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Drivers of Inter-Hospital CT Dose Variation in Saudi Arabian Tertiary Brain Imaging: Protocol-Level Analysis from a Five-Centre Dose Survey

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ABSTRACT:

Purpose: To identify and quantify the specific protocol, level determinants of inter hospital variation in CT dose indices for adult non-contrast brain CT at five Saudi tertiary hospitals, and to model the dose reduction expected from targeted protocol optimization.

Materials and Methods: The study performed a retrospective cross-sectional analysis of 488 adult non-contrast brain CT examinations at five tertiary hospitals. Primary dose metrics were CTDIvol (mGy) and DLP (mGy.cm). Protocol parameters collected during the study were reconstruction algorithm (iterative reconstruction versus filtered back projection), tube voltage (120 versus 130 kVp), and scan length at all five sites. The Kruskal-Wallis test with Dunn post-hoc comparisons and Bonferroni correction tested inter-hospital differences. Mann-Whitney U tests compared dose distributions by protocol subgroup. Epsilon-squared quantified effect sizes. Intra-hospital protocol-stratified analysis (within Hospital D, 120 kVp versus 130 kVp subgroups) isolated the contribution of individual protocol variables. Calculated for all hospitals were coefficients of variation to characterize within-hospital dose consistency.

Results: Inter-hospital differences were statistically significant (Kruskal-Wallis $H = 47.3$, $p < 0.001$, epsilon-squared = 0.18). Three independent protocol factors drove the variation. Tube voltage was the dominant variable: patients scanned at 130 kVp had a median CTDIvol 9.6 mGy higher than those at 120 kVp (56.7 versus 47.1 mGy, epsilon-squared = 0.21). Reconstruction algorithm accounted for an estimated 6 to 10 mGy difference between the filtered back projection only hospital and the iterative reconstruction-equipped hospitals at comparable kVp settings. Scan length added approximately 6.5 per cent to DLP at the above-DRL hospital. Coefficients of variation for CTDIvol were near identical across all five hospitals (17.8 to 18.2 per cent), demonstrating that within-hospital relative variability reflects AEC physiology rather than protocol inconsistency, and confirming that protocol-level changes will reduce the entire dose distribution proportionally.

Conclusion: Tube voltage selection is the single most impactful modifiable protocol determinant of brain CT dose variation between Saudi tertiary hospitals, with an effect size exceeding that of hospital membership itself. The absence of iterative reconstruction

software at Hospital D accounts for the majority of its above-DRL performance and is remediable through a software upgrade rather than capital equipment replacement. The combination of 120 kVp standardization, iterative reconstruction activation, and scan range restriction is projected to reduce Hospital D's facility median from 56.0 mGy to approximately 43 to 47 mGy without capital expenditure.

INTRODUCTION

CT brain imaging generates substantial and measurable inter-facility dose variation in every healthcare system that has studied it. The UK's 2019 national dose survey documented facility medians for adult non-contrast brain CT ranging from below 30 mGy to above 70 mGy CTDIvol across hundreds of hospitals (1). The ACR Dose Index Registry, with data from over 2,000 US facilities, shows a comparable spread (2). This variation is not attributable to differences in scanner hardware within a given technology generation since 128-slice CT systems from major manufacturers produce broadly equivalent image quality at equivalent technique settings. What varies is the technique for instance, tube voltage, reconstruction algorithm, and scan range. Notably, those technique choices are protocol decisions, not equipment limitations. Understanding which specific protocol variables drive inter-hospital variation has direct clinical and operational consequences. If tube voltage is the dominant factor, the primary intervention is a kVp protocol review, which is achievable without additional cost. If reconstruction algorithm adoption is the bottleneck, the intervention is a software upgrade that is achievable without scanner replacement. If scan length is the issue, the intervention is a protocol range specification that is achievable with a staff briefing. Different problem diagnoses point to different solutions, and without the analysis that connects dose variation to its protocol determinants, clinical optimization efforts can be misdirected at expensive equipment investments when straightforward protocol changes would achieve the same or greater dose reduction. Previous Saudi studies have documented inter-facility dose variation and called for protocol standardization (3–5), but none has quantified the independent contributions of specific protocol variables to the observed dose differences using comparative within-hospital subgroup analysis. This study addresses that gap. Using data from a five-hospital national brain CT dose survey, it applies a systematic analytical approach to isolate the relative contributions of reconstruction algorithm, tube voltage, and scan length to inter-hospital CTDIvol and DLP variation, and projects the dose reductions achievable through targeted protocol modifications at each identified source of excess.

MATERIALS AND METHODS

Study Design and Setting

This is a protocol-level analytical study using dose and protocol data from a retrospective cross-sectional multi-center dose survey. Data were collected from 488 eligible adult patients at five tertiary hospitals in Saudi Arabia. They include Abha (Hospital A), Khamis Mushait (Hospital B), Riyadh (Hospital C), Dammam (Hospital D), and Jeddah (Hospital E) all through 2024. All sites operated 128-slice CT scanners installed between 2018 and 2021. The primary dose metrics were CTDIvol (mGy) and DLP (mGy.cm), extracted from DICOM Radiation Dose Structured Reports (Hospitals B, C, E) or printed dose summaries (Hospitals A, D).

Protocol Variables

Three protocol variables were treated as explanatory factors for the dose analysis. The first was reconstruction algorithm, classified as iterative reconstruction (active at medium to high strength at Hospitals A, B, C, and E) or filtered back projection (Hospital D only, where the iterative reconstruction software module had not been procured). The second was tube voltage in kVp specifically, 130 kVp at Hospital A throughout, 120 kVp at Hospitals B, C, and E throughout, and a mixed protocol at Hospital D (approximately 60 per cent 120 kVp and 40 per cent 130 kVp, with the 130 kVp subset applied primarily to trauma referrals). The third was scan length, estimated from DLP/CTDIvol for each patient.

Statistical Analysis

The primary hypothesis test for inter-hospital dose differences used the Kruskal-Wallis H test at the individual patient level (five groups). Dunn post-hoc pairwise comparisons with Bonferroni correction (adjusted threshold $p < 0.005$ for ten comparisons) identified which specific hospital pairs differed significantly. Epsilon-squared quantified the proportion of total variance in CTDIvol explained by hospital membership.

Two sets of Mann-Whitney U comparisons isolated independent protocol variable contributions. The first compared all 130 kVp patients (from Hospitals A and D) against all 120 kVp patients across the dataset. The second compared Hospital D (filtered back projection) against the pooled four hospitals with iterative reconstruction. A within-Hospital D intra-hospital comparison between the 120 kVp and 130 kVp patient subsets isolated the kVp effect independent of the reconstruction algorithm difference. Coefficients of variation ($CV = SD/\text{mean} \times 100$) for CTDIvol and DLP were calculated for each hospital to characterize within-hospital dose consistency and to test whether the between-hospital dose differences reflected protocol-level or patient-level sources of variation. A proportional effect model estimated the expected dose reduction from full protocol optimization at Hospital D (implementing iterative reconstruction, standardizing to 120 kVp, and restricting scan length) based on the empirical intra-hospital effect sizes and the published iterative reconstruction dose reduction data.

Phantom Calibration Verification

All five hospitals were verified to be using 16 cm head phantom calibration for brain CT CTDIvol reporting before data collection began. Miscalibration against the 32 cm body phantom would produce systematically underestimated CTDIvol values, creating spurious inter-hospital differences if the phantom standard differed between sites. The confirmation of identical phantom standards across all five sites removes this potential source of artefact from the inter-hospital comparison.

Ethics

Institutional Review Board approval was obtained from all five participating hospitals and from the central Saudi National Biomedical Ethics Committee. Individual patient consent was waived under the minimal-risk retrospective observational classification. No patient identifiers were included in the analytical dataset.

RESULTS

Dataset Overview

The analyzed dataset comprised 488 patients. Hospital A 99 patients, Hospital B 97 patients, Hospital C 100 patients, Hospital D 95 patients, and Hospital E 97 patients. Twelve records were excluded during quality assurance. The pooled median CTDIvol was 49.2 mGy (range 31.2 to 98.4 mGy across all patients). The pooled median DLP was 901 mGy.cm. The proposed national DRL derived from these data is 55 mGy CTDIvol and 1050 mGy.cm DLP (75th percentile of facility medians). Table 1 summarizes scanner and protocol characteristics at each site.

Table 1. Scanner and Protocol Characteristics by Hospital

Parameter	A Abha	B Khamis Mushait	C Riyadh	D Dammam	E Jeddah
Year installed	2020	2021	2019	2018	2020
Iterative reconstruction	Yes - medium	Yes - medium-high	Yes - high	No - FBP only	Yes - medium
Standard kVp	130 (all patients)	120 (all patients)	120 (all patients)	120/130 mixed	120 (all patients)
AEC active	Yes	Yes	Yes	Yes	Yes
Mean scan length (cm)	18.5	18.1	18.3	19.6	18.8
Facility median CTDIvol (mGy)	52.4	47.3	44.1	56.0	49.4
SD (mGy)	9.4	8.7	8.1	10.2	9.0
CV (%)	17.8	18.2	18.2	18.1	18.1

Omnibus Inter-Hospital Test

The Kruskal-Wallis test confirmed highly significant inter-hospital differences in CTDIvol ($H = 47.3$, $df = 4$, $p < 0.001$) and DLP ($H = 45.8$, $df = 4$, $p < 0.001$). Epsilon-squared for CTDIvol was 0.18, indicating that hospital membership explains 18

per cent of total CTDIvol variance. This is a large effect. The remaining 82 per cent reflects within-hospital patient-level variation — predominantly AEC responses to head size differences, which was consistent across all five hospitals as indicated by the near-identical coefficients of variation. Dunn post-hoc comparisons (adjusted threshold $p < 0.005$) identified four significant pairwise differences for CTDIvol. Hospital D was significantly higher than Hospital B ($p = 0.003$), Hospital C ($p < 0.001$), and Hospital E ($p = 0.002$). Hospital A was significantly higher than Hospital C ($p = 0.003$). No other pairs reached significance. Table 2 presents the full pairwise comparison matrix.

Table 2. Dunn Post-Hoc Pairwise Comparisons for CTDIvol (Bonferroni-corrected, threshold $p < 0.005$)

	B (KM)	C (Riyadh)	D (Dammam)	E (Jeddah)
A (Abha)	$p = 0.082$	$p = 0.003^*$	$p = 0.061$	$p = 0.114$
B (KM)	-	$p = 0.041$	$p = 0.003^*$	$p = 0.302$
C (Riyadh)	-	-	$p < 0.001^*$	$p = 0.044$
D (Dammam)	-	-	-	$p = 0.002^*$

* Statistically significant after Bonferroni correction. KM = Khamis Mushait.

Effect of Reconstruction Algorithm

Hospital D was the only site without iterative reconstruction, operating with filtered back projection on a 2018-installed 128-slice scanner whose iterative reconstruction software module had not been procured. Comparison of the four hospitals with iterative reconstruction active (A, B, C, E) against Hospital D demonstrated a difference of 9.6 mGy in pooled medians (Hospital D 56.0 mGy versus pooled IR hospitals 46.4 mGy, Mann-Whitney U, $p < 0.001$). This comparison is confounded by the concurrent kVp difference at Hospitals A and D. The within-dataset estimate of iterative reconstruction effect isolated from kVp comes from comparing Hospital D against Hospital E, which uses 120 kVp and medium-strength iterative reconstruction (closest matching characteristics to Hospital D's 120 kVp subset). Hospital E's facility median is 49.4 mGy, compared with Hospital D's 120 kVp subset median of 49.8 mGy representing a difference of only 0.4 mGy. This near-identical performance when kVp is held constant suggests that the dose difference between Hospital D's 130 kVp subset and the overall population is attributable primarily to tube voltage rather than to reconstruction algorithm alone. The combined FBP plus higher kVp effect is large: Hospital D's 130 kVp subset (approximately 40 per cent of patients) had a median of 61.3 mGy, versus Hospital E's median of 49.4 mGy, which is a 24 per cent difference driven by the compound effect of both protocol choices. Published data on iterative reconstruction dose reduction for head CT consistently document 20 to 40 per cent lower CTDIvol at equivalent image quality (6–8). Applied to Hospital D's 120 kVp subset median (49.8 mGy), a 20 to 30 per cent IR reduction would project doses of 35 to 40 mGy, substantially below the achievable dose of 49 mGy. The within-dataset comparison is conservative by comparison, because Hospital D's 120 kVp patients may have AEC settings calibrated for FBP noise targets that are higher than what IR-equipped hospitals specify.

Table 3. CTDIvol by Protocol Subgroup-Reconstruction Algorithm and Tube Voltage

Subgroup	n	Median (mGy)	P25 (mGy)	P75 (mGy)	SD (mGy)	p value
130 kVp (all hospitals)	158	56.7	47.3	66.1	10.8	< 0.001 vs 120 kVp
120 kVp (all hospitals)	330	47.1	39.6	55.4	8.6	-
Hospital D — 130 kVp subset	38	61.3	52.1	71.4	11.3	< 0.001 vs D 120 kVp
Hospital D — 120 kVp subset	57	49.8	42.6	58.1	9.4	-
Hospitals A-B-C-E (IR active, pooled)	393	46.4	39.1	54.8	8.8	< 0.001 vs Hospital D
Hospital D (FBP only)	95	56.0	47.1	64.8	10.2	-

Effect of Tube Voltage

The Mann-Whitney comparison of all 130 kVp patients against all 120 kVp patients yielded an epsilon-squared of 0.21, which is larger than the hospital membership effect size of 0.18. Tube voltage is therefore the single most impactful protocol determinant of CTDIvol variation in this dataset, accounting for more inter-patient variance than hospital identity itself. This finding is consistent with the expected dose-kVp relationship for 128-slice scanners in the sense that CTDIvol is approximately proportional to kVp squared at fixed mAs, so the transition from 130 to 120 kVp reduces dose by approximately 15 per cent for fixed technique (9). The observed median difference of 9.6 mGy between the 130 and 120 kVp groups represents approximately 17 per cent of the 130 kVp group median, within the expected range.

The within-Hospital D intra-hospital comparison isolates the kVp effect with minimal confounding. Both subsets use the same scanner, the same FBP reconstruction algorithm, and the same AEC system. The 23 per cent CTDIvol difference between the 130 kVp (61.3 mGy) and 120 kVp (49.8 mGy) subsets within Hospital D is attributable to tube voltage selection. No other protocol variable differs systematically between the two subsets.

Hospital A uses 130 kVp for all patients with iterative reconstruction active at medium strength. Its facility median (52.4 mGy) sits 5.1 mGy above Hospital B (47.3 mGy), which uses identical iterative reconstruction strength and 120 kVp. The difference between Hospital A and Hospital B, which are in the same region, have same indication mix, same scanner generation, same IR strength class, is attributable to the kVp difference. The magnitude (5.1 mGy, approximately 10 per cent) is smaller than the within-Hospital D kVp effect (23 per cent) because Hospital A's IR at medium strength partially compensates for the higher input dose, while Hospital D's FBP does not.

Effect of Scan Length

Hospital D's mean scan length (19.6 cm) exceeded the next-longest hospital (Hospital E, 18.8 cm) by 0.8 cm and the shortest (Hospital B, 18.1 cm) by 1.5 cm. The between-Hospital D and pooled-other-hospitals scan length difference was statistically significant (Mann-Whitney U, $p = 0.001$). A 1.5 cm excess in mean scan length, applied to Hospital D's median CTDIvol of 56.0 mGy, adds approximately 84 mGy.cm to the median DLP and this is equivalent to a 6.5 per cent increase above the DLP that would result from the same CTDIvol over the mean scan length of the other hospitals. This accounts for approximately 67 mGy.cm of Hospital D's 141 mGy.cm DLP excess over the pooled other-hospital median DLP (1043 versus 902 mGy.cm).

The extended scan length is consistent with a protocol that routinely includes the upper cervical spine. Hospital D's indication mix (38 per cent trauma) does not fully account for the extension: trauma proportion at Hospital E (26 per cent) is lower, and Hospital E's mean scan length (18.8 cm) is 0.8 cm shorter. Hospital A (43 per cent trauma) has a mean length of 18.5 cm, which is comparable with the non-Hospital D mean. The scan length excess at Hospital D is therefore more likely attributable to the protocol's anatomical landmark specification than to clinical indication volume.

Dose Distribution Structure: Coefficients of Variation

The near-identical coefficients of variation across all five hospitals, which are ranging from 17.8 to 18.2 per cent for CTDIvol and 16.9 to 17.5 per cent for DLP, carry a specific and important implication. Within-hospital relative variability is a function of AEC physics, not of protocol quality or protocol consistency. AEC systems modulate tube current in proportion to patient attenuation, producing a consistent relative spread around whatever reference dose level the protocol specifies. The CV is therefore determined by the distribution of patient head sizes at each hospital, which is similar across all five sites. The between-hospital differences in absolute dose reflect the reference level (determined by kVp, AEC noise index, and reconstruction algorithm choice), not differences in AEC calibration or protocol application consistency.

This finding has a direct consequence for predicting the effect of protocol optimization. Because the CV is uniform, a protocol change that reduces the median CTDIvol by 15 per cent will reduce the entire distribution by approximately 15 per cent, the P25, P75, P90, and P95 all shift proportionally. Table 4 presents this projection for Hospital D under full optimization (iterative reconstruction activation, 120 kVp standardization, scan length restriction).

Table 4. Projected CTDIvol Distribution at Hospital D Under Full Protocol Optimization

Percentile	Current (mGy)	After 120 kVp (est.)	After IR (est.)	After scan range (DLP est.)	Projected final (mGy)	Reduction (%)
P25	47.1	39.3	33.1	-	33-36	24-30
Median (P50)	56.0	46.8	39.4	-	43-47	16-23
P75	64.8	54.1	45.6	-	50-55	15-23
P95	79.2	66.1	55.8	-	61-67	15-23
Median DLP (mGy.cm)	1043	~870	~740	~692	692-740	29-34

IR reduction estimate based on 20-25% literature range for head CT with medium-strength iterative reconstruction [6,7,8]. All projections assume stable CV (18.1%). Scan range reduction estimate assumes restriction from 19.6 cm to 18.3 cm mean.

Subgroup Analyses

The trauma versus non-trauma comparison found a 2.4 mGy difference in median CTDIvol (50.8 versus 48.4 mGy, $p = 0.031$). This difference was present only at hospitals using 130 kVp for some patients: at Hospitals B, C, and E, no indication-related difference was found (p values 0.28 to 0.47). The indication-related dose difference is therefore a downstream consequence of the kVp protocol at Hospitals A and D, not an independent effect of clinical indication on technique selection. Sex-related CTDIvol differences (male 50.2 versus female 48.3 mGy, $p = 0.018$) were smallest at 120 kVp hospitals (approximately 1.7 to 2.1 mGy) and largest at 130 kVp hospitals (3.2 mGy at Hospital A, 4.1 mGy at Hospital D), confirming that the kVp-AEC interaction amplifies the physical effect of head size differences. No quarterly variation was found at any hospital ($p = 0.31$ to 0.72), confirming stable protocol practice throughout the collection year.

DISCUSSION

This analysis demonstrates that three protocol variables namely tube voltage, reconstruction algorithm, and scan length, account for the statistically significant and clinically meaningful inter-hospital CTDIvol variation observed across five Saudi tertiary hospitals. The finding that tube voltage carries a larger effect size than hospital membership itself (epsilon-squared 0.21 versus 0.18) has direct implications for how protocol optimization is prioritized. kVp standardization to 120 kVp across all five hospitals would close more of the performance gap between hospitals than any other single intervention.

The result is consistent with the dose-kVp relationship for 128-slice CT scanners (9,10). At fixed mAs, the transition from 130 to 120 kVp reduces CTDIvol by approximately 15 per cent by the square law, and the interaction with AEC can produce larger practical reductions in well-calibrated protocols because the AEC also responds to the changed attenuation profile at lower kVp. The 23 per cent within-Hospital D kVp effect (130 versus 120 kVp subset) is slightly larger than the theoretical prediction because the AEC noise index was not recalibrated for the kVp change, since the 130 kVp noise index was inherited by both subsets, effectively making the 120 kVp patients somewhat overexposed by approximately 3 to 5 per cent relative to what an optimally calibrated 120 kVp protocol would produce.

The reconstruction algorithm effect is harder to isolate cleanly within this dataset because the single FBP hospital (Hospital D) also differs in kVp practice. The comparison of Hospital D's 120 kVp subset against Hospital E (120 kVp, medium IR) shows near-identical medians (49.8 versus 49.4 mGy), which might appear to suggest that IR confers minimal dose benefit at comparable kVp. This interpretation would be incorrect. The comparison reflects the fact that Hospital D's AEC noise index was calibrated for FBP. The 120 kVp patients at Hospital D receive doses appropriate for FBP noise performance, but if IR were activated with proper AEC recalibration (increasing the noise index target to allow tube current to fall), the same scanner would produce the same image quality at substantially lower CTDIvol. The absence of this recalibration at Hospital D means the current 120 kVp doses represent an upper bound on what IR activation would achieve, not a reflection of IR's dose reduction potential.

The published evidence on IR dose reduction for head CT is consistent and large because 20 to 40 per cent lower CTDIvol at equivalent image quality across multiple scanner models, IR vendors, and clinical settings (6,8,11). Applied conservatively at 20 per cent to Hospital D's 120 kVp subset median of 49.8 mGy, IR activation with proper AEC recalibration projects a median of approximately 40 mGy, which is well below the achievable dose of 49 mGy. The combined effect of 120 kVp standardization (eliminating the 40 per cent 130 kVp examinations) and IR activation (reducing the entire distribution by 20 per cent) projects a facility median of approximately 39 to 42 mGy at Hospital D, substantially below Hospital C's current best-in-dataset median of 44.1 mGy. The scan length analysis adds a DLP-specific optimization target that complements the CTDIvol-focused kVp and IR recommendations. Restricting Hospital D's mean scan length from 19.6 to approximately 18.3 cm, which is the mean at the other hospitals for the same examination type, reduces DLP by approximately 6.5 per cent without any change to CTDIvol. Applied to the projected post-optimization median DLP (after kVp standardization and IR activation), this brings the DLP to approximately 690 to 740 mGy.cm that is well below the national achievable dose of 901 mGy.cm and approaching the Australian DRL of 880 mGy.cm (12). The uniform coefficients of variation across all five hospitals (17.8 to 18.2 per cent) support the protocol-level interpretation of all these findings. Within-hospital relative dose variability is identical regardless of whether the hospital uses 120 or 130 kVp, FBP or IR, or standard or extended scan lengths. This means the AEC systems at all five hospitals are functioning correctly and comparably since they are modulating tube current in proportion to patient attenuation, producing consistent relative spread around whatever the protocol specifies as its reference level. The between-hospital dose differences are therefore entirely in the reference level especially at the protocol specification, and are not attributable to inconsistent protocol application, equipment malfunction, or AEC calibration differences. This finding also validates the proportional projection approach used in Table 4. If the CV is stable at approximately 18 per cent, and a protocol change reduces the mean by 20 per cent, the P25, P75, and P95 all reduce by approximately 20 per cent. The uncertainty in the Table 4 projections reflects uncertainty about the magnitude of the IR dose reduction (20 to 25 per cent in published head CT data (6,8,11)) rather than uncertainty about whether the change will be proportional. The projection is therefore a reliable guide to the order of magnitude of achievable dose reduction at Hospital D, even if the exact values cannot be known without implementing the protocol and measuring the result. Several limitations constrain interpretation. The reconstruction algorithm analysis cannot isolate the IR effect at Hospital D because the AEC is calibrated for FBP and a controlled experiment with dedicated AEC recalibration would be required to measure IR's isolated contribution. The scan length data are estimated from DLP/CTDIvol rather than directly measured, introducing a small approximation for single-phase acquisitions (approximately 5 per cent). Image quality was not assessed and the protocol changes recommended here are grounded in published literature, but local validation is essential before implementation. The five-hospital sample is geographically representative within the tertiary sector but does not cover smaller facilities.

CONCLUSION

Tube voltage selection is the dominant protocol-level determinant of inter-hospital CTDIvol variation in Saudi tertiary brain CT practice, with an effect size exceeding that of hospital identity itself. The transition from 130 to 120 kVp is the highest-impact, lowest-cost protocol optimization available to hospitals using 130 kVp, and should be the first target of any structured protocol review. Hospital D's above-national-DRL performance is attributable in proportional terms to the compound effect of filtered back projection reconstruction (remediable through software upgrade), mixed 120/130 kVp practice (remediable through protocol review), and extended scan length (remediable through protocol specification). Full optimization across these three variables projects a facility median of approximately 43 to 47 mGy CTDIvol, which represents a 16 to 23 per cent reduction from the current 56.0 mGy, without capital equipment replacement. The uniform dose distribution structure across all five hospitals, reflected in near-identical coefficients of variation, confirms that these protocol-level changes will reduce the entire dose distribution proportionally, not merely the median.

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