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A Systematic Evaluation of Imaging Performance Across a Fleet of Cone-beam CT Scanners

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Background

Cone-beam CT (CBCT) is rapidly expanding beyond dental imaging into musculoskeletal, extremity, and interventional applications, providing three-dimensional imaging on compact, procedure-adaptable platforms. However, fleet-wide benchmarking remains challenging because systems differ substantially in detector design, acquisition geometry, reconstruction methods, clinical protocols, and vendor-specific quality control. These variations influence gray-scale response, contrast and spatial resolution, image uniformity, and artifacts, limiting objective comparison across systems. A standardized, vendor-agnostic phantom-based evaluation framework is therefore needed to benchmark image-quality (IQ) performance across diverse clinical CBCT platforms.

Purpose

This study systematically evaluates and compares IQ performance across a diverse clinical fleet of CBCT scanners using a standardized, vendor-agnostic phantom-based framework under routine default clinical imaging protocols.

Methods

Scanner fleet

- Three interventional C-arm CBCTs: Philips Azurion, Siemens AXIOM-Artis, Canon Alphenix
- Two extremity CBCTs: CurveBeam PedCAT, Planmed Verity
- Default vascular or bone imaging protocols were used to reflect routine clinical operation

Acquisition

Acquisition settings varied widely across the fleet with limited ability to modify imaging attributes, including tube voltage (90–120 kVp), tube current (5–337 mA), FOV (20–48 cm), angular sampling (185°–360°), and voxel size (0.2 × 0.2 × 0.2 to 0.65 × 0.65 × 0.65 mm^3). System-reported CTDI ranged from 0.57–10 mGy, although some systems did not provide CTDI.

Performance endpoints

- Gray-scale sensitometry response across Catphan inserts
- Contrast-to-noise ratio (CNR)
- Spatial resolution, directional uniformity and artifact patterns
- X- and Y-axis normalized line profiles for cupping/shading assessment

Quantitative results

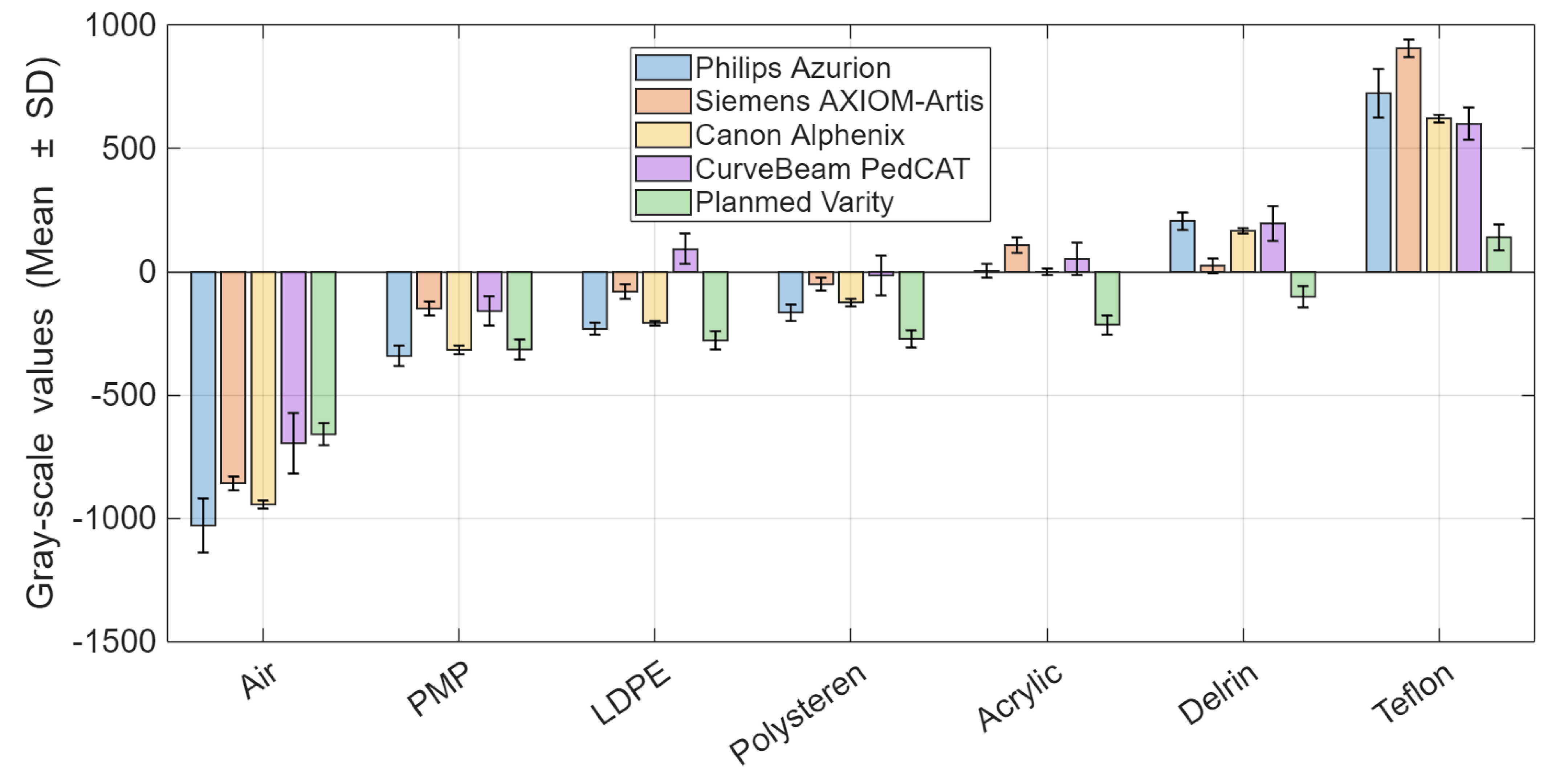

Figure 1. Gray-scale sensitometry response. *Mean gray-scale values varied widely across systems, including Teflon (140.6–955.3) and LDPE (−277.5 to 92.2), demonstrating protocol- and system-dependent gray-scale variability but highly correlated across the fleet.*

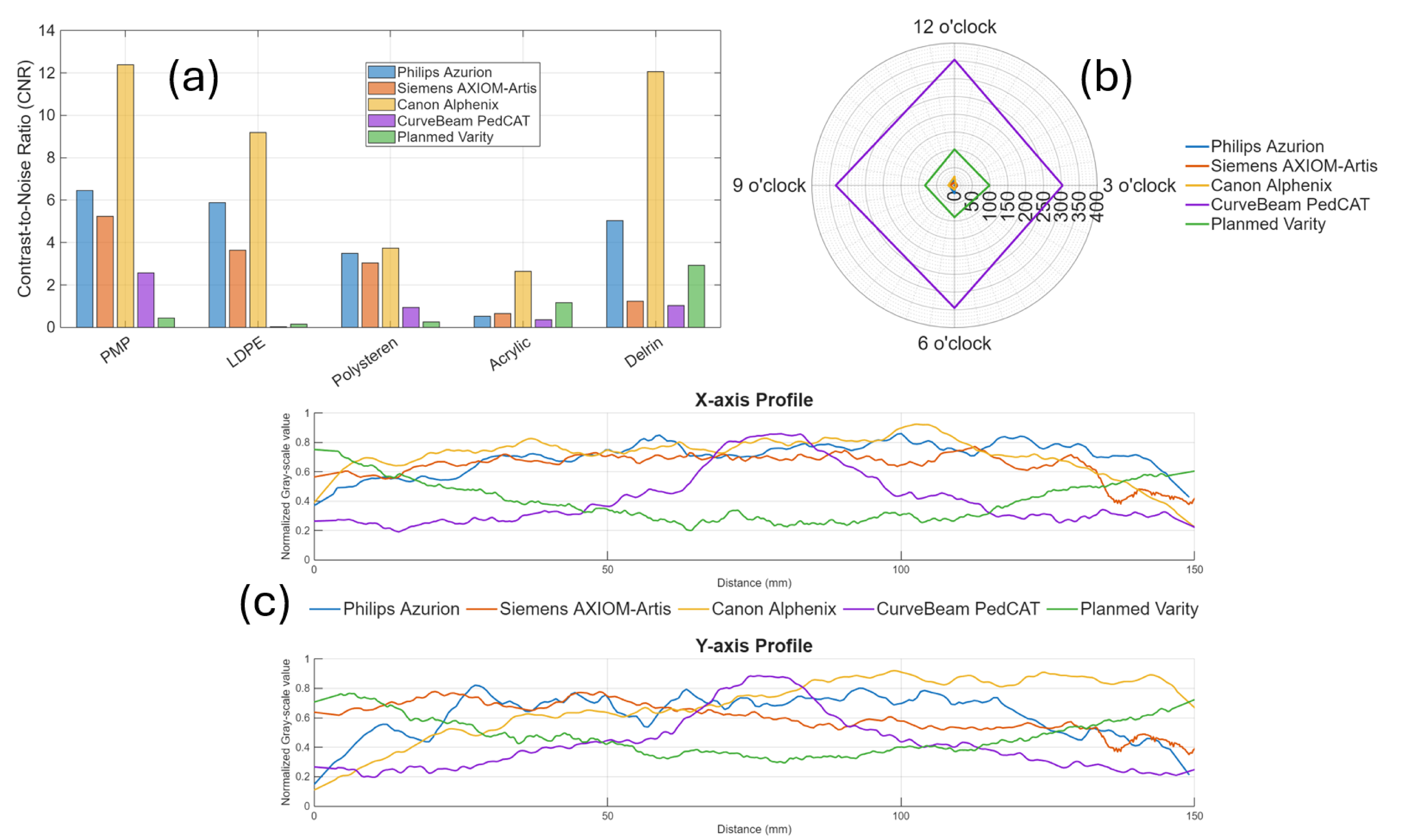

Figure 2. CNR, directional non-uniformity and line-profile behavior. *(a) CNR was highest for Canon Alphenix, intermediate for Philips Azurion and Siemens AXIOM, and lower for extremity CBCTs. (b) Directional non-uniformity and cupping/shading were markedly higher for Verity and PedCAT. (c) Smoothed X- and Y-axis line profiles showed system-dependent cupping/shading, with pronounced cupping in Varity and center-of-rotation artifact in PedCAT.*

Quantitative findings

- Across the CBCT fleet, gray-scale response values spanned a wide range across material inserts, from air (−1028.56 to −658.18) to Teflon (140.60 to 955.34). Gray-scale response patterns were highly correlated across systems (r = 0.96453–0.99938), with the highest similarity between Philips Azurion and Canon Alphenix and the lowest between Siemens AXIOM-Artis and CurveBeam PedCAT.
- CNR showed marked fleet-wide variability, highest for Canon Alphenix, intermediate for Philips Azurion and Siemens-AXIOM-Artis, and lowest for the extremity-CBCTs.
- Spatial resolution was higher for extremity-CBCTs (9 lp/cm) than IR- CBCTs (7–8 lp/cm). IR-CBCTs showed lower non-uniformity and cupping/shading artifacts than extremity-CBCTs.

Conclusion

- CBCT imaging performance varied across the fleet under clinical protocols despite highly correlated gray-scale response patterns.
- Extremity-CBCTs demonstrated higher spatial resolution but lower CNR and greater non-uniformity and cupping artifact than IR-CBCTs.
- Standardized phantom-based QC, coupled with protocol harmonization may enable fleet-wide benchmarking of CBCT imaging performance.

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Takeaway

Imaging performance varies widely across a fleet of CBCT scanners under default clinical protocols; standardized phantom-based QC with protocol harmonization may enable fleet-wide image-quality benchmarking.

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