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Scanner-Specific Variability in Neck CT Image Quality and Dose Efficiency: A Multicenter Quantitative Analysis

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ABSTRACT

Purpose: To evaluate neck CT image quality (IQ) and dose efficiency for lesion assessment across multiple scanners, identifying scanner-level differences and protocol optimization opportunities. Methods: This retrospective study included 957 contrast-enhanced CT neck soft tissue exams from 12 scanners across 8 hospitals over 6 months. IQ was objectively assessed using signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR), then subjectively via a blinded reader study performed by a radiologist who rated IQ-perceptibility on a 5-point scale. The ACR's Achievable Dose (AD) (15 mGy) to Diagnostic Reference Levels (DRL) (19 mGy) coupled with the Rose Criterion was used as a standardized reference. Dose and size metrics included CTDIvol (3.94-34.61 mGy), and water-equivalent diameter (WED) (18-59 cm). Regression and ANCOVA assessed relationships between IQ, dose, and scanner type. Results: CTDIvol showed no significant correlation with SNR or CNR (p>0.05), indicating that increasing radiation dose did not yield meaningful improvements in objective noise or contrast performance. CTDIvol also demonstrated no meaningful association with radiologist perceived IQ rating ($R^2 \approx 0.03$, p>0.05), and subjective perceptibility did not significantly correlate with SNR or CNR (p>0.05). However, regression analysis indicates that scanner type was the primary determinant of IQ. CTDIvol varied 5-fold across scanners (4.6-22.5 mGy), but radiologist ratings varied only 1.5-fold (3.0-4.6), with high-dose scanners (>18 mGy) achieving 4.30±0.14 versus 3.40±0.32 for low-dose scanners.

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METHODS

Study Design & Cohort Retrospective analysis of 957 contrast-enhanced neck soft tissue CT exams acquired over 6 months across 12 scanners at 8 hospitals. Scanners included Philips, Siemens (1A, 1B, 2, 3, 4, 5), and GE (1A, 1B, 2, 3, 4) platforms representing the institutional fleet.

Objective Image Quality ROIs were placed in homogeneous soft tissue and adjacent background to compute:

$$SNR = \frac{\mu_{signal}}{\sigma_{background}} \qquad CNR = \frac{|\mu_{signal} - \mu_{background}|}{\sigma_{background}}$$

Subjective Image Quality A blinded radiologist rated each exam on a 5-point perceptibility scale (1 = non-diagnostic, 5 = excellent). Cases were randomized and scanner identity was withheld.

Dose & Size Metrics CTDIvol was extracted from DICOM dose reports (range: 3.94–34.61 mGy). Patient size was characterized by water-equivalent diameter (WED) computed from axial images at the level of the thyroid:

$$WED = 2\sqrt{\frac{A_{ROI}}{\pi}\left(\frac{\overline{CT}_{ROI}}{1000}+1\right)}$$

where A_{ROI} is the cross-sectional area and $\overline{CT}_{ROI}$ is the mean CT number in HU. WED range: 18–59 cm.

Reference Standards
ACR Achievable Dose (AD): **15 mGy**
ACR Diagnostic Reference Level (DRL): **19 mGy**
Rose Criterion for lesion detectability: **CNR ≥ 5**

Statistical Analysis Linear regression assessed CTDIvol vs. SNR, CNR, and radiologist rating. ANCOVA tested scanner type as a predictor of IQ while controlling for WED. Pearson correlations were computed between rating and each objective metric. Significance threshold α = 0.05.

Results

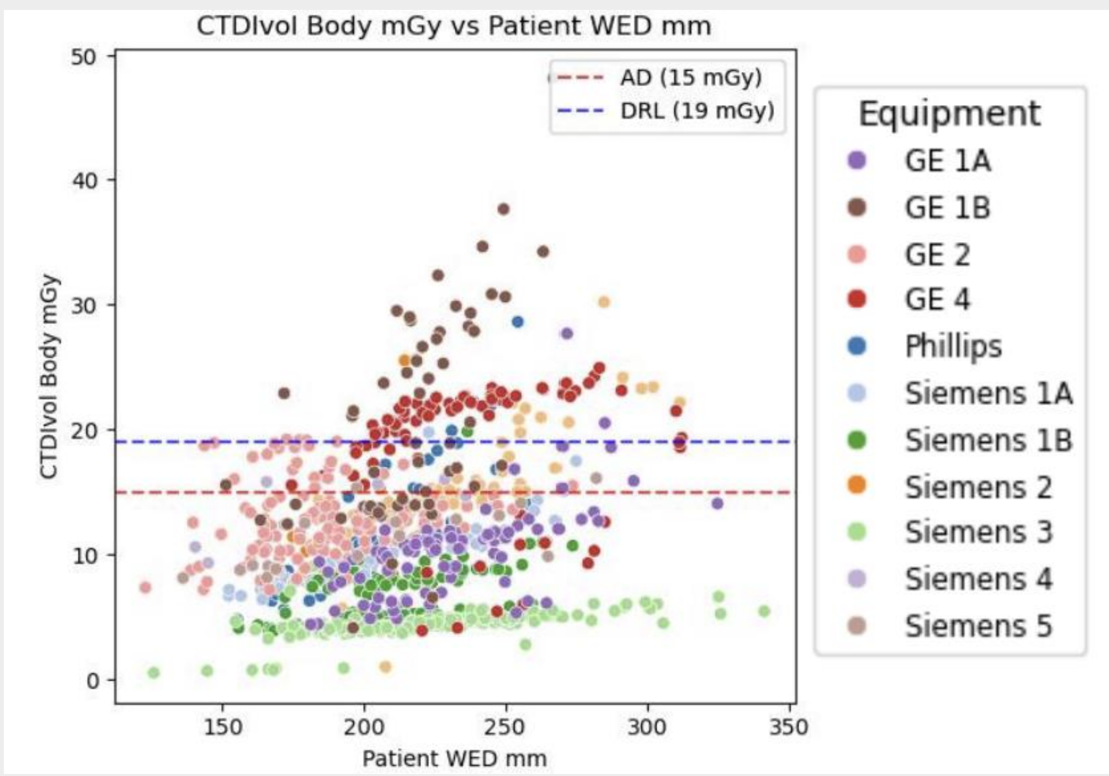

Figure 1: CTDIvol (mGy) versus patient water-equivalent diameter (WED, mm) across all scanners. CTDIvol varied up to twofold at similar WEDs, with differences driven primarily by scanner-specific protocols rather than patient size.

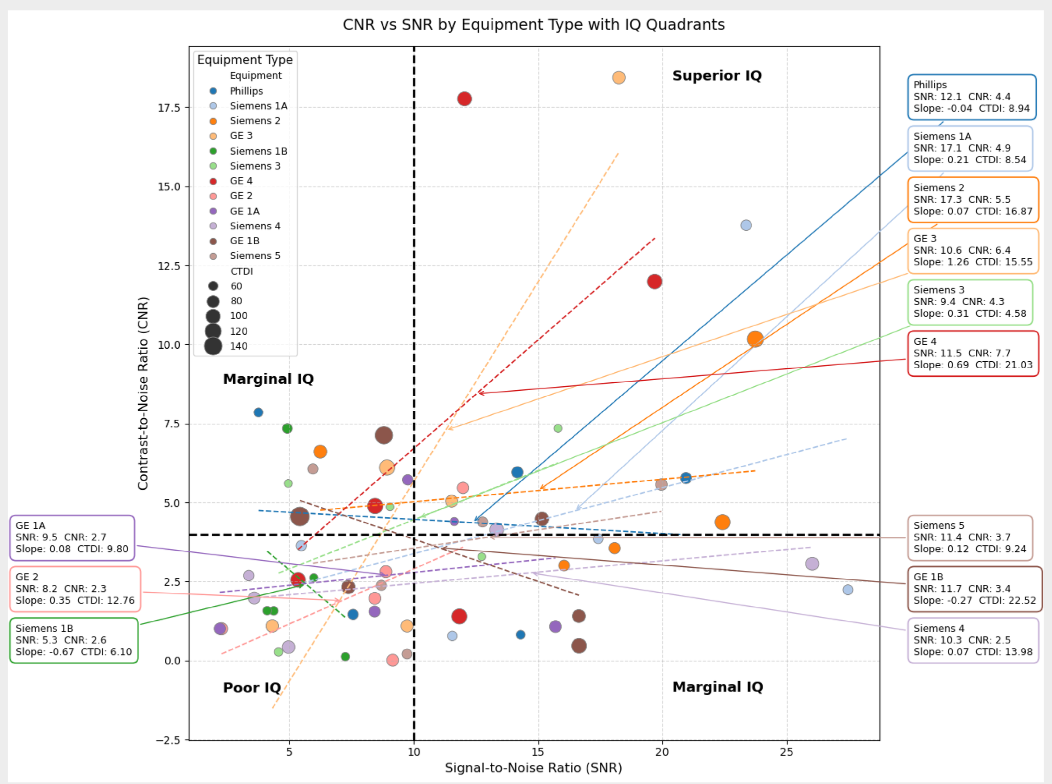

Figure 2: CNR versus SNR regression analyses by scanner type. Scannerspecific relationships varied in slope and intercept. Certain scanners achieved higher CNR at equivalent SNR independent of dose, while higher-dose scanners did not demonstrate proportional CNR gains, indicating opportunities for protocol optimization.

Equipment	CTDI (Mean ± SD)	SNR (Mean ± SD)	CNR (Mean ± SD)	Rating (Mean ± SD)
Philips	8.94 ± 2.55	12.15 ± 6.66	4.37 ± 3.07	3.2 ± 0.45
Siemens 1A	8.54 ± 0.82	17.05 ± 8.83	4.85 ± 5.13	3.8 ± 1.10
Siemens 2	16.87 ± 6.63	17.30 ± 6.92	5.54 ± 2.93	4.6 ± 0.55
Siemens 1B	6.10 ± 1.21	5.33 ± 1.29	2.65 ± 2.77	3.0 ± 0.82
Siemens 3	4.58 ± 0.57	9.43 ± 4.88	4.27 ± 2.67	3.4 ± 0.55
GE 1A	9.80 ± 2.98	9.55 ± 4.93	2.75 ± 2.17	4.2 ± 0.45
GE 2	12.76 ± 0.55	8.15 ± 3.56	2.25 ± 2.08	4.0 ± 0.00
Siemens 4	13.98 ± 3.27	10.26 ± 9.71	2.46 ± 1.38	4.4 ± 0.55
GE 1B	22.52 ± 7.89	11.68 ± 5.04	3.39 ± 2.45	4.2 ± 1.30
Siemens 5	9.24 ± 1.46	11.43 ± 5.36	3.72 ± 2.42	3.6 ± 0.89
GE 3	15.55 ± 3.72	10.55 ± 5.06	6.36 ± 7.13	3.8 ± 0.45
GE 4	21.03 ± 1.53	11.48 ± 5.35	7.72 ± 6.96	4.4 ± 0.89

Table 1. Radiation dose and image quality metrics across 12 CT scanner types. Higher CTDIvol values did not consistently correlate with improved CNR or SNR. Several lower-dose scanners demonstrated comparable or superior image quality, indicating inefficient dose utilization across platforms.

DISCUSSION

Dose and image quality are decoupled. Despite a 5-fold range in CTDIvol across scanners (4.6–22.5 mGy), radiologist ratings varied only 1.5-fold (3.0–4.6), and CTDIvol showed no significant correlation with SNR, CNR, or perceived quality. This challenges the assumption that higher dose reliably yields better diagnostic images at the neck.

Scanner type is the dominant driver. ANCOVA identified scanner as the primary determinant of IQ after controlling for patient size. Several low-dose scanners matched or exceeded the IQ of high-dose scanners — most notably Siemens 3 (4.58 mGy, rating 3.4) achieving comparable diagnostic ratings to GE 1B (22.52 mGy, rating 4.2). Reconstruction algorithms, detector design, and protocol parameters appear to explain more IQ variance than dose itself.

Patient size does not explain the variation. Figure 1 shows up to 2-fold CTDIvol differences at equivalent WEDs, confirming the variation is protocol-driven rather than anatomically necessary.

Clinical implications. Many institutions deliver radiation above the ACR DRL without measurable diagnostic benefit. Conversely, scanners operating below the AD demonstrate that diagnostic-quality neck CT is achievable at substantially lower doses. A scanner-specific approach to protocol standardization — rather than a one-size-fits-all dose target — would better serve the ALARA principle.

Limitations. Single-reader subjective scoring introduces rater variability; multi-reader validation is planned. Retrospective design precludes controlled protocol manipulation. Lesion-specific detectability was not assessed and warrants prospective follow-up.

CONCLUSIONS

Radiation dose and image quality are decoupled in neck CT. Scanner type, not dose, is the primary determinant of diagnostic quality. These findings support **scanner-specific protocol optimization** with the potential to **reduce patient dose by 30–50%** without compromising diagnostic capability, providing a replicable framework for evidence-based ALARA implementation across radiology departments.

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