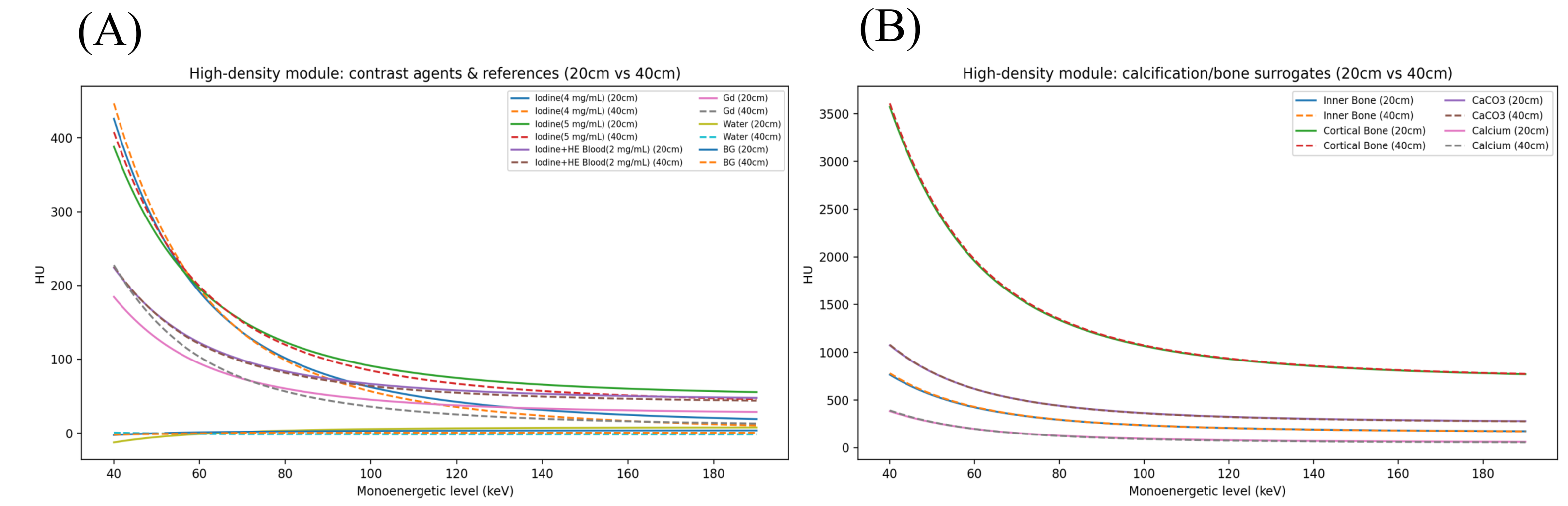

Figure 2. (A) Contrast agents & references — monoenergetic HU vs keV for 20 cm and 40 cm phantoms (iodine, iodine+blood, Gd, water, background).
(B) Bone/calcification surrogates ($CaCO_3$, cortical/inner bone, calcium) — HU vs keV for 20 cm and 40 cm phantoms.

(C) (D)

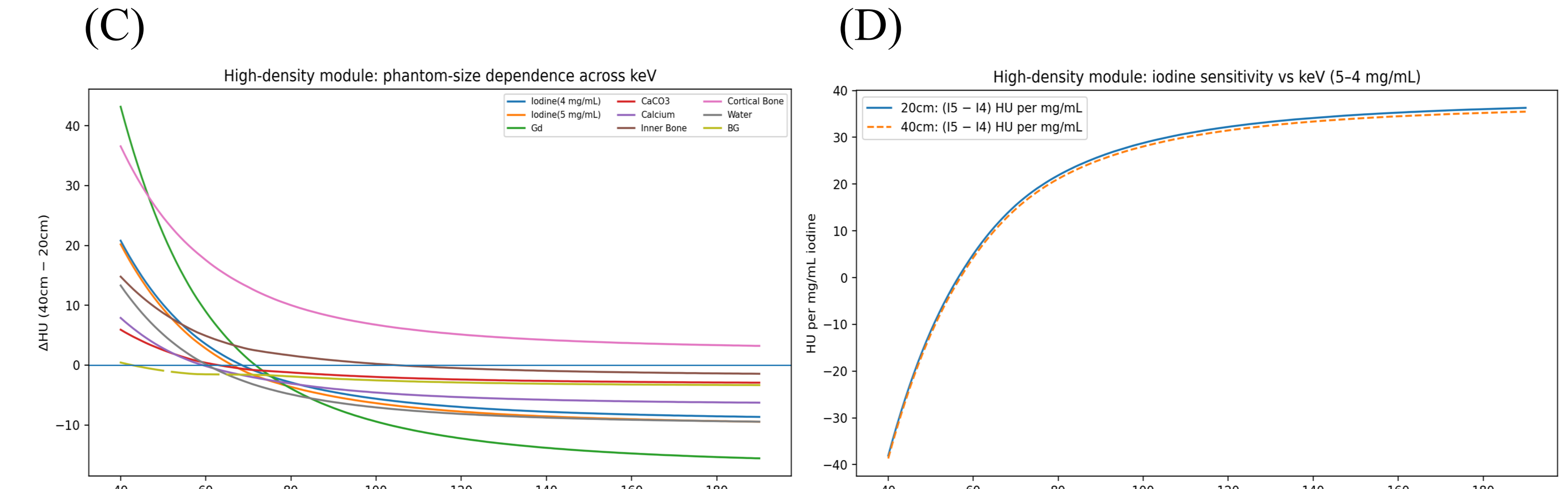

Figure 3 : (C) . Size dependence ΔHU (40−20 cm) across keV. Curves approach/cross zero near 60–80 keV; cortical bone stays positive.

(D) Iodine sensitivity (I_5−I_4 HU per mg/mL) vs keV; near-identical for 20 cm and 40 cm.

Results (cont.)

ΔHU_{size} decreased with keV and approached or crossed zero in the mid-keV range for most materials, indicating that ~60–80 keV minimizes size-related HU bias in this phantom (cortical bone remained positive).

Across 40–190 keV, maximum $|\Delta HU_{size}|$ reached ~43 HU (gadolinium), ~37 HU (cortical bone), and ~20 HU (iodine), showing residual size sensitivity in quantitative monoenergetic HU despite PCCT acquisition.

Table 1. Size-dependent HU bias ΔHU_{size} (40−20 cm) at low vs high keV.

Material	ΔHU @ 40 keV	ΔHU @ 190 keV
Gadolinium	+43	−16
Cortical bone	+37	+3
Iodine (4 mg/mL)	+21	−9
Water	+13	−9
Background	~0	−3

Conclusion

Monoenergetic HU for contrast and calcification surrogates in PCCT remains size dependent in an energy-specific manner, with the largest bias at low keV and reduced bias at high keV.

Selecting mid-keV VMIs (~60–80 keV) may reduce patient/phantom size–dependent HU bias for quantitative applications.

These findings support choosing energy ranges and QC expectations that account for object size when interpreting quantitative HU metrics for contrast- or calcification-related tasks.

References

1. Rajendran K, et al. First clinical photon-counting detector CT system: technical evaluation. Radiology. 2022;303(1):130–138.
2. Vrbaski S, et al. Quantitative performance of photon-counting CT at low dose: virtual monochromatic imaging and iodine quantification. Med Phys. 2023;50(9):5421–5433.
3. Albrecht MH, et al. Review of clinical applications for virtual monoenergetic dual-energy CT. Radiology. 2019;293(2):260–271.
4. Jacobsen MC, et al. Dual-energy CT: lower limits of iodine detection and quantification. Radiology. 2019;292(2):414–419.